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Eric Vandendriessche

String Figures as Mathematics?

An Anthropological Approach to String Figure-making in Oral Tradition Societies

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To my wife Séverine and my sons
Yoann and Oscar

Preface

WHAT IS AT STAKE IN THE STUDY OF STRING FIGURES?

As children, I assume we all learned from friends how to make half a dozen string figures. In some parts of the world, however, for example, in the Trobriand Islands and in the Chaco region of Paraguay, on which Eric Vandendriessche concentrates in this book, some expert actors are able to produce hundreds of such figures. This difference in the order of magnitude is not insignificant. It goes along with a striking sophistication of the figures described with a loop of string. It also clearly entails a qualitative difference in the processes of memorization and production of string figures. Unlike the rest of us, these expert actors seem to have practiced this activity throughout their lives and on different occasions. What is the nature of the knowledge they put into play to generate and memorize these huge sets of string figures? This is one of the key issues Vandendriessche addresses in this book.

Needless to say, there is no single, simple answer to such a question. Yet, the importance of the issue cannot be overestimated and demands that we do not leave it unattended. Investigating string figures in various contexts will widen our understanding of the nature of knowledge systems that human collectives have shaped by giving us a better grasp of the variety of these systems. Further, this exploration of a little-understood activity will help us appreciate the subtlety of cognitive processes that are foreign to us. Indeed, Vandendriessche's inquiry into this practice yields insights into manifest and unusual competences of these expert actors. The reader will make their acquaintance in the pages of this book and will learn to understand their amazing skills. Vandendriessche's contribution constitutes a significant step and will hopefully raise awareness that action must be taken to preserve this important part of mankind's heritage, which is threatened with disappearance.

But there is more. What I learned in the school playground in Paris suggests that there are local elements in any body of knowledge of string figures. To be sure, not everybody on earth learns how to make an Eiffel Tower with a loop of string. Vandendriessche's analyses in this book yield deep insights into the diversity of forms that activities with string figures have taken in different contexts around the world. He shows how this diversity is not merely a matter of what name the actors give to the figures and what forms they recognize in them. More deeply, the diversity appears in the various sets of elementary operations and types of procedures that actors bring into play in their production of the set of string figures they know. Perhaps, as Vandendriessche's analysis seems to suggest, the general organization of the various explorations of patterns that can be achieved over time with a loop of string displays a striking similarity, everywhere showing the establishment of intermediary positions and the dissection of a procedure into subprocedures that lead from a certain position to another. Whatever the case, however, one of the important results Vandendriessche establishes in this book is that in different contexts, the distribution of operations that actors use systematically to make string figures differs. Diversity thus lies at the heart of these different practices in that the different tools different collectives have shaped to carry out their activity.

This result, which sheds light on the texture of such practices, is one of the side benefits that derive from the core questions addressed in the book. The questions can be formulated as follows: In what respects can we understand these string figure activities as mathematical? And what does this tell us about the nature of mathematics? It is important here not to misinterpret the questions. The point is not to start from the a priori assumption that this activity is simply mathematical and then freely project the resources of modern mathematics onto it to prove the fact. Put in these terms, it is clear that had Vandendriessche followed such an approach, his method would be flawed. It would unjustifiably deny the "motley" facets that characterize activities with string figures. Moreover, such a way of proceeding would uniformize the mathematical features of these activities, aligning them with modern mathematics. It would thus deprive us of the important insight that they could possibly offer on the nature of mathematics. Instead, Vandendriessche is much more careful, as his introduction makes it clear. His starting point is historical.

The fact is that anthropologists have been interested in string figure making from virtually the beginning of professional anthropology. Cambridge ethnologist Alfred Cort Haddon (1855–1940) appears to have been the first to have focused systematically on this type of activity. Essential for Vandendriessche is the fact that through discussions with Haddon, Cambridge mathematician Walter William Rouse Ball began working on and practicing with string figures. In other words, mathematicians' attention was drawn to string figures almost as early as anthropologists became interested in the activity. The results of Rouse Ball's work were included in the fifth edition of his *Mathematical Recreations and Essays*, published in 1911. We can interpret this choice of a venue for publication as a way for Rouse Ball to assert the mathematical dimension he perceived in the activity while not being able to associate it clearly with a specific mathematical subdiscipline at the time. After all, this should not surprise us: The fact recurs in the history of mathematics. For instance, the same can be said of Euler's explorations of the Koenigsberg bridge problem: It was only much later that a mathematical subdiscipline to the problem could be attached, that is, graph theory took shape.

To return to Rouse Ball the mathematician, he thus appears to have been the first to have raised the issue of the mathematical dimension of the practice of producing string figures. He did so by bringing a procedural approach and geometric ideas into play to present some figures and analyze them. As Vandendriessche shows, Rouse Ball was followed by numerous other mathematicians whose publications explored string figures from different mathematical perspectives. Perhaps the most striking figure of them all is Thomas Storer, the first Native American to become an academic mathematician in the United States, who devoted impressive writings to string figures. He too approached string figures from a mathematical viewpoint shaping a topologicoprocedural approach to them. In this context, he was able to design a specific symbolism allowing practitioners to work on sequences of characters rather than motions of loops and thereby introduce a concept that proved essential for Vandendriessche: that of the heart sequence.

It is as a historian of mathematics that Vandendriessche analyzes the ways in which past mathematicians have approached string figures. He draws two main sets of conclusions from this research. This history can be read as a regularly reasserted statement whereby mathematicians expressed their perception that this activity clearly had a mathematical facet. This in and of itself justifies the project of inquiring into the ways in which the making of string figures relates to mathematics. At the very least, the mathematicians' contribution sheds light on how they understand the mathematical dimensions in the activity. In fact, these mathematicians' explorations provide a wealth of ideas and concepts with which to analyze string figures as a practice and as a body of knowledge offering a guide in the survey of this terra incognita.

This is the point where the research carried out by Vandendriessche the historian of mathematics meshes with the task Vandendriessche the anthropologist set himself. To explore the mathematical dimensions of the making of string figures, he draws inspiration from these previous publications while at the same time developing his own anthropological approach. It is to be noted how important Vandendriessche's own practice of producing string figures proves to be in this respect. This is essential, for instance, in enabling Vandendriessche to formulate criticisms of some features of Storer's symbolism that pass over important aspects of the actual process of making string figures. On this basis, Vandendriessche can thus plead for a transformation of this first symbolism, which better accounts for these aspects of the string figures under study. More generally, the actual practice of forming figures with a loop of string provides the basis on which Vandendriessche offers a new conceptualization of the process of bringing about a string figure, which is essential for the unfolding of his analyses. Two main threads of results follow.

Vandendriessche forcefully establishes how the mathematical approach he has designed yields tools for analyzing string figures and the procedures shaped to produce them. This approach gives amazing insights into the various corpora of string figures, whether one is interested in the structure of these corpora or the properties of the sets of procedures yielding them. To mention but one example of his results, this is precisely how, as underlined above, Vandendriessche is able to demonstrate a quite unexpected conclusion: the diversity among the various corpora and sets of procedures. Interestingly enough, this example illustrates how Vandendriessche parts from Rouse Ball in the type of analysis deployed. Much in the way in which a mathematician usually reads an ancient text, Rouse Ball decontextualized string figures and dealt with them altogether without keeping track of the different contexts from which they originated. Such a method inevitably hampers the discovery of disparity among different corpora. By contrast, by paying both historical and anthropological attention to contextualization, Vandendriessche is able to perceive the diversity among corpora.

Until now, mathematical concepts and ideas have been observers' tools used to carry out the analysis of data. If we except the attention given to operations and procedures, actors remain in the shadow. However, these observers' tools have borne fruit, allowing Vandendriessche to capture structural features of the corpora and immediately leading him to raise a key question: that of determining whether in fact these observers' tools grasp the features of actors' own concepts of what they are doing. The observers' tools again prove useful in addressing this question, helping the anthropologist formulate specific questions about the actors' operations and focus on specific features of the actors' terminology and procedures. It is then through a subtle and convincing argument that Vandendriessche is able to move from the observers' categories to the actors' perceptions of their own practice and operations, establishing how some mathematical properties of corpora and procedures that he brought to light actually correspond to the actors' own understanding of their activity.

In conclusion, Vandendriessche thus opens a new chapter in the anthropological exploration of mathematical ideas. This page documents the exploration of a new range of mathematical ideas in oral societies by people who operate outside the academic world. What can this new type of evidence of mathematical activity bring to a general reflection on the nature and practice of mathematics in the past as well as in the present day? How will our understanding of it change through the advancement of mathematics? These are questions that Vandendriessche's book, exemplary for its interdisciplinary character, compels us now to address.

Paris, France Karine Chemla[1]

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Part IV String Figures in the Field

Chapter 1
Introduction

For a long time, historians and philosophers of mathematics left out societies of oral tradition from their field of study. One may discern in this neglect the influence of philosophers such as Lucien Lévy-Bruhl, who claimed that the members of these societies are characterized by their "primitive mentality", described by him as "prelogical". Allegedly, this mentality made them hardly capable of dealing with abstraction or of reasoning in a rational way. Lévy-Bruhl wrote: "In defining it [primitive mentality] as prelogical, I just want to say that it does not compel itself first and foremost to refrain from contradiction, as our way of thinking does"[1] (Lévy-Bruhl 1910, p. 76). As sociologist and anthropologist Jean Cazeneuve commented, "in fact, this mentality obeys a principle that is not radically opposed to the principle of non-contradiction, but is merely indifferent to it. It is this principle that Lévy-Bruhl calls the principle of participation. Under this principle, beings can be both themselves and something else, and they can be linked in a way that has nothing to do with our logic. Because logical operations and prelogical ones are intertwined in the mind of primitive men, they are much less capable of abstracting and generalizing than we are"[2]—my translation (Cazeneuve 1963, pp. 25–26).[3]

[1]Original text: "En l'appelant prélogique, je veux seulement dire qu'elle ne s'astreint pas avant tout, comme notre pensée, à s'abstenir de la contradiction."

[2]Original text: "En vérité, cette mentalité obéit à un principe qui n'est pas en opposition radicale avec celui de la non-contradiction, mais lui est simplement indifférent. Et c'est ce principe que Lévy-Bruhl appelle le principe de participation. En vertu de cette loi, les êtres peuvent être à la fois eux-mêmes et autre chose qu'eux, et ils peuvent être unis par des rapports n'ayant rien à voir avec ceux de notre logique. Du fait que les opérations logiques et prélogiques sont, en son esprit, étroitement mêlées, il résulte que le primitif est beaucoup moins apte que nous à abstraire et à généraliser."

[3]See also Keck (2008). About the use of "logic" in social sciences during the twentieth century, particularly as a means of assessing the rationality of individuals in a given society, see the article by sociologist Claude Rosental entitled "What is the logic for which rationality? Representations and uses of social logic" (Rosental 2002).

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Although this view has long been abandoned by scholars, it did have a profound influence throughout the twentieth century. However, even by the 1920s, some anthropologists had made observations that were in contradiction with Lévy-Bruhl's theory. For instance, after having spent many months in a Melanesian society in the New Hebrides (renamed Vanuatu in 1980 when this South Pacific island group became independent), Bernard Arthur Deacon underlined:

> The older men explained the system [kinship system] to me perfectly lucidly, I could not explain it to anymore better myself. It is perfectly clear that the natives (the intelligent ones) do conceive of the system as a connected mechanism which they can represent by diagrams[4]... It is extraordinary that a native should be able to represent completely by a diagram a complex system of matrimonial classes. The way they could reason about relationships from their diagrams was absolutely on a par with a good scientific exposition in a lecture room. I have collected in Malekula, too, some cases of a mathematical ability. I hope, when I get my material together, to be able to prove that the native is capable of pretty abstract thought (Deacon 1934, p. xxiii).

Deacon died tragically shortly after writing these words,[5] and the questions he raised about New Hebrides natives' mathematical ability were to be left unanswered for some decades.[6] Deacon's observations were nevertheless predictive of the epistemological turning-point which occurred on this issue in the second half of the twentieth century, particularly through the work of anthropologist Claude Lévi-Strauss, as it can be perceived in the following extract of *The Savage Mind*:

> This appetite for objective knowledge is one of the most neglected aspects of the way those we call primitive think. Although it is rarely directed to realities at the same level as those associated with modern science, it involves comparable intellectual approaches and methods of observation. In both cases, the universe is an object of thought, as well as a means to satisfy needs (Lévi-Strauss 1962, p. 13)- My translation.[7]

In the first societies studied by social anthropologists, mathematics did not generally appear as an autonomous category of indigenous knowledge. As it has been suggested by Deacon's testimony, and later confirmed by a large number of ethnographies from various "traditional societies" (Deacon and Wedgwood 1934; Lévi-Strauss 1947; Gladwin 1986; Austern 1939), a form of rationality seems however to occur within different practices, such as navigation, calendars, ornaments,

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[4]These diagrams were drawn for Deacon on the sand.

[5]Bernard Arthur Deacon (1903–1927) was a student of Cambridge anthropologist Alfred Cort Haddon. He died of malaria on Malekula Island, New Hebrides, where he had carried out fieldwork in the years 1926–1927. His ethnographical field notes were published in 1927 and 1934 by another student of Haddon, anthropologist Camilla H. Wedgwood (1901–1955) (Deacon 1927, 1934; Deacon and Wedgwood 1934).

[6]Mathematician Marcia Ascher has analysed some of Deacon's materials in an ethnomathematical perspective (Ascher 1988, 1991). See below.

[7]Original text: "Cet appétit de connaissance objective constitue l'un des aspects les plus négligés de la pensée de ceux que nous nommons primitifs. S'il est rarement dirigé vers des réalités de même niveau que celles auxquelles s'attache la science moderne, il implique des démarches intellectuelles et des méthodes d'observation comparables. Dans les deux cas, l'univers est objet de pensée, autant que moyen de satisfaire des besoins."

games, kinship systems, etc. The epistemological issue is then to determine whether some of these activities relate to mathematical practices, and how. The following question will be central throughout this volume: How is an activity recognized as "mathematical" when it is not identified as such by those who practise it? What criteria should we use? This is the major question I try to answer in this book.

Philosophy in general, and the philosophy of mathematics in particular, does not yet offer efficient conceptual tools to tackle this issue, as it often takes for granted all that is mathematical. According to the philosopher of mathematics Jean-Jacques Szczeciniarz, a lot remains to be done in that perspective, even though a few recent works were carried out in an attempt to better characterize mathematical objects[8] (Caveing 2004).

However, regarding the issue of determining whether or not an activity is related to mathematics, it can be noticed that there is a significant difference between activities that involve numbering and/or measuring, and those dealing with geometrical forms. The counting of yams with a basket as it is practised in Melanesia—in the Trobriand islands (Papua New Guinea), for instance—is quite readily recognized by academia as mathematical, as it involves the use of a particular counting method. By contrast, other practices that require "geometrical" abilities (such as weaving, basketry, ornamental frieze making…) are usually not—or not so readily—regarded and analysed as mathematical by scholars.

The last decades have seen the development of a new interdisciplinary field of research, called ethnomathematics, which lies between the history of science and anthropology, and aims to study cultural variations in mathematics (D'Ambrosio 1985; Ascher and Ascher 1986; Gerdes 1994; Ascher and D'Ambrosio 1994; Eglash 2000). In the 1970s and 1980s, the first ethnomathematical studies were conducted by mathematicians. In most cases, these seminal works were not carried out on the basis of first hand ethnographical data, but rather on secondary sources drawn from ethnographical literature and often (but not always) from a didactic point of view (Zaslavsky 1973; Crowe 1975; Ascher and Ascher 1981; Lancy 1983; Moore 1988). In the latter case, the main idea was—and remains in more recent studies in ethnomathematics—to promote the teaching of mathematics in connection to indigenous knowledge (Nunes et al. 1993; Gerdes 1995, 1999; Knijnik 2007; Trouré and Bednarz 2010).

Mathematician Marcia Ascher is one of the founders of ethnomathematics whose approach has largely inspired the first steps of my own research in this field. Instead of focusing on didactic issues, her seminal books (Ascher 1991, 2002) analyse the mathematical aspects of certain activities carried out within small-scale indigenous societies. "To avoid being constrained by Western connotations of the word mathematics", inherited from various definitions of what mathematics *is*, and mainly based on Western experiences of historians and philosophers of mathematics, Ascher introduced the concept of "mathematical ideas". She defined as a mathematical idea any idea "involving numbers, logic or spatial configurations, and even more significant, combinations or organization of these into systems

[8] Personal communication 2010.

or structures” (Ascher 1991, p. 3). An activity is then considered as relating to mathematics when it contains such ideas or deals with them. Ascher also demonstrated how the use of mathematical modelling methods allows us to shed light on mathematical knowledge embedded in various indigenous activities.

Since the 1990s, some ethnomathematicians seek to articulate the conceptual approaches of their predecessors (mathematical modelling, historical, philosophical, and/or pedagogical perspectives) with fieldwork. This approach enables them to collect new data about some activities that involve “mathematical ideas”, and, at the same time, to understand better how these activities are embedded into the social organization and symbolic systems of the societies that practice them. Furthermore, meeting and interacting with persons recognized as “experts” by the other members of the group allow ethnomathematicians to study the cognitive acts that underlie the practice of such mathematical activities (Vellard 1988; Eglash 1999; Chemillier 2007, 2011). My present study is conceived as a contribution to this renewed perspective of ethnomathematics.

The issue of recognizing an activity as mathematical will be addressed in this volume through the analysis of the procedural activity of “string figure-making”. This practice has been carried out for a long time in many societies throughout the world, and especially in those of oral tradition. To make a string figure, you first need to knot the ends of a one to two-meter-long string, in order to create a loop. The activity then consists in applying a succession of operations to the string, using mostly the fingers, assisted sometimes by the teeth, wrists, knees and toes. This succession of operations, which are generally performed by an individual, or sometimes by two individuals playing together, is intended to produce a figure.

Bowelogusa displaying the figure *Samula kayaula* (a river),
Trobriand Islands, Papua New Guinea

Since the end of the nineteenth century, a few mathematicians have been interested in the activity of string figure-making. To my knowledge, mathematician Walter William Rouse Ball (1850–1925), professor at Trinity College in Cambridge, was the first mathematician who publicly expressed an interest in this activity. He devoted a chapter to string figures in his very popular book *Mathematical Recreations and Essays*. Although Ball does not mention it explicitly, the fact that he chose to include such a topic in a book of recreational mathematics suggests that he certainly considered the making of string figures as a mathematical activity.

Two American mathematicians later focused their attention on string figure-making as well. Ali Reza Amir-Moez (1919–2007) published a small book entitled *Mathematics and String Figures*, in which, in relation to a few particular string figures, he discussed the possible connection between the creation of these figures and mathematics (Amir-Moez 1965). About two decades later, Thomas Frederick Storer (1938–2006) published a long article in which he developed several mathematical approaches for encoding and analysing string figure processes (Storer 1988).

In the 1990s, a team of Japanese and Malaysian researchers (Masashi Yamada, Burdiato Rahmat, Hidenori Itoh and Hirohisa Seki) published a series of articles that sought to describe and test different algorithms involved in computer programs, in order to display on a video screen the step-by-step construction of some string figures, from the initial position to the final figure (Yamada et al. 1994). This research has led them to connect string figure-making with knot theory (Yamada et al. 1997). Finally, in the article "Cat's cradles, Calculus Challenge",[9] the mathematician Ian Stewart claims that the description and mathematical characterization of string figure-making is still an open issue and could be a challenge to contemporary mathematicians (Stewart 1997). These predecessors' tendency to see the activity of string figure-making as mathematical has prompted me to try and analyse the nature of this connection.

The practice of making figures with a loop of string is most certainly very ancient. For thousands of years probably, men and women have explored, by manipulating a piece of string, the endless possibilities offered by continuous deformations of a loop of string that mathematicians call "trivial knot". Thanks to the work done since the late nineteenth century by some anthropologists, explorers and enthusiasts, who showed a keen interest in string figure-making within societies of oral tradition, many corpora of string figures from various cultural areas were published throughout the twentieth century.

An overview of these works will be given throughout this volume. What can be underlined here is that the first description of some (Eskimo) string figures was published in 1888 by anthropologist Franz Boas (1858–1942) (Boas 1888, pp. 229–230). Two years later, archaeologist and ethnologist Harlan I. Smith

[9] In the narrow sense of the word, "Cat's Cradle" is a series of string figures the making of which requires two partners (see Chap. 4). It was likely imported from Asia to Europe a few centuries ago (Ball 1920, 1960 edition, p. 40). Since the early twentieth century, the term "Cat's Cradle" can also be used more broadly when referring to string figure-making.

published some drawings illustrating the different stages of the making of two string figures known by the Salish Indians in British Colombia (Smith 1900). Cambridge anthropologist Alfred Cort Haddon (1855–1940) was however the first to carry out a significant study on the subject, in collaboration with anthropologist, neurologist and psychiatrist William H. R. Rivers (1864–1922). In 1902, they published a seminal article in which they explained their methodology for collecting string figures. They proved their nomenclature's efficiency by writing down the making of some Melanesian string figures that they had collected in 1898 in the Torres Straits Islands, South Pacific. Thereafter, Haddon published other corpora of string figures from different cultural areas: America (Haddon 1903), South Africa (Haddon 1906), Melanesia (Haddon 1912). Haddon and Rivers' article induced other anthropologists to pay attention to the topic and helped them to collect string figures in their own fields. We will encounter a number of these scholars all along this book. It is also noticeable that we owe to non-academic enthusiasts some relevant collections of string figures, which I shall often refer to in the following. The first book about string figures was published in 1906 by Caroline Furness Jayne (1873–1909), who compiled ethnographic field notes that some anthropologists had shared with her (Jayne 1962, 1st ed. 1906).

As will be shown in the following pages through the analysis of both published corpora and personal fieldwork findings—collected in the Trobriand islands (Papua New Guinea) and in the Paraguayan Chaco—the "creation" of string figures is underlain by a form of rationality which can be analysed as mathematical.

The first chapter focuses on the context and goal of the early ethnographical collections of string figures. The methodology proposed by Haddon and Rivers is described in this chapter, and the reader is encouraged to memorize it and become a practitioner himself. In Chap. 3, different modes of conceptualization of string figure-making are introduced, and several ethnographical sources are analysed with these conceptual tools. It gives evidence that the creation of string figures can be regarded as the result of an intellectual process of organizing elementary operations through genuine "algorithms" (or "procedures"), based on investigations of complex spatial configurations and constantly dealing with concepts of transformation and iteration. Approached in this way, string figures appear to be the product of a mathematical activity.

After this first inquiry into a mathematical approach to string figures, the book adopts a history of mathematics viewpoint in order to study how mathematicians approached string figures in the past and how their research inspired ideas for the present study. In this vein, Chap. 4 analyses the text devoted to string figures by mathematician William W. Rouse Ball in his book on mathematical recreations. This text can be seen as the first (published) attempt by a mathematician to demonstrate a connection between mathematics and procedural activities such as string figure-making. Although, the epistemological stake of such a connection is not explicitly addressed by Ball, he has selected some particular string figures in ethnographical publications and has conceived the structure of his chapter in order to emphasize the mathematical aspects of this practice, dealing with concepts such as classification, operation and transformation.

We then turn to the various mathematical approaches to string figures developed by mathematician Thomas Storer in the 1980s (Chap. 5). One of these, called the "heart-sequence" of a string figure, has been of fundamental importance in my personal investigations. The idea is to focus on the movements of the string without taking into account how the fingers operate on it. By focusing on these movements during the process, and by converting them into a mathematical formula, the heart-sequence gives, in that sense, a "topological" view of a string figure algorithm. On the basis of this observer's viewpoint (the heart-sequence), one can attempt to reconstruct the ways in which the "actors" (practitioners from various societies) have explored string figure procedures.

These explorations provide us with key resources to turn to an ethnomathematical study of the practice of string figure-making. In that perspective, Chap. 6 concentrates on different string figure procedures, which were collected in geographically and culturally distant societies, and which all lead to "look alike" string figures. It will be demonstrated that the heart-sequence is an efficient mathematical tool to study formally and systematically such a set of procedures for devising look-alike string-figures. At a "topological" level, this tool enables us to point out the similarities in string figure procedures that are very different at first sight, thus providing a methodology to classify them.

Within the various corpora of string figures, the concept of transformation is omnipresent. The ethnographical sources give evidence that the practitioners worked out how to transform one figure into another. In Chap. 7, the analysis of some of these transformations through the conceptual tool of "heart-sequence" brings some new light on the methods invented by the practitioners to implement these transformations.

A more overall analysis of my own fieldwork findings is then carried out. At this level, the conceptual tools in use allow us to bring to light both invariant and distinguishing features in the ways string figure practice is embedded in two societies of oral tradition, namely the Trobriand islanders in Papua New Guinea and the Guarani-Ñandeva in the Paraguayan Chaco. Major information about the ways string figures are perceived within these societies is given in Chap. 8, through the analysis of the names given to the string figures, oral texts which sometimes accompany the making of these figures, the practitioners' gender, the process of transmission of these procedures, the relationship between this practice and the kinship system—as well as my interactions with highly skilled practitioners of this activity. The conceptual tools introduced in Chaps. 3 and 5 provide a methodology to analyse and compare the Trobriander and Guarani-Ñandeva corpora of string figures, at an overall level. In Chap. 9, two fundamental outcomes emerge from this comparative analysis. The first one concerns the operations included in these two corpora, as each corpus differentiates from the other by the use or non-use of some operations and by the frequency of use of similar operations included in both corpora. The second outcome shows that both corpora actually share the same tree structure, somehow reflecting how these string figures were created, and, to a certain extent, their history. Finally, Chap. 9 returns to the epistemological issue of determining whether or not the activity of creating string figures can be seen as mathematical. I conclude by showing that, in both the Trobriander and Guarani-Ñandeva corpora, some phenomena reflect intellectual processes that can be regarded as mathematical, which supports the thesis of a connection between the creation of string figure algorithms and mathematics.

References

Amir-Moez AR (1965) Mathematics and string figures. Edwards Brothers, Ann Arbor

Ascher M (1988) Graphs in cultures: a study in ethnomathematics. Hist Math 15:201–227

Ascher M (1991) Ethnomathematics: a multicultural view of mathematical ideas. Brooks and Cole Publishing, Pacific Grove, 199p. Translation in French, "Mathématiques d'ailleurs: nombres, formes et jeux dans les sociétés traditionnelles", by Karine Chemla and Serge Pahaut, Editions du Seuil, 1998, 280p

Ascher M (2002) Mathematics elsewhere: an exploration of ideas across cultures. Princeton University Press, Princeton/Oxford

Ascher M, Ascher R (1981) Code of quipu: a study in media, mathematics, and culture. University of Michigan Press, Ann Arbor

Ascher M, Ascher R (1986) Ethnomathematics. Hist Sci 24:125–144

Ascher M, D'Ambrosio U (1994) Ethnomathematics: a dialogue. Learn Math 14(2):36–43

Austern L (1939) The seasonal gardening calender of Kiriwina, Trobriands Islands. Oceania 9:237–253

Ball WWR (1920) An introduction to string figures. W. Heffer and Sons, Cambridge. (Reprinted by W. Heffer and Sons as String Figures, 1921 (2nd edn), 1928 (3rd edn). Reprinted by Dover publications, as Fun with String Figures, New York, 1971, 80p. Reprinted in String Figures and other Monographs, Chelsea Publishing, New York, 1960, pp 1–72)

Boas F (1888) The game of cat's cradle. Int Arch Ethnogr I:229

Caveing M (2004) Le problème des objects dans la pensée mathématique. Librairie philosophique J. Vrin, Paris

Cazeneuve J (1963) Lévy-Bruhl. Puf, Paris

Chemillier M (2007) Les mathématiques naturelles. Odile Jacob, Paris

Chemillier M (2011) Fielwork in ethnomathematics. In: Thieberger N (ed) The Oxford handbook of linguistic fieldwork. Oxford University Press, Oxford/New York

Crowe CM (1975) The geometry of African art II: a catalog of Benin patterns. Hist. Math. 2(3):253–271

D'Ambrosio U (1985) Ethnomathematics and its place in the history and pedagogy of mathematics. Learn Math 5(1):44–48

Deacon A (1927) Geometrical drawings from Malekula and other islands of New Hebrides. J R Anthropol Inst G B Irel 57:325–342

Deacon AB (1934) Malekula, a vanishing people in the New Hebrides. G. Routledge and Sons, London. (Edited by Camilla H. Wedgwood; with a preface by A. C. Haddon)

Deacon A, Wedgwood C (1934) Geometrical drawings from Malekula and other islands of New Hebrides. J R Anthropol Inst 64:129–175

Eglash R (1999) African fractals: modern computing and indigenous design. Rutgers University Press, New Brunswick/New Jersey/London

Eglash R (2000) Anthropological perspectives on ethnomathematics. In: Selin H (ed) Mathematics across cultures: the history of non-western mathematics. Kluwer Academic, Boston/Dordrecht

Gerdes P (1994) Reflections on ethnomathematics. Learn Math 14(2):19–22

Gerdes P (1995) Une tradition géométrique en Afrique. Les dessins sur le sable – Tome 2. Exploration éducative et mathématique. L'Harmattan, Paris

Gerdes P (1999) Geometry from Africa. Mathematical and educational explorations. The Mathematical Association of America, Washington, DC

Gladwin T (1986) East is a big bird. Navigation and logic on Puluwat atoll. Harvard University Press, London

Haddon AC (1903) A few American string figures and tricks. Am Anthropol 5(2):213–223

Haddon AC (1906) String figures from South Africa. J Antropol Inst G B Irel 36:142–149

Haddon AC (1912) String figures and tricks. In: Reports of the Cambridge Anthropological Expedition to the Torres Straits, Cambridge University Press, vol 4:320–341

Jayne CF (1962) String figures and how to make them: a study of cat's cradle in many lands. Dover Edition, New York. (A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York)

Keck F (2008) Lévy-Bruhl: Entre philosophie et anthropologie. CNRS Editions, Paris

Knijnik G (2007) Mathematics education and the Brazilian landless movement: three different mathematics in the context of the struggle for social justice. Philos Math Educ J 21(1):1–18

Lancy D (1983) Cross-cultural studies in cognition and mathematics. Academic, New York

Lévi-Strauss C (1947) Les structures élémentaires de la parenté. Mouton de Gruyter, Paris, réédition 1967

Lévi-Strauss C (1962) La pensée sauvage. Plon, Paris

Lévy-Bruhl L (1910) Les fonctions mentales dans les sociétés inférieures. Félix Alcan, Paris

Moore CG (1988) The implication of string figures for American Indian mathematics education. J Am Indian Educ 28(1):16–26

Nunes T, Schliemann AD, Carraher DW (1993) Street mathematics and school mathematics. Cambridge University Press, New York

Rosental C (2002) Quelle logique pour quelle rationalité ? représentations et usages de la logique en sciences sociales. Enquête 2:69–92

Smith HI (1900) The Thompson Indians of British Colombia: publications of the Jesup Pacific expedition, by James Teit. Mem Am Mus Nat Hist 2 "Anthropology", I:281. Fig 270

Stewart I (1997) Cat's cradles, calculus challenge. Sci Am 277(6):118–120

Storer T (1988) String figures, vol 1. Bulletin of the String Figures Association 16, Special Issue: 1–212

Trouré K, Bednarz N (2010) Une étude ethnomathématique au Burkina Faso: l'arithmétique au quotidien. Can J Sci Math Technol Educ 10(4):307–320

Vellard D (1988) Anthropologie et sciences cognitives: une étude des procédures de calcul mental utilisées par une population analphabète. Intellectica 2:169–209

Yamada M, Burdiato R, Itoh H, Seki H (1994) A string diagram processing based on genetic algorithm. Trans Inf Process Soc Jpn 35(10):2059–2068

Yamada M, Burdiato R, Itoh H, Seki H (1997) Topology of cat's cradle diagrams and its characterization using knots polynomials. Trans Inf Process Soc Jpn 38(8):1573–1582

Zaslavsky C (1973) Africa counts. Number and pattern in African cultures. Prindle, Werber and Schmidt, Boston

Part I
How to Study String Figure-Making

Chapter 2
String Figures and Ethnography

2.1 First Surveys: Context and Issues

After his studies at Christ's College, Cambridge, Alfred Cort Haddon was appointed Professor of Zoology at the College of Science in Dublin. In 1888, he took part as a zoologist in the first expedition to the Torres Strait Islands, located between Papua New Guinea and Australia. It seems that his interest was drawn to both anthropology and string figures during this fieldwork in Oceania:

> In the summer of 1888 I went to Torres Strait to investigate the structure and fauna of the coral reefs of that district. Very soon after my arrival in the Straits I found that the natives of the islands had of late years been greatly reduced in number, and that, with the exception of but one or two individuals, none of the white residents knew anything about the customs of the natives, and not a single person cared about them personally. [. . .] So it was made clear to me that if I neglected to avail myself of the present opportunity of collecting, information on the ethnography of the islanders, it was extremely probable that knowledge would never be gleaned [. . .] I felt it my duty to fill up all the time not actually employed in my zoological researches in anthropological studies [. . .] (Haddon 1890, pp. 297–298)

In 1906, Haddon wrote:

> In ethnology, as in other sciences, nothing is too insignificant to receive attention. Indeed it is a matter of common experience among scientific men that apparently trivial objects or operations have an interest and importance that are by no means commensurate with the estimation in which they are ordinarily held[1] (Jayne 1962, p. v).

So it is no surprise that Haddon became interested in string figure-making upon meeting Torres Strait islanders. They played a game very close to the cat's cradle string game he used to play in his childhood—though theirs was infinitely more sophisticated. In her book *Cat's Cradles From Many Lands*, which I will discuss

[1]Haddon wrote this in the introduction of Caroline Furness Jayne's *String Figures* (1906), the first book ever published on the topic of string figures. See Chap. 4.

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_2

later, Kathleen Haddon[2] mentions that Haddon brought back a few string figures from the 1888 expedition, probably fixed on a rigid support, but without recording the methods by which they were made (Haddon 1911, p. xii).

Upon his return to Britain in 1890, Haddon showed a growing interest in so-called "Primitive Arts" and particularly in the drawings, engravings and motifs produced by these arts. Anthropologist Carlo Severi pointed out that Haddon's scientific approach in this domain came from the academic discipline called "biology of images" or "biology of ornaments", initiated by General Pitt Rivers in the mid-nineteenth century (Severi 2007, p. 48). The general idea of this theory was to study art objects "scientifically", just as living beings are studied within the framework of the theory of evolution. According to the "biology of images" theory, art objects created by people from different geographical areas could have a common origin, and, following the principle of "natural selection", these objects could evolve or disappear depending on the "milieu" in which they are produced. Even though this approach survived until the 1930s, for instance in the work of Aby Warburg (1866–1929), Haddon was one of the last researcher who explicitly inscribed his research on primitive arts within the "biology of images" field (Severi 2007, pp. 34–46). We can reasonably assume that his studies in zoology, adding to his interest in cultural phenomena, naturally led him to embrace this theory. In 1895, Haddon published a book entitled *Evolution in Art: As illustrated the Life-Histories of Designs* in which he explains his approach:

> The fundamental law in biology is that expressed in the well known aphorism, Omne vivum e vivo ("All life from life") [...] In studying savage art we are irresistibly forced to an analogous conclusion. By carefully studying a number of designs we find, providing the series is sufficiently extensive, that a complex, or even an apparently simple pattern, is the result of a long series of variations from a quite dissimilar original. The latter may in very many cases be proved to be a direct copy or representation of a natural or artificial object. From this it is clear that a large number of patterns can be shown to be natural developments from a realistic representation of an actual object, and not to be a mental creation on the part of the artist. (Haddon 1895, p. 308)[3]

In order to emphasize these iconographic sequences, Haddon recommends to study the patterns' geographical distribution, as biology had begun to do for living beings:

> No part of the study of Biology is more fascinating that which deals with the geographical of organisms [...]. The geographical distribution of art is as yet uninvestigated, but with careful and capable handling we may expect it to yield results not less interesting than those of distribution of animals (Haddon 1895, p. 319).

In this book, Haddon does not mention the activity of string figure-making that he had observed a few years before in Papua New Guinea, probably because

[2]Kathleen Haddon (1888–1961) was Haddon's daughter. He passed on his interest in string figures to her. As a photographer, she accompanied her father in the field many times.

[3]See also the chapter "The scientific method of studying decorative art" (Haddon 1895, pp. 306–338).

he had not yet collected sufficient data. Nevertheless, it was in this scientific context that Haddon returned to that matter later on. He did so in collaboration with English anthropologist, neurologist and psychiatrist, William H. R. Rivers (1864–1922), during the second Cambridge ethnographic expedition (1898) which Haddon conducted in the Torres Strait Islands. Publications by Boas (1888) and Smith (1900), as well as observations made by Haddon in Papua New Guinea in 1888, suggested that string figure-making was practiced in various culturally and geographically distant societies. Haddon thought that a large number of collections of string figures, gathered on every continent, would allow to carry out a comparative study in order to enable a better understanding of the origins and evolution of this practice. To undertake such a research, it became necessary to develop a method for recording the full process leading to a string figure.

> It became evident to me that no progress could be made in comparative study of string figures and tricks[4] until a definite nomenclature had been devised which would indicate with precision all stages involved in making a figure (Jayne 1962, p. xii).

His use of the term "nomenclature" seems to indicate that Haddon considered the study of string figure-making as a genuine discipline in its own right. It was thus necessary to establish a specific vocabulary to define its specificity. Furthermore, by mentioning "all stages", he shows his interest in the "procedure" leading to the final figure, beyond the final figure itself. The point was therefore not only to record the final figures, but also to describe accurately each step of the procedure used to reproduce a figure with a loop of string.

Haddon and Rivers implemented this recording method during their 1898 ethnographic mission and tested its effectiveness while collecting thirty-one string figure procedures, all of which were included in the expedition's report (Haddon 1912). Upon their return, Haddon and Rivers published the seminal article "A Method of Recording String Figures and Tricks" (1902). In this paper, the authors introduce six adjectives that define the six perpendicular directions of the space in relation to the different parts of the hand (see below Sect. 2.2). These adjectives, in addition to some action verbs ("picking up", "hooking up" the string, etc.), enabled Haddon and Rivers to write down the succession of operations applied to the string step by step. Moreover, they proved their nomenclature's efficiency by writing down the making of 12 Torres Strait string figures. Haddon and Rivers' article was meant to attract other anthropologists' attention to the topic and help them to collect string figures in their own fields:

> Our object is to induce field workers to pay attention to the subject and to record the method of making the figures, and to assist them in this we offer the following nomenclature and method of description. We have little doubt that those who interest themselves in this simple amusement will find that their labour has not been in vain (Haddon and Rivers 1902, p. 147).

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[4] Tricks are generally knot or complicated arrangements of the strings which run out freely when pulled (Haddon and Rivers 1902, p. 147).

This actually happened, as shown by the numerous collections of string figures published over the twentieth century in journals of anthropology, using Haddon and Rivers' nomenclature or closely related ones. In particular, anthropologists Diamond Jenness (1920s), James Hornell (1930s) and Thomas Paterson (1940s)—all of which we shall encounter in the course of this book—have documented the practice of string figure-making and published articles using Haddon and Rivers' methodology. That is how many papers and a few seminal books on string figures were published during the twentieth century. In the following pages, many examples will be extracted from these publications.

On the basis of these published collections of string figures, some authors have undertaken comparative analyses in the first half of the twentieth century. These studies, conducted in the context of diffusionism, led them to compare corpora collected in various societies. By doing so, they aimed at acquiring a better understanding of circulation and contacts between these populations. They found that identical string figures collected from distant areas are quite rare: given the unlimited number of figures which can theoretically be made with a loop of string, they considered it very unlikely that exactly the same string figure could have been independently invented in two separate regions of the world. This argument can be found in the work of missionary Guy Mary-Rousselière. In the 1960s, he stayed among the Netsilik Eskimos and documented the practice of string figure-making by the *Arviligjuarmiut* of Pelly Bay, Canadian Arctic (1969). Mary-Rousselière writes that if an ethnographer observes similar string figures in different geographical areas, he

> can usually infer that they have a common origin. [...] When these geographical areas are adjacent, these common features can be easily explained by contacts between the two groups. And when these string games are found in geographically distant areas, more ancient contacts or a common origin can be generally admitted, as in the case of two identical harpoons found in two distant areas (Mary-Rousseliere 1969, p. 135) - my translation.

This idea was also put forward in the 1930s by French ethnographer and explorer Paul-Emile Victor who collected string figures on the east coast of Greenland among the Angmagssalik Eskimos. Victor hypothesizes that string figures "are part of the elements that will throw light on contacts between different populations and, therefore, will facilitate the study of migrations" (Victor 1940, p. 207)-(my translation).

A few studies deal with that issue: one can quote the work of Thomas Thomson Paterson (1909–1994), who was head of Cambridge's Archaeology and Ethnology Museum in the 1950s. In 1949, he published the long paper *Eskimo String Figures and their Origin*. After having recorded a large number of string figures on the West coast of Greenland and the Northern Baffin Island (covering 1,500 kilometres in Northern Canada and Eastern Greenland), Paterson undertook a comparative study of Inuit string figures, based on the entire data published at that time. He compiled these data, obtaining statistical outcomes relating to the distribution of these figures in the Arctic area (Paterson 1949). On the basis of these numerical data, Paterson suggested that transmission of string figures could have occasionally occurred between different “Eskimo” groups:

> The transmission of figures demands the closest of contact between group and group. It is plain that the intricacy of some figures cannot be learned quickly, and therefore this element of culture cannot be handed on like a material object, a riffle or such. The sharing of leisure is demanded, for it is then that figures are practised. The distribution of figures itself demonstrates this point. Though there are a great number (105) with only local occurrence, that is, confined to one area, there are very few (10) found only in two adjoining areas, and a similar number (9) in three adjoining areas. Whereas there are a great many (90) found widespread. It appears therefore, that figures arising locally do not seem to be transmitted readily, contrasting strongly with the ease with which figures must have been dispersed at an earlier period. This dispersion can be most easily explained by assuming that one group of people dispersed and took the figures with them (Paterson 1949, p. 50).

According to Paterson, it could consequently be assumed that the number of string figures known in a given region will evolve, either by local invention of new string figure procedures or by integrating new groups likely to pass on their own knowledge.

Beyond this diffusionist comparative approach, some ethnologists and anthropologists also aimed to better understand how this practice is embedded within different cultures. In particular, some ethnographers have recorded the songs or stories that sometimes accompany string figure-making. These materials gives a few elements about the cultural context of this practice in different societies (function, right time for making string figures, gender, prescription and prohibition, ritual efficacy) (Jenness 1924; Andersen 1927; Hornell 1927; Dickey 1928; Maude and Emory 1979).

It has been observed in particular that string figures could be sometimes performed for their positive or negative ritual efficacy. In the 1910s, anthropologist G. Landtman noticed such a phenomenon among the Kiwai Papuans, British New Guinea. In this society, it was the string itself, after having performed Cat’s Cradles (string figures) with it, that was considered to have a magical power and a positive impact on the growing of yams:

> On the whole cat’s cradles are regarded by the Kiwai people purely as play, but in certain cases a more particular interest attaches to them. The game is most commonly played when stalks of the newly planted yams begin to shoot up from the earth. Sticks are put in the ground to support the winding tendrils, and the first few stems are tied to them by means of pieces of strings which have been used for making cat’s cradle. It is sufficient, however, to hang pieces of these strings on top of the first few sticks without actually tying the stalks with them, and some people merely throw a few pieces of cat’s cradle strings here and there on the ground in their gardens. In each case the purpose is to “help” the stalks of the yams to grow well and wind in the right way (Landtman 1914, p. 221).

Was it the making of any string figure (as this extract suggests), or, on the contrary, the making of a particular string figure that gave its magical power to the string? It is difficult to tell, but there are a few ethnographical sources that seem to show that the making of certain string figures in Melanesia was used in a ritual context.

In the 1920s, anthropologist Diamond Jenness[5] made a similar observation (benefit for the yams gardens) in the Goodenough Islands, an archipelago located off the East coast of Papua New Guinea (see Chap. 8). He also noticed other contexts where string figures appear to be connected with magic in this society:

> The native use the string bags (*walia'va*) to carry their vegetables home from gardens. Whenever any of the vegetables in it were stolen they should employ a string figure, *walia'va* (N° XXV) to discover the thief. An incantation was first sung, then the figure was made. As the name of each suspected person was pronounced, the right hand was jerked downwards between the loops. If it passed through freely he was innocent, but if it stuck he was guilty. Another figure, *bu'ibui*, which I have not recorded, is performed only when the clouds seem to prophecy fine weather; the word itself means a certain type of cloud, the cumulus. Probably this figure also has a magical significance (Jenness 1924, p. 301).

In Inuit societies, some ethnographical data collected in the 1910s and the 1920s—in particular during the Canadian Arctic Expedition of 1913–1918 and the Fifth Thule Expedition of 1921–1924—attest that the practice of string figure-making was generally embedded into a system of prohibitions and prescriptions. For instance, in most of these societies, from Alaska to Greenland, playing string figures (lit. *ajaraaq* in Inuktitut, the Inuit language) was prohibited in the presence of sunlight, since it was generally believed that the game could hinder the rise of the sun (Rasmussen 1929, p. 183). Conversely, this practice was indeed encouraged in period of darkness.

In the region of Iglulik (Canadian Arctic), such prohibition sought to prevent hunting incidents. Anthropologist Knud Rasmussen noticed that "boys who have not yet caught bearded seal or walrus must not play cat's cradle (string figures). If they do, then they are liable to get their fingers entangled in the harpoon lines and be dragged out into the sea" (Rasmussen 1929, p. 177). The Inuit refer to an entity named *Tuutarjuk* (also named *Tuutannguaq* or *Tuutannguarjuk*, depending on the society) as the spirit of string figures. In the 1920s, Rasmussen recorded the following story among the Netsilik Eskimos:

> Tuutannguarjuk is the spirit of the string figures. It has its name after a certain string figure that is called by the very name of tuutannguarjuk. It is a dangerous spirit that sometimes attacks women, and may even carry away those who become too eager to play with string figures. There was once a child who at night, instead of sleeping, lay awake and made string figures on the platform. While the child lay there tuutannguarjuk came in and started to make string figures too, using his own intestine as string. When he was in the middle of one of the figures he said suddenly: "Let us see which of us can make tuutannguarjuit quickest." The people of the house were asleep, that is why tuutannguarjuk was so bold. He was finished first, and was just going to spring at the child when one of the sleeping men awoke suddenly and sat up. At the same moment tuutannguarjuk jumped to his feet and fled out through the passage, and the man's light sleep thus saved the child from being carried away (Rasmussen 1931, p. 248).

[5] New Zealand anthropologist Diamond Jenness (1886–1969), studied at the University of Wellington in New Zealand and the Balliol College, Oxford. It was during his years at Oxford that he made a one year field study (between 1911 and 1912) in the Goodenough Islands, off the coast of Papua New Guinea. Subsequently he became a specialist of the Arctic and participated in several polar expeditions. In 1926, he was appointed director of the National Museum of Anthropology Ottawa.

Beyond the connection of string figure-making with that dangerous spirit *tuutannguarjuk*, this story suggests that there is (or was) a quest for performance, i.e. competition to preform string figures in a quicker way than a "partner".

Some ethnographical studies on string figures suggest that an ethnolinguistic approach could also be of great interest. Among the Inuit, for instance, string figures have often retained their original name. After years, the meaning of these names were sometimes lost, whereas people have continued to use them. According to Mary-Rousselière, these names testify to a forgotten vocabulary.

> It is likely that the gathering of a complete collection of string games of the Central and Eastern Eskimos East with their names and their accompanying oral texts—a task that has yet to be achieved—would throw some interesting light on paleolinguistics (Mary-Rousseliere 1969, p. 130)- my translation.

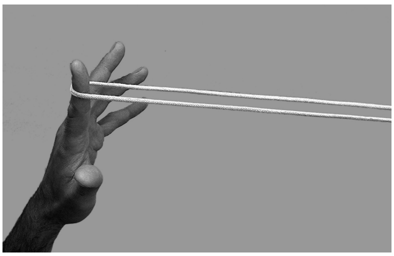
According to this author, such a survey would certainly enable researchers to go back in time and obtain information about changes in the Inuit language. I will refer several times to these anthropological and ethnolinguistic issues in the course of this book. And in Part IV, I will present and analyse my own ethnographic data.

Let us now turn to Haddon and Rivers' method of recording the whole process leading to a string figure. This methodology will enable the reader to make the string figures that I will refer to and analyse in the following. In order to try out by himself all string figures described in this book I now invite the reader to knot the ends of a flexible piece of string (one to two meter long) and make a loop. It is indeed only by practising string figure-making that one can get an in-depth understanding of the processes involved in the creation of these figures.

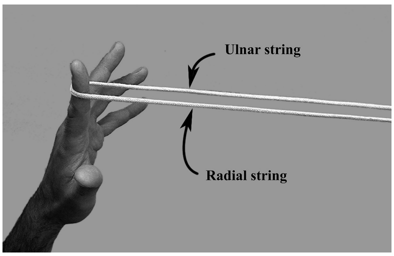
2.2 Haddon and Rivers' Terminology

Most string figure operations are made by using the fingers. I will therefore constantly refer to the thumb, the index, the middle, ring and little fingers of both left or right hands.

The string passing around a finger forms a loop. Picture 2a shows a loop carried by the left index. A loop consists in two strings, both of them starting from the finger which carries the loop.



2a – Left index loop



2b – Ulnar and radial strings

Anything which lies towards the thumb is said to be “radial”, and anything which lies towards the little finger is said to be “ulnar”. A loop is thus made of one radial and one ulnar string (picture 2b).

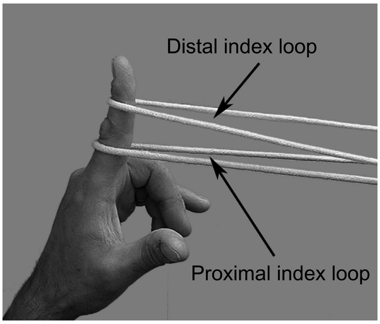
Using the names of the 5 fingers and the terms “radial”, “ulnar”, “left” and “right” makes it possible to define any of the 20 potential strings that can be extended between the 2 hands.

Anything which lies towards the palm is said to be “palmar”, whereas anything lying towards the back of the hand is said to be “dorsal”.

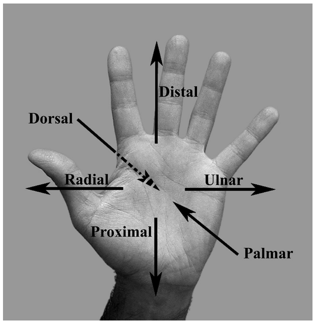
We will distinguish anything lying towards the wrist from anything lying towards the tip of the fingers, by describing them as “distal” and “proximal” respectively.

Each finger has therefore a “palmar” and a “dorsal” side, a “radial” and an “ulnar” side, and finally, a “proximal” and a “distal” zone. From time to time, one finger may carry two loops: one will be the “proximal” loop and the other the “distal” one (picture 3a).

These six adjectives match the six perpendicular directions of the space, defined in relation to the different parts of the hand (picture 3b).



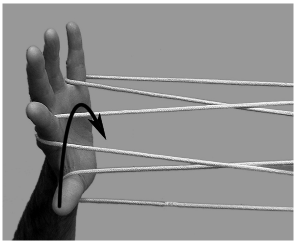
3a – Distal and proximal loops



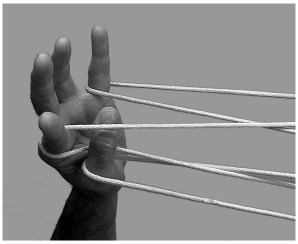
3b – The six perpendicular directions of the space

Summary of the terminology	
Adjectives	Part of the hand
Radial	Towards the thumb
Ulnar	Towards the little finger
Palmar	Across the palm
Dorsal	Across the back of the hand
Distal	Near the tip of finger
Proximal	Near the wrist

When a finger is inserted into a loop, it is specified whether the insertion is done “from the distal side” or “from the proximal side” of the loop (pictures 3c and 3d). When the hands face each other, fingers pointing up, these two expressions correspond to the expressions "from below" and "from above" respectively. However, the adjectives "distal" and "proximal" will be preferred since they do not depend on the position of the hands.



3c – Inserting from distal side



3d – Done

2.2.1 *Position I and Opening A*

Haddon and Rivers chose to define as "Position I" a starting position for the making of many string figures, in the Torres Strait Islands as in many other societies all over the world.

> ***Position I***.- This name may be applied to the position in which the string is placed on the hands when beginning most of the figures.
> Place the string over the thumbs and little fingers of both hands so that on each hand the string passes from the ulnar side of the hand round of the back of the little finger, then between the little fingers and ring fingers and across the palm; then between index and thumb and round the back of the thumb to the radial side of the hand. When the hands are drawn apart the result is a single radial thumb string and a single ulnar little finger string on each hand with a string lying across the palm [picture 4a] (Haddon and Rivers 1902, p. 148).

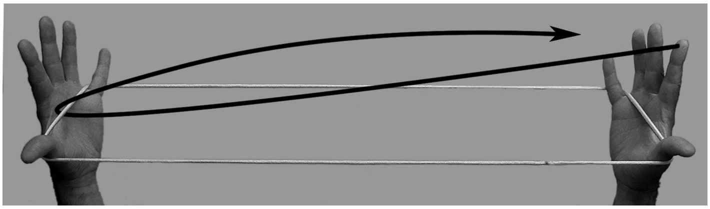
4a – Position I

From this position, the same sequence of movements is involved in the making of many string figures (in the Torres Strait and elsewhere). Haddon and Rivers called it "Opening A".

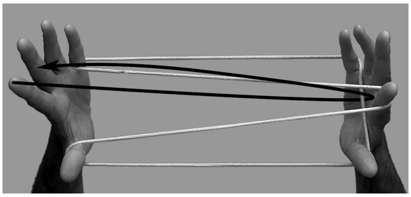
> Opening A.- This name may be applied to the manipulation which form the most frequent starting point of the various figures. Place string on hands in Position I. With the back of the index of the right hand take up from proximal side (or from below) the left palmar string and return. There will now be a loop on the right index, formed by strings passing from the radial side of the little finger and the ulnar side of the thumb (. . .) [pictures 4b and 4c].

Then, pass the left index through the right index loop from the distal side (personal indication),

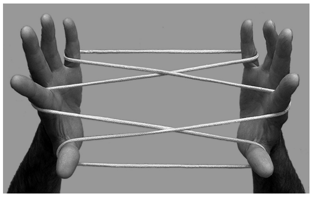
> with the back of the index of left hand take up from proximal side (or from below) the right palmar string and return, while keeping the index with the right index loop so that the string now joining the loop on the left index lies within the right index loop.
> The figure now consists of six loops on the thumb, index, and little finger of the two hands [pictures 4c and 4d] (Haddon and Rivers 1902, p. 148).



4b



4c



4d

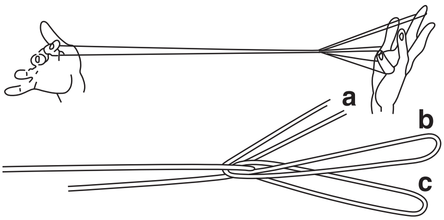
There are many other possible starting positions and openings. Although some of them, as Position I and Opening A, have been observed in many societies, we will see later that certain of these starting positions and openings seem to be characteristic of a cultural area.

2.2.2 String Figure Fish-Spear

In order to familiarize the reader with Haddon and Rivers' terminology, let's quote the instructions given by these authors to describe the making of the Torres Strait string figure called *baur* (Fish-Spear):

2.2.2.1 The Fish-Spear

> Position I. Take up, with the right index, the transverse string on the left palm from its proximal side, give one (or two) twist and return. Pass the left index through the right index loop from the distal side and take up the transverse palmar string of the right hand from the proximal side and return. Drop the thumb and little finger loops of the right hand and pull the hands apart (Haddon and Rivers 1902, p. 149).

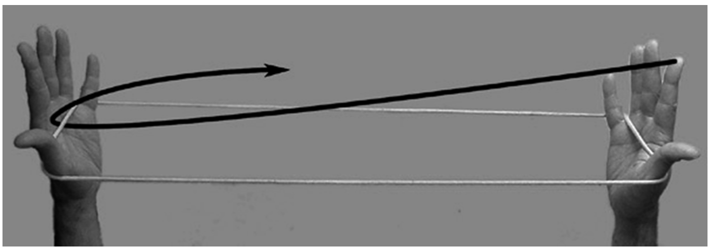


5a – *baur* (Fish-Spear) (Haddon and Rivers 1902, p. 149)

These instructions are followed by a drawing of the final figure (picture 5a). This is the only drawn figure: the text is assumed to be precise enough to teach how to make this string figure. However, the sketches are always made with great precision. When two strings intersect, one can identify their relative positions. The reader can then follow—more or less easily—the path on the string, and thus validate his own construction.

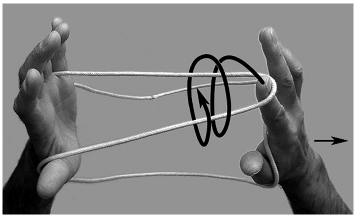
To facilitate the reading and memorizing of such instructions, further authors had the idea of dividing the instructions into successive numbered steps. This presentation is more appropriate, especially for long descriptions. In order to help the reader to make figures more easily, I have include pictures to illustrate most string figure-making instructions featured in this book. The making of figure "Fish-Spear" can be described by the following illustrated sequence:

1. Position I (picture 5b).

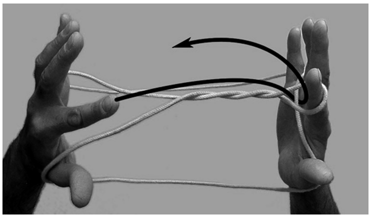


5b

2. Take up, with the right index, the transverse string on the left palm from its proximal side, give one (or two) twist and return (picture 5c).

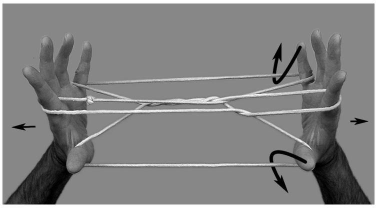


5c

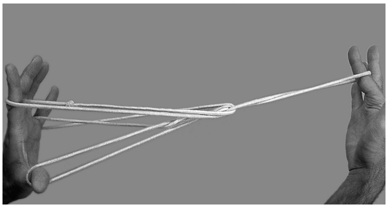


5d

3. Pass the left index through the right index loop from the distal side and take up the transverse palmar string of the right hand from the proximal side and return (picture 5d).
4. Drop the thumb and little finger loops of the right hand and pull the hands apart (pictures 5e and 5f).



5e



5f – Final figure of *baur* (Fish-Spear)

In the next chapter, I will come back on this way of writing down string figure instructions as a sequence. We shall see how the different steps ethnographers have noted down in the field were most certainly inspired by string games practitioners themselves. For now, let us look into a first conceptualization of string figure-making.

References

Andersen J (1927) Maori string figures. Board of Maori Ethnological Research, Memoirs, vol 2. Wellington. (Reprint edition 1979, New York: AMS Press)

Boas F (1888) The game of Cat's cradle. Int Arch Ethnogr I:229

Dickey LA (1928) String figures from Hawaii, including some from New Hebrides and Gilberts Islands. Bishop Museum, Honolulu. (Reprint Edition 1985, Germantown, New York ed., vol Bulletin n° 54)

Haddon AC (1890) The ethnography of the western tribe of torres straits. J Anthropol Inst G B Irel 19:297–440

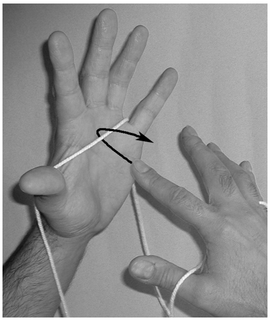
Haddon AC (1895) Evolution in art: as illustrated by the life-histories of designs. W. Scott, London
Haddon K (1911) Cat's Cradles from many lands. Albert Saifer, Watchung
Haddon AC (1912) String figures and tricks. In: Reports of the Cambridge anthropological expedition to the Torres Straits, vol 4. Cambridge University Press, Cambridge, 320–341
Haddon AC, Rivers WH (1902) A method of recording string figures and tricks. Man 2:146–149
Hornell J (1927) String figures from Fiji and Western Polynesia. Bishop Museum, vol 39. The Museum, Honolulu. (Reprint edition 1971, Germantown, New York: Periodicals Service Co)
Jayne CF (1962) String figures and how to make them: a study of Cat's Cradle in many lands. Dover Edition, New York. (A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York)
Jenness D (1924) Eskimo string figures. Report of the Canadian Arctic expedition 1913–1918, Part B, vol XIII. F.A. Acland, Ottawa
Landtman G (1914) Cat's cradle of the Kiwaï Papuans, British New Guinea. Anthropos 9:221–232
Mary-Rousseliere G (1969) Les jeux de ficelles des Arviligjuarmiut. Bulletin n°233. Musées nationaux du Canada, Ottawa
Maude H, Emory K (1979) String figures of the Tuamotus. Homa Press, Canberra
Paterson TT (1949) Eskimo string figures and their origin. Acta arctica, fasc. 3. E. Munksgaard, København
Rasmussen K (1929) Intellectual culture of the Iglulik Eskimos, vol VII, n° 1. Gyldendalske Boghandel, Copenhagen.
Rasmussen K (1931) The Netsilik Eskimos. Social life and spiritual culture, vol VIII, n° 1–2. Gyldendalske Boghandel, Copenhagen.
Smith HI (1900) The Thompson Indians of British Colombia: publications of the Jesup Pacific expedition, by James Teit. Memoirs of the American Museum of Natural History, vol 2, Anthropology I:281. Fig 270
Severi C (2007) Le principe de la chimère: une anthropologie de la mémoire. Editions Rue d'Ulm/Presses de l'Ecole normale supérieure, Paris
Victor P-E (1940) Jeux d'enfants et jeux d'adultes chez les Eskimo d'Angmassalik: Les jeux de ficelle. Meddelelser om Gronland 125(7):1–212. Copenhagen

Chapter 3
A Conceptualization of String Figure-Making

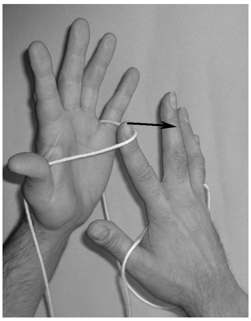
3.1 The Concept of Elementary Operation

The process of making a string figure can be analysed as a series of “simple movements” that I call “elementary operations”, insofar as the making of any string figure can be described by referring to a certain number of these operations. A string figure can thus be seen as the result of a “procedure” consisting of a succession of elementary operations.

Let us consider once again procedure Fish-Spear that is mentioned in the previous chapter. From Position I, taking up the left hand palmar string with the right index’s dorsal side can be defined as an “elementary operation”. More precisely, the elementary operation consisting in taking up a “string” with the dorsal side of a finger will be called “picking up” (a string). A consequence of the “picking up” elementary operation is to create a new “loop” on the finger which has implemented this operation (pictures 6a and 6b). After having picked up the right palmar string with the left index, the right hand returns to its original position. This return will be seen as an elementary operation called “returning to position”.



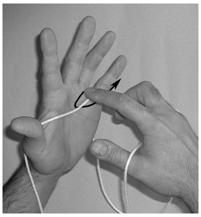
6a – Picking up a string with the dorsal side of a finger



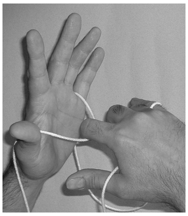
6b – Done

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_3

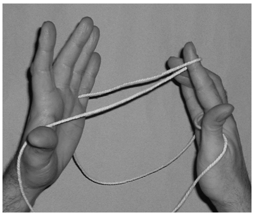
In some cases, the string is taken up with the palmar side of the finger. This elementary operation will be called "hooking up" (a string). For instance, it is possible to start procedure Fish-Spear by "hooking up" the left palmar string (instead of "picking up" it) with the right index as shown in the pictures 6c–6e. This variation on the Fish-Spear can be found in the corpus of string figures from Ammassalik, East Greenland, documented by P. E. Victor in the 1930s. This procedure is called *nukit* (Bird-Spear) (Victor 1940, pp. 24–25).



6c – Taking up the string with the palmar side of the finger...

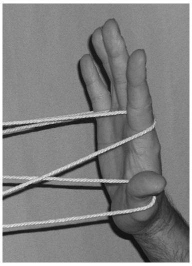


6d – ... rotating the latter, while returning to position

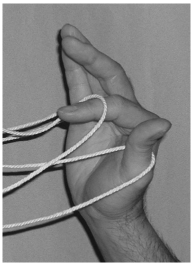


6e – Hooking up

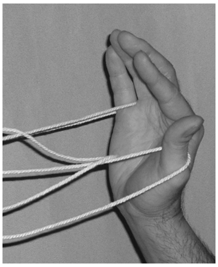
Some other elementary operations can be extracted from procedure Fish-Spear. At the end of it, the thumb and ring fingers of the right hand release their loop. This operation will be called "releasing" (a finger or a loop).



6f

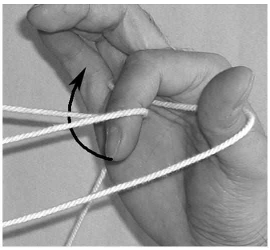


6g – Releasing

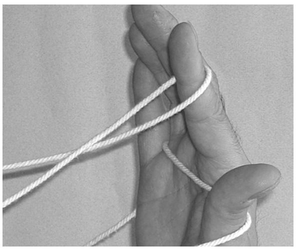


6h

Within the same procedure, the right index is rotated 360° several times on itself. I call this elementary operation "twisting".

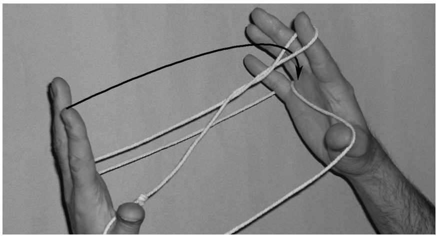


6i – Rotation 360°

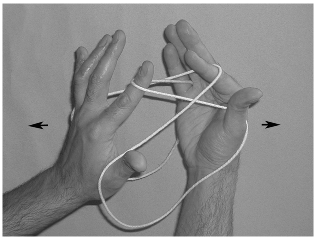


6j – Twisting

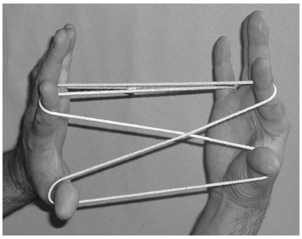
After having performed the "twisting" elementary operation, the left index is inserted, from the distal side, into the right index loop. This elementary operation will be called "inserting" (picture 6k). To finish the making of the spear, hands are drawn apart, extending the string. This elementary operation will be called "extending". This operation also occurs in Opening A (pictures 6l and 6m).



6k – Inserting

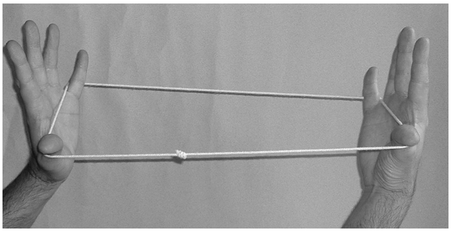


6l

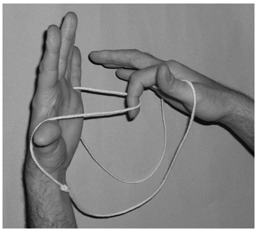


6m – Extending

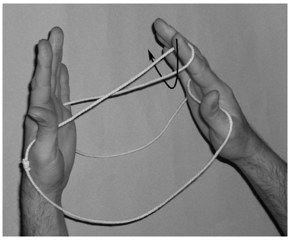
The following pictures (7a–7i) illustrate the succession of elementary operations leading to Arctic figure "Bird-Spear" mentioned above and described by Victor: Position I—Hooking up—Twisting (several times)—Picking up—Returning to position—Releasing—Extending.



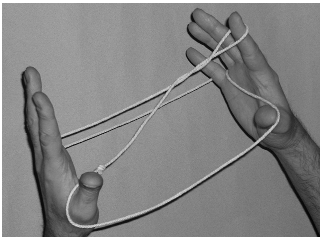
7a – Initial Position I



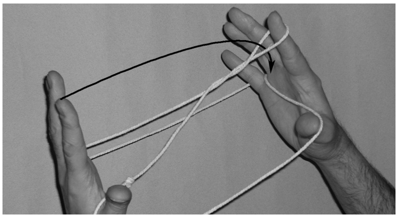
7b – Operation "Hooking up"



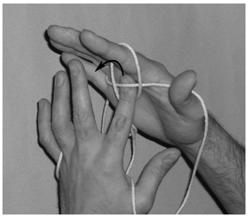
7c – Operation "Twisting"...



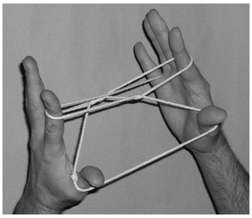
7d – Iterated several times



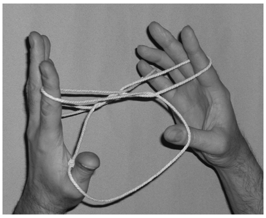
7e – Operations "Inserting",...



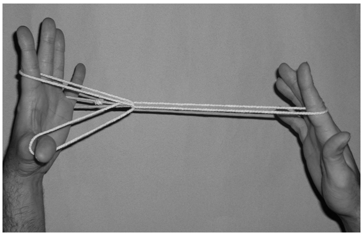
7f – "Picking up" implemented by left index and "Returning to position"



7g – 5. Right thumb and little finger release their loop



7h – : Operation "Releasing"



7i – Operation "Extending"—the string is extended and the spear appears'

3.1.1 Niu (Star) from the Solomon Islands

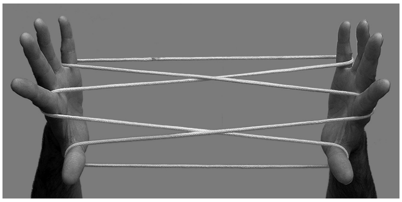
Now, let's give other examples of how the elementary operations mentioned above can be organized in procedures leading to various final figures. A procedure called *Niu* (star) in the Solomon Islands, Melanesia (South Pacific), has been collected by New Zealand anthropologist Raymond Firth (1901–2002) in 1928–1929. Working on Firth's field notes, Honor Maude[1] described this procedure in the book she devoted to Solomon Islands string figures[2] (Maude 1978).

Ethnologists and anthropologists who collected string figures in the field generally adopted Haddon and Rivers' nomenclature. However, this terminology is implemented through sentences whose structures often vary from one author to another. I have chosen to standardize the string figure instruction texts quoted in this chapter, using Honor Maude's instructions as a reference, as I found them to be the clearest. Moreover, this standardization will make the comparison of different procedures easier. The reader will find reference to the original text following each series of string figure-making instructions. In order to help the reader of these sometimes slightly arid texts, instructions will be illustrated by numerous pictures.

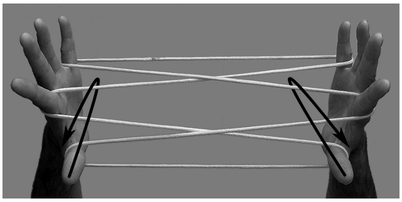
Procedure *Niu* begins with Opening A. The "inserting" and "picking up" operations are implemented several times. Finally, the operation "releasing" occurs thrice during the procedure.

3.1.1.1 Procedure *Niu*

1. Opening A (picture 8a)



8a



8b – Inserting and picking up

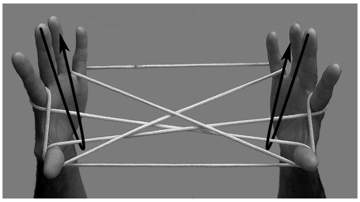
2. Insert thumbs, from distal side, into index loops and return with ulnar index strings (picture 8b).

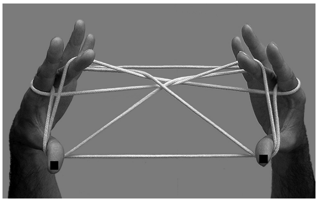
   This step consists in an "insertion" followed by the "picking up" and "returning to position" operations.

[1]Honor Maude (1905–2001) was Henry Evans Maude's wife. He spent many years as a civil servant in the colonial British colonies of the Pacific, then taught History of the Pacific at the Australian National University in Canberra. During Maudes' stays in the Pacific Islands, Honor Maude developed an interest in string figures and made numerous collections throughout the Pacific.

[2]In this book, Honor Maude compiled two unpublished collections of string figures from the Solomon Islands. The first was gathered in 1928–1929 by Raymond Firth (1901–2002) and the second by Christa de Coppet in 1963–1965. Firth collected *Niu* string figure in Fenualoa. Coppet found the same procedure as *Uuma* (a shell breast ornament), three decades later in Takatake, a village of the Malaita province.

3. Pass middle fingers *distal to*[3] radial index strings, insert into thumb loops from proximal side, then return with proximal ulnar thumb strings (picture 8c) and release thumbs (picture 8d).

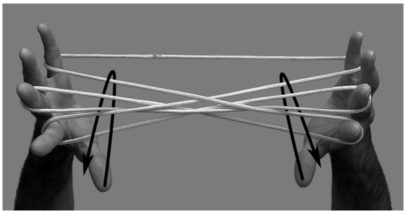

8c – Inserting and picking up

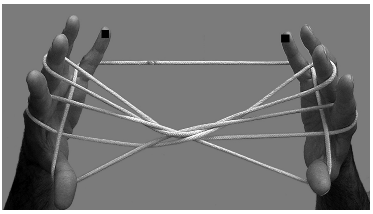

8d – Releasing

Graphical convention: a black square drawn on a finger indicates that the loop(s) carried by a finger is (are) released (see picture 8d).

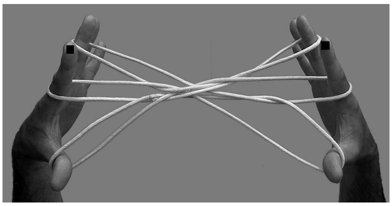
The same successive "inserting" and "picking up" operations are implemented in both steps 2 and 3, followed by a "releasing" operation in step 3.

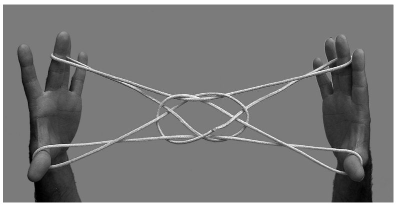
4. Pass thumbs, from distal side, through index loops, insert into little finger loops from proximal side, then return with radial little finger strings (picture 8e) and release little fingers (picture 8f).


8e – Inserting and picking up


8f – Releasing

5. Release indices (picture 8g) and extend slowly (picture 8h). (Instructions extracted from Maude 1978, pp. 1–2).


8g – Releasing


8h – Final figure of *Niu*

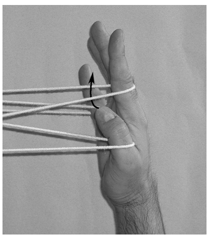
[3]Honor Maude uses the expressions "distal to" and "proximal to" which mean respectively "from the distal side" and "from the proximal side".

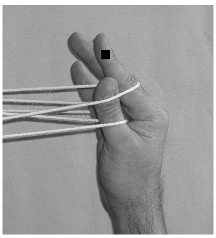
Some “elementary operations”, such as “releasing” or “extending”, occur very frequently in many string figures corpora. It is of the essence to identify all of these elementary operations. A little number of such operations could certainly be defined as “basic operations”. It would be useful to isolate and analyse them. Carrying out a comparative analysis of different corpora by identifying basic operations, either common or not, would certainly help us to understand why and how a set of elementary operations can generate, through combinations, a given corpus of string figures. We will come back to this point in Part IV of this book. The comparison of two corpora through the prism of “elementary operations”, using statistical methods, will throw some new light on this issue.

3.2 The Concept of Sub-procedure

3.2.1 Succession of Elementary Operations Shared by Several String Figure Procedures

In step 3 of the previous procedure (*Niu*), there is an operation that will be termed “transferring” (a loop): it aims to transfer a loop carried by a given finger to another finger. This operation has a high occurrence within every corpus that I have studied so far: to transfer the loop carried by the “finger A” to the “finger B” one just needs to insert the finger B, from the distal (or proximal) side into the loop of the finger A, then release the latter finger A. Two elementary operations are therefore involved in a transfer: the first is the insertion of a finger into a loop (inserting), followed by the release of a loop by a finger (releasing). In step 3 of procedure *Niu* the thumbs transfer their proximal loops to the middle finger. The “Transferring” operation can be seen as the succession of two elementary operations (Inserting + Releasing)—a succession that occurs in the making of many string figures. Pictures 9a–9c illustrate the transfer of the right index loop to the right thumb.


9a – Inserting


9b – Releasing


9c – Transferring

Definition I define a “sub-procedure” as any succession of elementary operations either shared—i.e. used in the same way in several string figure procedures—or iterated in the same one.

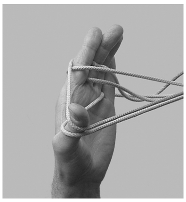
The “transferring” operation occurs frequently in many corpora of string figures. It can thus be seen as a sub-procedure consisting in two successive elementary operations. Let me give further examples of such sub-procedures.

3.2.1.1 The Openings: Starting Sub-procedures

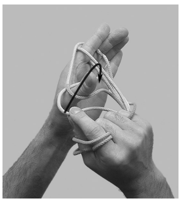
Opening A, as described above, is involved in every string figure corpora that I have analysed so far. Starting from Position I, it consists in a succession of four elementary operations (picking up—inserting—picking up—extending). It can therefore be seen as a sub-procedure. As it is the case for the making of string figure *Niu*, this sub-procedure occurs generally at the beginning of the procedure. In every corpus, there always exist a limited number of starting sub-procedures that ethnographers, following Haddon and Rivers, have defined as “openings”. Several descriptions of such openings will be given in the following.

3.2.1.2 Sub-procedure “Navaho”

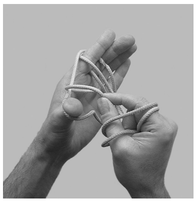
Another example of a sub-procedure is given by an operation called “Navaho” in the ethnographical literature. When two loops lie on the same finger (picture 10a) the “Navaho” operation is implemented on this finger by passing the proximal loop over the distal one, and then, over the fingertip (pictures 10b–10d). The term “Navaho” is also used as a ver—for instance, “Navaho the right index” or “Navaho the thumbs”.



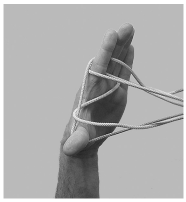
10a



10b



10c



10d

Sub-procedure “Navaho” thus consists in the succession of three elementary operations:

1. Grasping the string between thumb and index (of the opposite hand) (picture 10b).
2. Passing the string over the tip of the finger (pictures 10b and 10c).
3. Releasing the string (picture 10d).

I have noticed that this sub-procedure occurs very frequently within Oceania, Canadian Arctic and South America string figures corpora. The reader will be invited to perform it several times as part of both string figure procedures “Ashes” and “Ten Men” described in the following.

To my knowledge, the term "Navaho" was first used in this context by Kathleen Haddon, in her book *Cat's Cradle from Many Lands* (1911), where she defines the expression "Navahoing":

> When there are two loops on a digit, a distal one and the proximal one, you are often required to lift the proximal loop over the distal one, and over the tip of the digit onto its palmar aspect. This movement I refer to as "Navahoing" in account of its frequent occurrence among the string figures of Navaho Indians of New Mexico, USA (Haddon 1911, p. 5).

Though Kathleen Haddon does not mention it, we can assume it is the high occurrence of this "movement" in a large number of string figure procedures that led her to name it. Indeed, this sub-procedure occurs very frequently within Oceanian, Arctic and South American corpora of string figures. Furthermore, by choosing the name of a society to designate this operation, Kathleen Haddon suggests that a "movement" (sub-procedure) could be characteristic of a group of individuals. There are only a few examples of sub-procedures specifically named in ethnographical papers. Another example is given by the so-called "Caroline extension".

3.2.1.3 The "Caroline Extension"

To my knowledge, the expression "Caroline extension" has been used for the first time by Henry and Honor Maude in their article "String-figures from the Gilbert Islands" (Maude and Maude 1936). Although they do not specify it, it is likely that this name was chosen due to the high frequency of this operation in the Caroline Islands, South Pacific.[4] However, as far as I know, the Caroline extension occurs frequently in every Oceanian string figures corpora. Unlike sub-procedure Navaho, the Caroline extension does not seem to have been used by Inuit practitioners.[5] This remark suggests that certain sub-procedures are very localized and specific to a particular region, while others are common to many corpora collected in geographically distant areas. Local sub-procedures certainly have a strong impact on the shape of the corpus in which they are included. Carrying out an in-depth analysis of the nature of the links between the corpora of string figure procedures and the sub-procedures they contain should lead to a better understanding of a given string figures corpus' specificity. We will return to this point later.

Caroline extension—When a thumb carries a loop and the index of the same hand is free, the Caroline extension consists in picking up the ulnar thumb string (picture 11a), while pressing the thumb against the index in order to seize the latter string (picture 11b), and, finally, rotating the hands outwards (pictures 11b and 11c).

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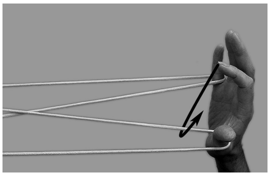
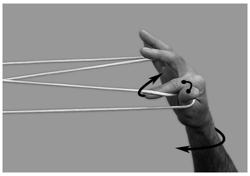
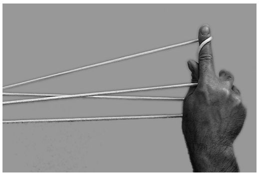
[4] Caroline Furness Jayne had first described this "movement", without naming it, in her book (1962, pp. 260–264, first edition 1906). Later, in 1930, Kathleen Haddon described the same operation under the vernacular term "Pindiki" without specifying which vernacular language this term came from Haddon (1930, p. 156).

[5] The "Caroline extension" operation is not involved in the three main documented corpora of string figures from the Canadian Arctic (Paterson 1949; Mary-Rousseliere 1969; Jenness 1924).


11a – Picking up


11b – Seizing and rotating


11c – Caroline extension

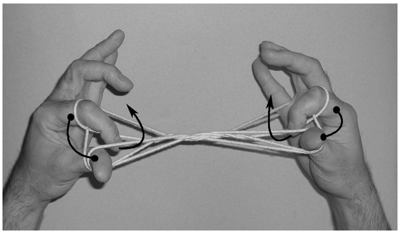
Graphical convention: an arc drawn between two fingers and closed by two endpoints, will mean that the two fingers in question are pressed against one another (pictures 11b and 11c).

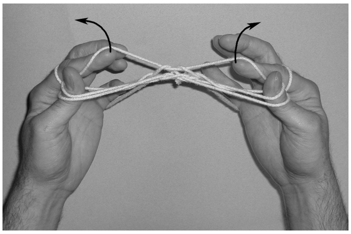
This sub-procedure is composed by three elementary operations:

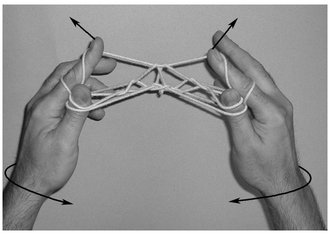
1. "Picking up" the ulnar thumb string with the index (picture 11a).
2. "Seizing" this string between the thumb and the index (picture 11b).
3. "Rotation" of the hands (pictures 11b and 11c).

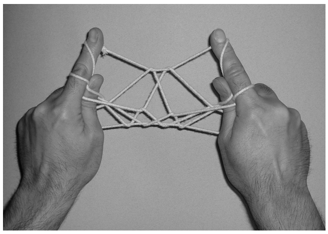
Rotations occur frequently in many corpora. One can distinguish two forms of rotation: rotation about a vertical axis as in the Caroline extension, and rotation about an horizontal axis, which we will encounter in the following description of procedure "Ashes".

A Caroline extension often concludes a string figure procedure, allowing to display the final figure as for Solomon string figure *Waru hou roko* (eight days of darkness, pictures 12a–12d) (Maude 1978, p. 126).


12a


12b

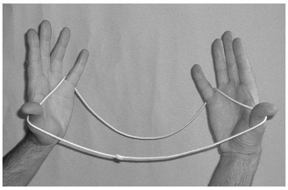

12c

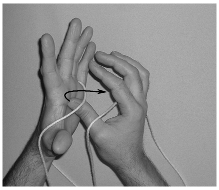

12d – Final figure of *Waru hou roko*

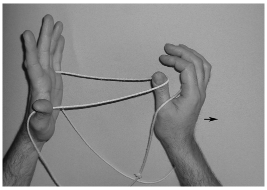
However, it is not the only "function" of this sub-procedure: there are Oceanian string figure procedures in which the Caroline extension is not performed at the end of the process, but during the course of the procedure. Such is the case in the making of string figure “Ashes”, collected by Philip Noble[6] in 1974, in Papua New Guinea (Itokama area, Central Province).

3.2.1.3.1 String Figure “Ashes”

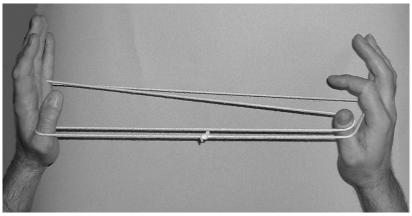
1. Position I (picture 13a).
2. Pass right thumb, from proximal side, under left palmar string. Return with left palmar string (pictures 13b and 13c).

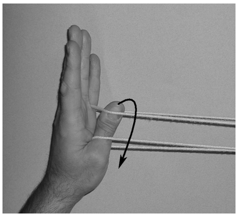

13a


13b

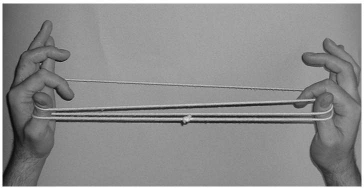

13c

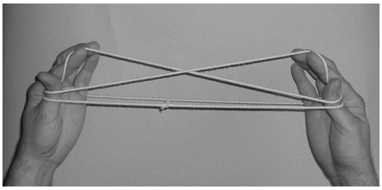
3. Insert left thumb, from proximal side, into the left little finger loop, return with radial little finger string (pictures 13d and 13e).


13d


13e

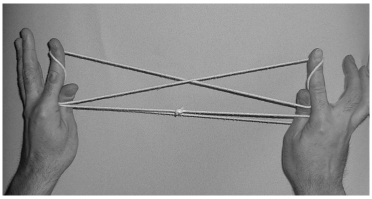
4. Caroline extension (pictures 13f–13h).

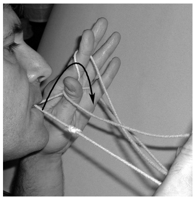

13f

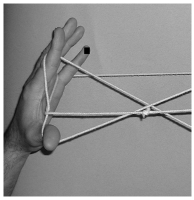

13g

[6] Anglican minister Philip Noble stayed in Papua New Guinea from 1972 to 1975, as a missionary. On this occasion, he became interested in string figure-making and documented a corpus of 140 procedures (Noble 1979).

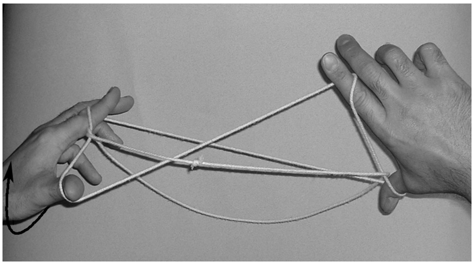
5. “Navaho” the thumbs (use the mouth to do this: picture 13i). Release little fingers (picture 13j).

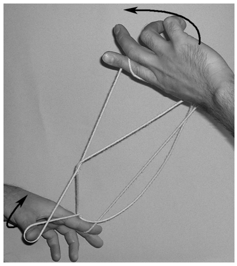

13h

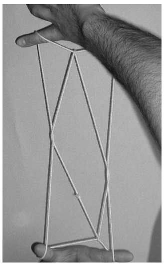

13i

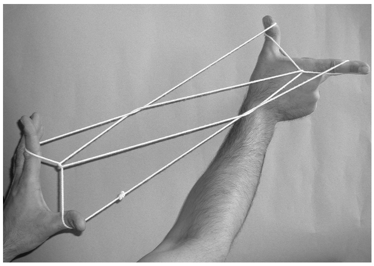

13j

6. Maintain tension on the strings and keep right hand still, palm out, fingers pointing upwards, circle left hand vertically down away so that the fingers point to the ground (pictures 13k–13n) (Instructions of Ashes adapted from Noble 1979, p. 122).


13k


13l


13m


13n

Defining sub-procedures, such as “Transferring”, “Navaho” and “Caroline extension”, is crucial. These sub-procedures result from the organization of a set of elementary operations. An intellectual process has certainly led the practitioners to identify these ordered sets of operations, having a significant impact on different substrata (configurations of string). This is confirmed by the fact that the practitioners themselves have sometimes given vernacular names to some of these sub-procedures. We will come back to this important point later (Sect. 3.2.3).

3.2.2 *Iterative Sub-procedures*

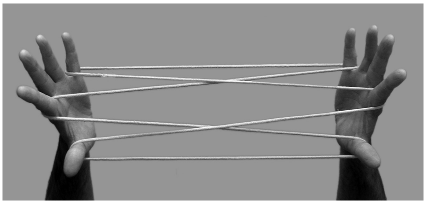
In some cases, the same sub-procedure is iterated several times within the same string figure procedure. I define such a sub-procedure as an "iterative sub-procedure".

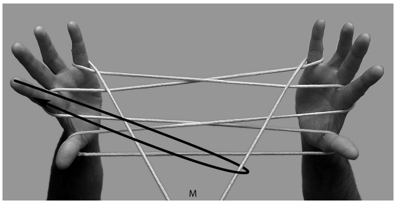
3.2.2.1 String Figure Ten Men

Procedure Ten Men was recorded in 1902 in the Caroline Islands by anthropologist William Henry Furness, and published in 1906 by his sister, Caroline Furness Jayne (1962, pp. 150–156). As the following description will show, this procedure is based on the iteration of a sub-procedure. Procedure Ten Men can be found in many published collections of string figures from Oceania. This procedure is indeed longer and more complicated than the previous ones. As we will see, the sub-procedure Navaho is also involved in the making of Ten Men, as part of the iterative sub-procedure.

3.2.2.1.1 Procedure Ten Men

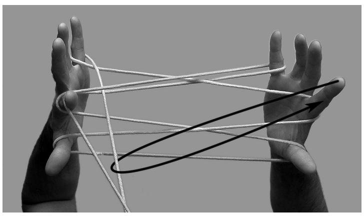
1. Opening A (picture 14a).
2. With teeth, draw the ulnar little finger string towards you, distal to all strings (picture 14b).

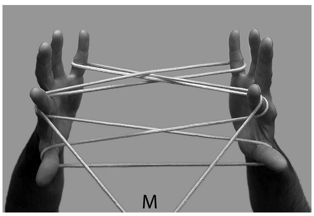

14a



14b

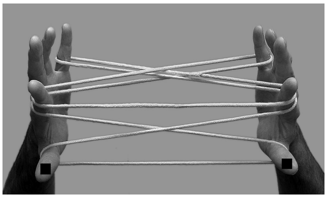
3. Insert left index, from distal side, into the loop held by teeth, then return with the right string of the loop (picture 14b).
4. Bend right index, proximal to the left string of the loop held by teeth (picture 14c), then return with the left string of the loop (picture 14d). Unclench teeth.


14c

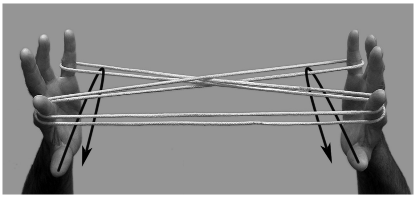


14d

5. Release thumbs (picture 14e) and extend.
6. Pass thumbs, proximal to index loops, insert into little finger loops, from proximal side, return with radial little finger strings (picture 14f).

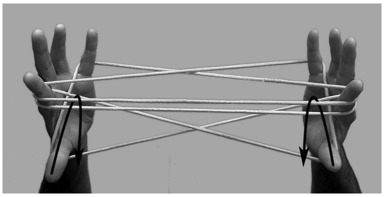


14e

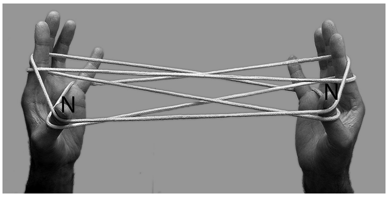


14f

7. Insert thumbs from proximal side into distal index loops, then return with distal radial index strings (picture 14g). "Navaho" the thumbs (picture 14h).

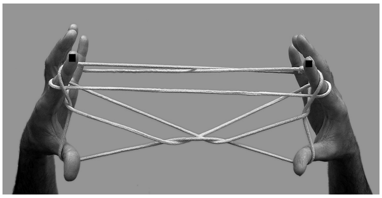


14g

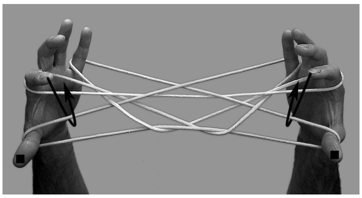


14h

8. Release indices from distal loops (picture 14i). Insert indices, from proximal side into index loops then, transfer thumb loops to indices (picture 14j).

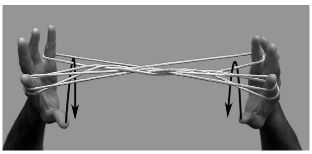


14i

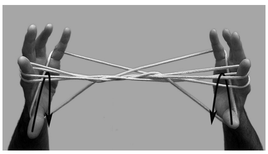


14j

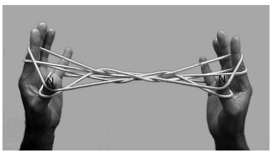
9. Repeat (6, 7) (pictures 14k–14m).



14k

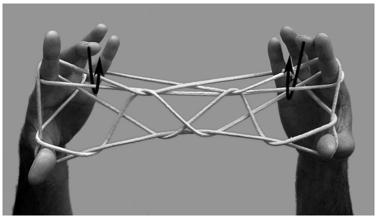


14l

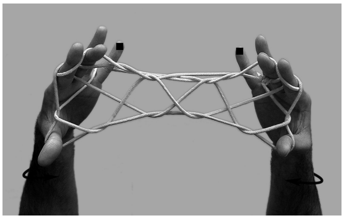


14m

10. Pass middle fingers, distal to distal ulnar index strings, insert from distal side, into proximal index loops, return with proximal radial index strings (picture 14n).

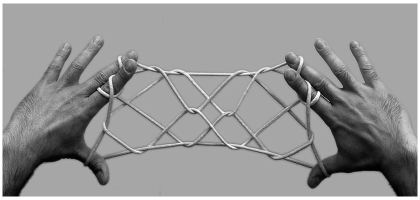


14n

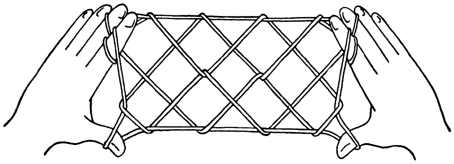


14o

11. Release little fingers (picture 14o), then extend turning palms away from you with fingers spread out (picture 14p) (Instructions of Ten Men adapted from Jayne 1962, pp. 150–156).



14p



14q – Final figure of "Ten Men" (Jayne 1962, p. 156)

In this procedure, a series of elementary operations is repeated twice in the same way. More precisely, it is steps 6 and 7, that are iterated in step 9. Notice that this sub-procedure is applied to two different configurations (substrata). In this case, the "iteration" of an ordered set of elementary operations allows to define the (iterative) sub-procedure applied successively to different substrata.

3.2.2.2 String Figure *Bava*

Several examples in ethnographical literature suggest that these iterative sub-procedures have been sometimes identified as such by the creators of string figures. It is actually the case for the iterative sub-procedure involved in procedure Ten Men. In the collection of string figures from British New Guinea published by anthropologists James Hornell and W.E. Rosser, procedure Ten Men is described as *beira* (not translated).[7] Immediately afterwards, these authors give the instruction

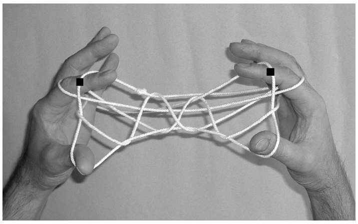
[7] See Rosser and Hornell (1932, p. 47). Hornell and Rosser actually do not detail the instructions for making figure *beira*. However, they refer to Tongan string figure *Laoukape* described by Hornell

for making string figure *bava* (crab), which can be seen as a continuation of procedure *beira*. Procedure *bava* can be described as follows:

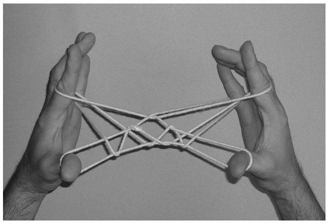
3.2.2.2.1 String Figure *Bava* (Crab)

1. Ten Men: stages 1–9.
2. Release indices from distal loops (pictures 15a and 15b). Insert indices, from proximal side into thumb loops (picture 15c), then transfer thumb loops to indices (pictures 15d and 15e).

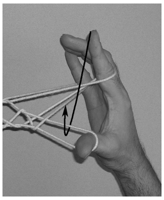
   Notice that this step is similar to step 8 in procedure Ten Men.



15a



15b



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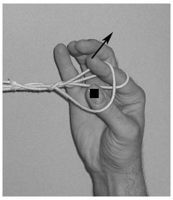
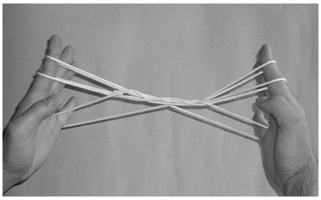


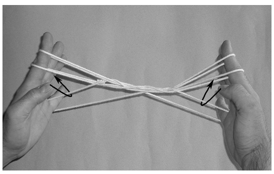
15d



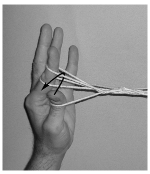
15e

3. Repeat stages 6–7 of Ten Men:

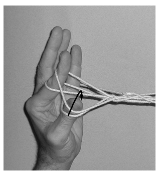
   – Pass thumbs, proximal to index loops, insert into little finger loops, from proximal side, return with radial little finger strings (picture 15f).
   – Insert thumbs, from proximal side, into distal index loops, return with distal ulnar index strings. "Navaho" the thumbs (pictures 15g–15i).



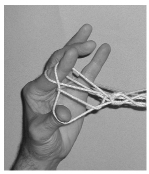
15f



15g



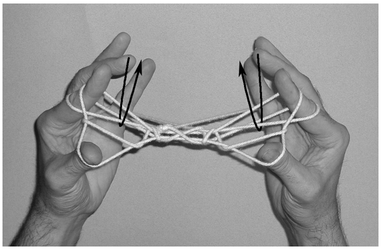
15h



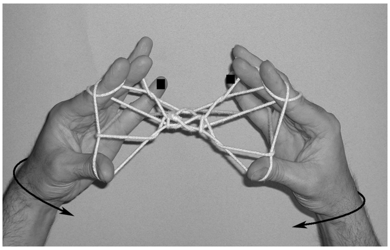
15i

in a previous publication devoted to string figures from Fiji and Western Polynesia (Hornell 1927). Procedure *Laoukape* actually slightly differs in the making of the configuration concluding Ten Men's step 5. Let's not focus for the moment on this variation; it will be analysed later in the book.

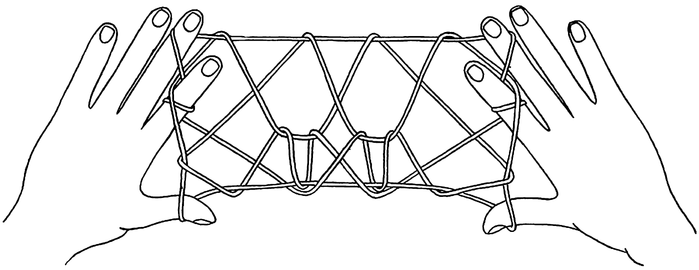
4. Stages 10–11 of Ten Men:
   - Pass middle fingers, distal to distal ulnar index strings, insert from distal side, into proximal index loops, then return with proximal radial index strings (picture 15j).
   - Release little fingers, and then extend turning palms away from you, with fingers spread out (pictures 15k and 15l) (Instructions adapted from Rosser and Hornell 1932, p. 47).



15j



15k



15l – Final figure of *Bava* (crab) extracted from Rosser and Hornell (1932, p. 47)

Let A be the iterative sub-procedure previously identified in Ten Men (steps 6 and 7) and B the sub-procedure that appears in step 8 of Ten Men as well as in step 2 of *Bava* i.e. the release of the indices, followed by the transfer of the index loops to the thumbs. The structure of procedure *Bava* can then be written down as follows:

1. Ten Men's steps 1–5 (leading to a configuration to which sub-procedure A is applied).
2. Sequence $ABABA$.
3. Operations allowing the extension of the final figure (same as for Ten Men).

Sub-procedure A is repeated three times. Sub-procedure B can be seen as a succession of operations that leads to a configuration to which sub-procedure A can be applied. Notice that one could also consider that sub-procedure AB is iterated twice. Procedure *Bava*'s creation seems to have been inspired by procedure Ten Men (well known throughout the Pacific): its creator has clearly identified into the latter procedure a series of elementary, easy to iterate operations. It is theoretically possible to iterate sub-procedure AB, as many times as allowed by the string's length. However, so far, I have not found such a continuation of procedure *Bava* in the ethnographical literature. The iteration of a sub-procedure as many times as possible (depending on the length of the string) occurs in many corpora of string figures. An example will be given later in this chapter.[8]

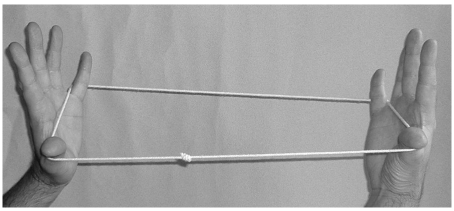
The concepts of "elementary operation", "sub-procedure", "procedure" previously introduced, are valuable conceptual tools. They provide a basis for developing a methodology aimed at studying the structure of various corpora of string figures. However, before entering into these methodological considerations, we shall ask ourselves whether these concepts echo with what is known about string figures practice among people from traditional societies. The above example of string figure *Bava* suggests that sub-procedures could have been, in some cases, conceptualized as such by the creators of string figures themselves. This is confirmed by the use of a vernacular terminology that is sometimes associated to the practice of string figures in some societies.

3.2.3 Vernacular Terms Associated to String Figure-Making

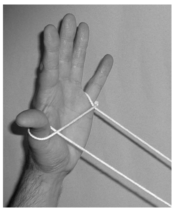
Some ethnographical studies document a list of vernacular terms used by practitioners while making string figures. In particular, such a list is provided by missionary Guy Mary-Rousselière in his work about string figures made by the *Arviligjuarmiut* of Pelly Bay in the Canadian Arctic (1969, pp. 5–6).

3.2.3.1 The Example of Pelly Bay

In this Inuit society the term *Ayarauseq*[9] denotes the final figure extended at the end of the procedure. There are two terms defining an initial position: *Pauriicoq* refers to previously described Position I (picture 16a) and *Paurealik* (or *Paureadlak*) is the name of a very similar position—in this case, however, the loops on the thumbs and little fingers must be "closed" (picture 16b).



16a – *Pauriicoq* (Position I)



16b – *Paurealik*

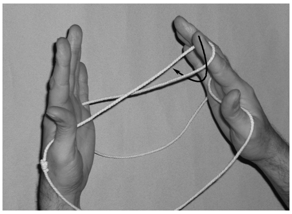
[8]See Sect. 3.4.3 (Transformation through iteration).

[9]Mary-Rousselière's spelling—although it does not match the conventional system adopted in the 1970s to transcribe the Inuit language (Inuktitut).

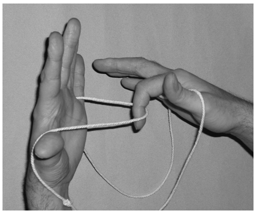
In a large number of Inuit string figure procedures, operations are not performed simultaneously and symmetrically on both hands. The hands can perform either different operations (as in procedure Bird Spear described above—Sect. 2.2.2) or the same series of operations, one hand after the other. It is most certainly the description of these two situations that led to the use of the terms *Iglupiak* and *Iglugêk*, meaning respectively "on one side" and "on both sides".

Some terms were used to denote some operations that I define as "elementary operations":

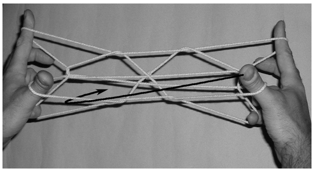
– *Pakiniglugo*: Hooking up or picking up (the string).
– *Sapkudlugo*: Releasing a finger from its loop.
– *Qilorqitidlugo*: Extending the string between both hands.
– *Qipisimasuerlugo*: Turning a loop closed on a finger in order to open it (pictures 16c and 16d).
– *Qîncrerlugo* means "putting two loops together" and consists in inserting one finger, from the proximal side, into the loop of the other hand's same finger, picking up the radial string, then returning to the initial position (pictures 16e and 16g).



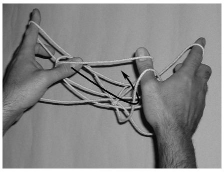
16c



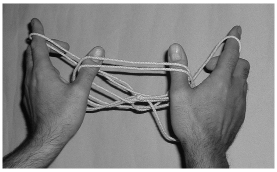
16d – Operation *Qipisimasuerlugo*



16e



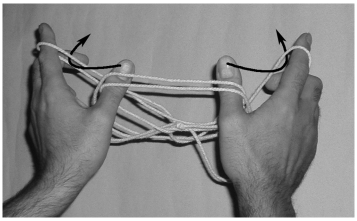
16f

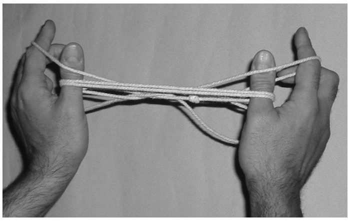


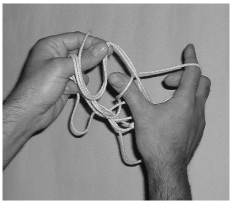
16g – Operation *Qîncrerlugo*

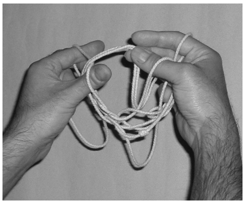
Among the *Arviligjuarmiut*, some elementary operations have been named by string figures practitioners. Although Mary-Rousselière does not mention it, these vernacular terms were most likely used by the *Arviligjuarmiut* to facilitate transmission of these difficult procedures. It is also noteworthy that some terms denote a movement which can be analysed as a series of operations. This suggests that some sub-procedures have been identified as such by this Inuit society's practitioners.

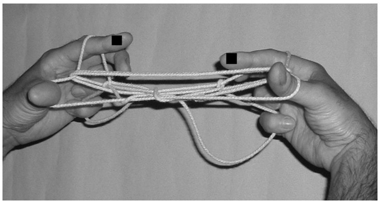
- *Ayorarlugo*: performing Opening A.
- *Anitidlugo*: passing (a loop) into/through another.[10]
- *Katilluik*: This series of operations can be applied when loops are formed on the thumb and index of both hands. This series begins with operation *Qînerelugo* described above (pictures 16e–16g). The thumbs are inserted, from proximal side, into index loops (pictures 17a and 17b). Operation Navaho is then performed on each thumb, one hand after the other (pictures 17c and 17d). Finally, the indices release their loops (picture 17e) and the string is extended (picture 17f).

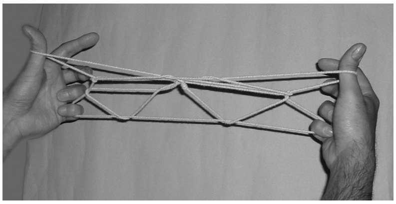

17a


17b


17c – Navaho the thumbs, one hand . . .


17d – . . . after the other


17e


17f

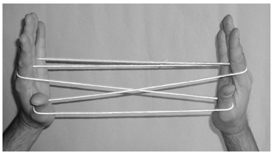
[10]This operation has been used by American mathematician Thomas Storer as a starting point for a new conceptualization of string figure-making (Heart-sequence). We will return to this, in greater detail, in Part II of this book.

3.2.3.2 The Example of the Goodenough Islands

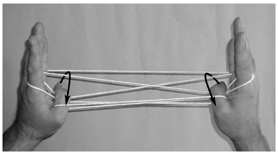
In Oceania, it is also attested that a technical terminology was sometimes associated to string figure-making.[11] In his paper on Goodenough Islanders' string figures, ethnologist Diamond Jenness mentions that two sub-procedures, frequently occurring in the corpus he has documented, were given specific names (Jenness 1920, p. 300). The first one is called *nauwa*. It is performed when at least one loop is made on each thumb and little finger—for instance, in the configuration obtained through Opening A (picture 18a).

This short sub-procedure can be described as follows:

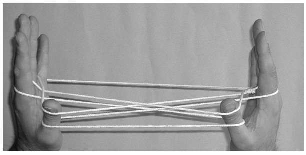
– Pass thumbs distal to all intermediate strings, insert into little finger loops from proximal side, pick up radial little finger strings and return to position[12] (pictures 18a–18c).



18a



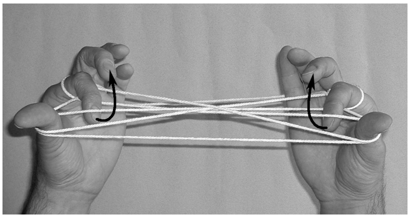
18b



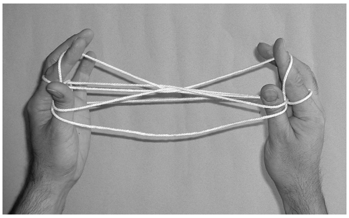
18c

The second one is called *luatataga*, and occurs most often consecutively to sub-procedure *nauwa*. It can be performed when each thumb carries two loops, a proximal and a distal one. It then goes as follows:

– Insert indices, from proximal side, into proximal thumb loops, pick up the ulnar thumb strings and return to position[13] (pictures 18d and 18e).



18d



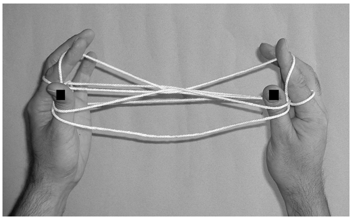
18e

[11] See in particular Maude and Emory (1979), Maude (1971), Maude and Maude (1936), and Maude and Firth (1970).

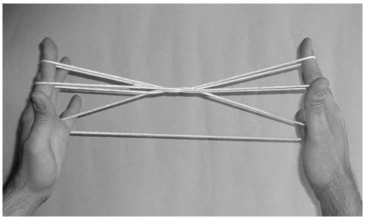
[12] Instructions adapted from Jenness (1920, p. 300).

[13] Instructions adapted from Jenness (1920, p. 300).

Jenness does not say it explicitly, but, in the string figure procedures described in his paper, sub-procedure *luatataga* is generally followed by a release of the thumbs, in particular when it is performed immediately after *nauwa*[14] (pictures 18f and 18g).



18f



18g

Jenness does not mention any other vernacular technical term echoing the concepts of elementary operation and sub-procedure. Was there nothing else to notice or did Jenness interrupt his ethnographic research in this direction? It is hard to tell. However, his crucial observations confirm those made by Mary-Rousselière. These two examples demonstrate that a vernacular technical terminology associated to the practice of string figures was in use in some societies. This vocabulary may contain some terms corresponding to what I have defined as "sub-procedures". Both testimonies reveal that ordered sets of elementary operations were sometimes recognized, memorized and named by string figures practitioners. Further ethnolinguistic research on such vernacular nomenclatures associated to string figure-making could allow to identify operations involved in a given corpus, rendering the actors' viewpoint. In fact, it seems that string figure practice is not conceptualized in the same way in every society. Raymond Firth and Honor Maude underline this concerning the Tikopia practitioners from the Solomon Islands:

> Like the Navaho Indian who, on being shown an intricate and beautiful Nauruan design, replied that "it is not a string figure", the islanders too have their aesthetic conceptions of what constitutes a perfect pattern [...] (Maude and Firth 1970, p. 9).

A comparative ethnolinguistic study of the technical terms relating to the practice of string figure in different societies could then be a promising way to identify and analyse different modes of this practice's vernacular conceptualization.

3.2.4 Summary

Reading ethnographical papers on string figures made me able to familiarize myself with the terminology (distal, radial, etc.) used by ethnographers, since Haddon and

[14]See for instance, procedures *Guva'ta* (The Seine) or *Yavunu'ga* (The Pleiades) (Jenness 1920, pp. 309–310). Sequence "*Nauwa* - *Luatataga* - Release the thumbs" is a sub-procedure involved in the making of several string figures in the neighbouring islands of the Trobriand archipelago. I will come back to it below, in Part IV (Sect. 9.3) of this book.

Rivers, to record string figure procedures. Thanks to them, I have learnt (though not without difficulty) how to make numerous string figures. This led me to a first conceptualization of this practice: a string figure procedure can be analysed as a series of simple "movements" (picking up, releasing, etc.) that I define as elementary operations; these elementary operations are organized in procedures, and each of these procedures is meant to display a final figure. Finally, I have defined a sub-procedure as being any succession of elementary operations either shared—that is, used in the same way in several string figure procedures—or iterated in the same procedure (iterative sub-procedures).

In some societies, the use of a vernacular terminology relating to string figures suggests that this conceptualization of string figure-making sometimes is or was close to the actors' viewpoint. This conceptualization will be the keystone of a methodology aimed at carrying out a comparative study of different corpora of string figures. After learning the procedures of a given corpus, the elementary operations should be listed and the sub-procedures identified. Undertaking this task for a large number of corpora would probably allow us to answer some fundamental questions. Is there a great variety of elementary operations? Would some of them be characteristic of a given corpus? Or rather, is there a small number of elementary operations occurring within various corpora, but organized through sub-procedures that differ from one corpus to another? In the latter case, a given corpus could be characterized by the sub-procedures it gathers, more than by the elementary operations themselves. In all cases, one will seek to classify the elementary operations, trying to describe their impact on the different configurations of the string. Carrying out this comparative study should lead us to a better understanding of the procedural aspects of string figure practice.

These questions and this methodology have guided my ethnographical research among the Trobrianders of Papua New Guinea and the Guarani-Ñandeva of the Chaco, Paraguay. The outcomes of this research will be presented in Part IV of this book. The conceptual tools previously introduced are based on a "dissection" of the procedure, highlighting the simple elements which constitute it. From another viewpoint, we might now intend to analyse a string figure-making process as a whole, thus trying to tackle the global shape of these procedures.

3.3 Another Way of Analysing String Figure Procedures

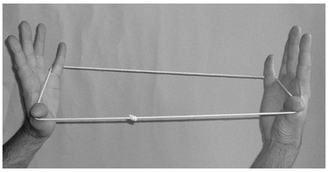
3.3.1 The Concept of "Position"

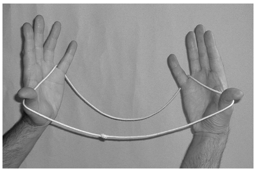
3.3.1.1 "Initial", "Normal" and "Final" Positions

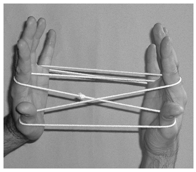
In his article "Langage de ficelles: Au fil d'une enquête dans le Chaco argentin", Argentinian ethnolinguist José Braunstein develops the idea that a string figure procedure can be analysed as a "message", and can thus be regarded as belonging to a genuine communication system:

> This system has the advantage of showing similarities to a system which has been analysed for a long time: oral language. The first is the existence of a polymorphic system selected by each culture, resulting from the articulation of particular human organs with an external element. In spoken language, the organs of phonation—the tongue and different points of nasal and oral cavities—are used in combination with air breathed in and out. In string figure-making, these organs are those parts of the hand—mostly fingers, but also, exceptionally, forearms, elbows and the lower limbs' extremities—which interact with a continuous thin (endless) string (Braunstein 1996, p. 141) - my translation.

Through this analogy, Braunstein suggests that it would be of great interest, to those studying string figure-making, to borrow some methods from linguistics. I will not go further into that, but let us keep in mind the idea of "structured message". What are the analysis tools that emerge when looking at string figure procedure as a message that begins with an "initial position" (e.g. Position I) and which ends on a "final position or figure"? Braunstein demonstrates that the message gets its rhythm from two possible states of the string: taut or slackened; the slackened state allows the operations to be performed. For example, let us consider a procedure starting with Opening A: in Position I, the string is held taut (picture 19a). To be able to perform Opening A, one needs to slacken the string (picture 19b). Finally, the string is once again extended (picture 19c).


19a


19b


19c

The taut state is termed "normal position" by Braunstein, who also defines as a "passage" any succession of operations between two returns to a "normal position". A string figure process can then be seen as a sequence, which begins with an initial position (Position I for instance), followed by an "opening" to take up the string in the first "normal position". Then, some "passages" are performed from one normal position to the next, and the "final figure" concludes the message (Braunstein 1996, p. 142).

3.3.1.2 The Procedure *Pilun*

In order to illustrate Braunstein's viewpoint, let me describe a string figure procedure called *Pilun* on the Caroline Islands.[15] This procedure starts by taking up the string in Position I (initial position).

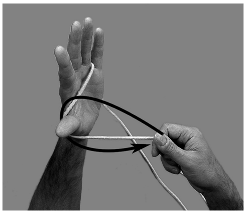
[15]This procedure was recorded in 1902 by anthropologist William Henry Furness in a village in Uap, one of the Caroline Islands (Jayne 1962, pp. 252–259). Very similar procedures have been collected in several places throughout the Pacific (Noble 1979, pp. 41–42; Maude 1978, pp. 59–60).

1. Position I (picture 20a).

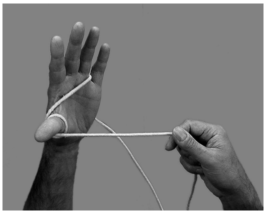
   Taken together, the following steps (2 and 3) form the first "passage". The string is slackened to allow the elementary operations to be performed.

20a

2. Twist radial thumb string once round left thumb (pictures 20b and 20c).



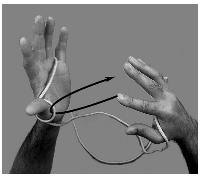
20b



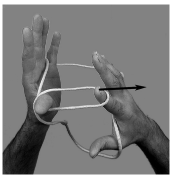
20c

3. Insert right index, from proximal side, into loop round left thumb and return to position (pictures 20d–20f).

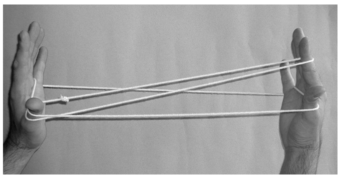
   At this stage the string is taut, and the second normal position is reached (picture 20f). Step 4 corresponds to the second passage.



20d



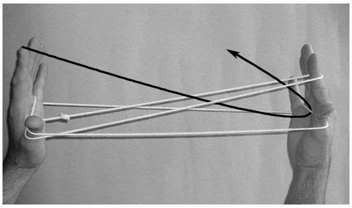
20e

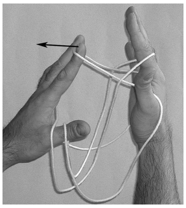


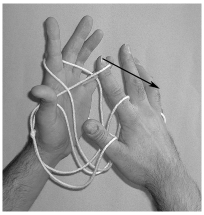
20f

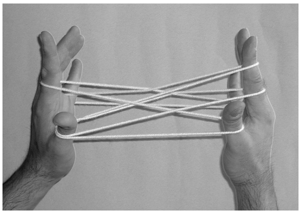
4. Pass left index, from distal side, through right index loop, pick up left palmar string and return to left (pictures 20g and 20h); likewise, pick up left palmar string with right index (pictures 20i and 20j).

In Part IV, we will see that this string figure procedure is known in the Trobriand Islands, Papua New Guinea, under the name *Tokopokutu* (lice comb).


20g

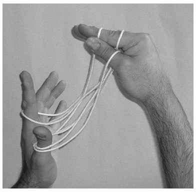

20h

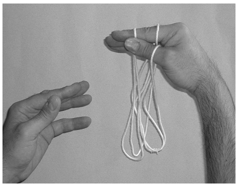

20i

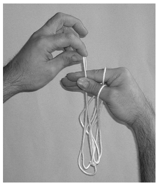

20j

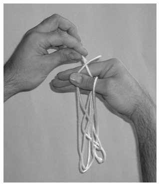
Once again, the string is taut and the third normal position is reached (picture 20j). The following steps, from 5 to 7, form the third passage.

5. Release left hand (pictures 20k and 20l), then raise slightly the distal loop on right index (picture 20m).
6. Pass left index and thumb through this small distal index loop, from distal side, and pull up the proximal index string (picture 20n).

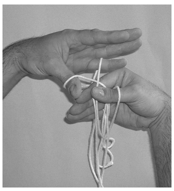

20k

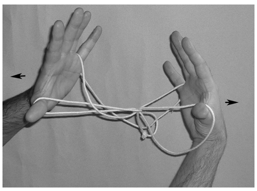

20l

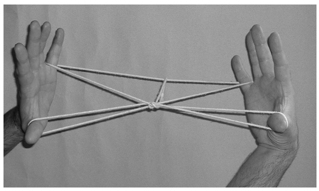

20m


20n

7. Pass left thumb, from proximal side, into former proximal small loop; and pass left little finger, from distal side, into former distal small loop (picture 20o). Release right index and extend (pictures 20p and 20q).

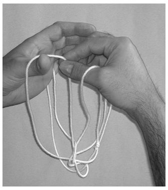

20o

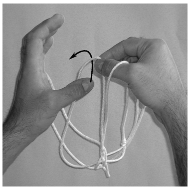

20p

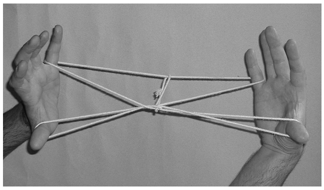

20q

Step 8 is the passage from this fourth normal position (picture 20q) towards the fifth one, the last one before displaying the final figure.

8. With opposite hand grasp ulnar string, remove loop from thumb, then replace it turned over towards you (pictures 20r and 20s). Extend (picture 20t).

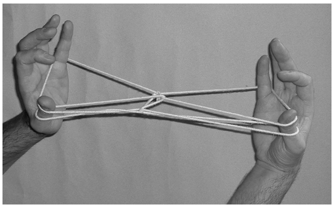

20r

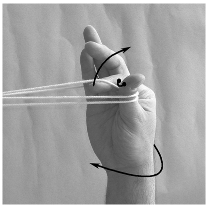

20s

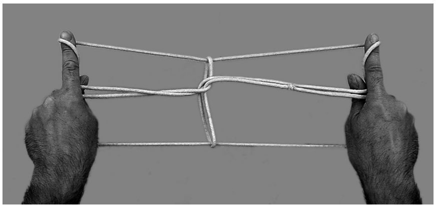

20t

Finally, steps 9 and 10 form the last passage towards the last normal position i.e. the final figure.

9. Insert thumbs, from proximal side, into little finger loops, return with radial little finger strings (pictures 20t and 20u).
10. Caroline extension (pictures 20v and 20w) (Instructions extracted from Maude 1978, pp. 59–60).


20u


20v


20w – Final figure *Pilun*

3.3.1.3 A Non-normal Initial Position

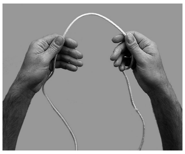
As pointed out in the previous example, Position I can be seen as a normal position. However, an initial position is not necessarily a "normal position". In order to illustrate this, let me describe an opening known, in ethnographical publications, as the Murray opening.[16]

[16]To my knowledge, this expression is due to Honor Maude (Maude and Firth 1970, p. 13).

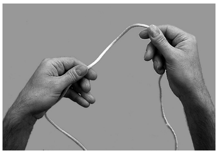
The initial position of this opening can be described as follows:

Both hands grasp the string between thumb and index, leaving about 15 cm of the string between the two hands, and the other part of the string hanging as a large loop (picture 21a). This position is clearly not a normal position.

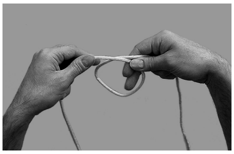
From this initial position, make a small loop by placing the right hand behind the left hand (pictures 21b and 21c). Then, introduce the index towards you and through the small loop, continue the movement, pointing the index upwards (picture 20d) while extending the string (pictures 21e and 21f).



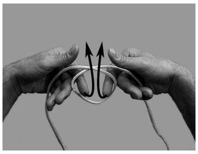
21a



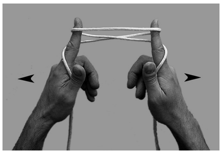
21b



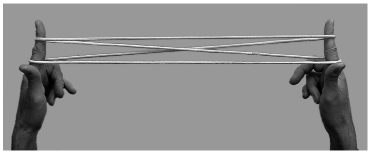
21c



21d



21e



21f

The first normal position is thus formed: each index carries two loops and the radial string are parallel, whereas the ulnar ones intersect each other. We will encounter this opening many times in this book. In particular, it will be involved, in Part IV, in a fundamental outcome relating to the comparison of this opening, known in many societies throughout Oceania, with another one known in some North and South American societies.

3.3.2 Analysing String Figures Corpora Through the Concept of Position

3.3.2.1 Relevance of the Concept

José Braunstein created this conceptualization of string figure-making in the 1990s, while collecting string figures among the Maka and the Eastern Mataco from the Argentine Chaco province (Braunstein 1992a,b). I was able to verify that this sequential view of string figure-making seems to be also relevant for describing the string figure procedures from the Arctic and Oceania. In the example of *Pilun* above, both states (taut and slackened) appear distinctly. But this is not always the case. At first sight, Braunstein's conceptualization does not seem to fit the Ten Men and *Niu* examples given above. However, the slackness of the string, even if it is slight, is absolutely necessary to be able to implement a series of elementary operations (passage) between two returns into a taut state (normal position). We may therefore hypothesize that this conceptualization of string figure-making will be relevant to study string figure procedures from many other regions of the world (North America, Africa, Asia, etc.). A systematic and comparative study of the Initial, Normal and Final Positions, and the different passages involved in various corpora, would probably throw light on some characteristic and distinctive features of these corpora. Analysing a given corpus of string figure procedures will begin by identifying all the openings it contains i.e. the Passages from an Initial Position to the first Normal Position. Some of these openings, as Opening A, occur in a large number of corpora. Therefore, each of these openings leads to a (first) normal position from which many string figures were created. These singular normal positions served as a basis for producing many procedures. We shall address the question of the reason of such "fertility". Are some openings common to a large number of corpora, while occurring a small number of times within each of these corpora? Are some openings characteristic of a given corpus, generating a great number of the procedures it contains? Or are there any links between the openings known in a given geographical or cultural area? Can we have evidence that an opening has been transformed to generate another one? Answering all of these questions, and analysing each of the openings thus identified, might allow us to better understand what makes a given opening's degree of fertility. In Part IV, I will describe the first outcomes of this approach, which has guided me in analysing my own ethnographical data.

3.3.2.2 The Sequential Viewpoint: Actors or Observers' Viewpoint?

To write down a string figure-making process, the ethnographers have generally broken down the procedure into several numbered steps, corresponding to its main stages. As shown in the *Pilun* example, these steps often correspond to the passages from one normal position to another. It would thus seem natural to think that this division into steps was certainly induced in the field by the practitioners themselves. This hypothesis is supported by an audio-visual document that Eibl-Eibesfeld made in 1983 in the Trobriand Islands, Papua New Guinea.[17] This 20 minutes video shows 2 young women performing successively 13 string figures. Obviously, both these practitioners give a rhythm to the making of these figures: a phase during which the operations are performed is always followed by a short pause where nothing happens. The alternation of these two phases provides rhythm during the whole process. The pauses generally occur when in normal positions, which are here "stable positions", allowing a short break in the process (Eibl-Eibesfeld 1987). The rhythmic aspect of string figure-making processes, brought to light by this video, has been widely confirmed by my own observations in the field (Marquesas Islands, Vanuatu, Papua New Guinea and Paraguay.[18])

[17]This film was shot as part of German ethnolinguist Gunter Senft's research program in the Trobriand Islands. This documentary film and an article on Trobriand string figures that Senft published in collaboration with his wife Barbara Senft (Senft and Senft 1986), proved to be of great value for my own fieldwork in the Trobriand Islands. We will return to this matter in Part IV.

[18]See Part IV.

At the beginning of my learning experience in string figures practice, I had to achieve such a figure through a continuous process: a too long pause generally prevented me from carrying on, forcing me to start the procedure all over again. In particular, I could hardly correct myself when I tried to resume the procedure after making a mistake. In Eibl-Eibesfeldt's film, both young women actually seem to have the same problem. They try to remember a string figure procedure they have forgotten, failing to do so several times. Each time, they have to start all over again. This observation shows that the short breaks, that make it easy to continue the procedure, are made on purpose, following a rhythm specific to each procedure. This suggests that conceptualization of a string figure procedure, as a message cadenced by singular positions, can sometimes proceed from the actors' viewpoint.

3.4 Transformation

As noted by Jenness in the 1920s, the activity of string figure-making was called *gi'wala* in Goodenough Island. However, *gi'wala* was also the name given to a procedure very close to procedure Ten Men. Jenness mentions that the latter procedure was considered by the islanders as the original string figure, the one "which is supposed to have originated all the others" (Jenness 1920, p. 300). Is it technically possible, as the belief of Goodenough islanders suggests, that the procedure *gi'wala* served as a basis to create some other string figure procedures in this society? Although it is difficult, at this stage, to answer this question, this example shows that the concept of "transformation" of a string figure into another was sometimes clearly expressed by practitioners. Furthermore, some string figures corpora could have been organized in connection to a certain system of transformation.

Within the string figures corpora that I have studied so far, the concept of transformation is at work at different levels. On one hand, this concept is omnipresent since a string figure is the result of the continuous transformation of a loop of string. On the other, as we will see below, analysing the sources suggests that the practitioners worked out how to transform one figure into another.

3.4.1 A Series of String Figures: The Procedure Mother-Father-Son-Hole

Yukio Shishido and Hiroshi Noguchi[19] published a corpus of string figures collected in the Highlands of Papua New Guinea. In this collection, the authors describe a string figure procedure that begins as a first stage by procedure Ten Men (except for some details, see below). The figure thus obtained in this case is called "Mother"

[19] In 1978, Japanese mathematician Hiroshi Noguchi and Anglican missionary Philip Noble have created the International String Figure Association (ISFA) (website: www.isfa.org). This organization aims to bring together people of all nationalities who share an interest in string figures. It has a hundred members and publishes a bibliography as well as an annual bulletin.

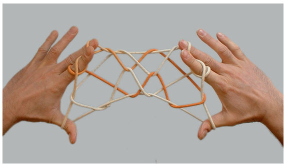
(Shishido and Noguchi 1987, pp. 45–47). The latter is transformed into a second intermediate figure called "Father", which is then transformed into two other figures: first, figure "Son" is displayed, followed by a final figure called "Hole". The whole process thus allows to display successively three intermediate figures and one final figure. Note that the first three figures have a name relating to kinship, suggesting generation of a figure from the previous ones.

This example demonstrates that the final figure of a procedure sometimes becomes the starting point of a continuation, leading to another figure. The description of the procedure Mother-Father-Son-Hole will allow us to analyse this phenomenon in depth.

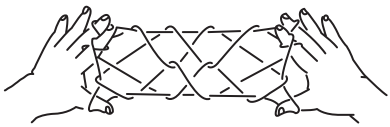
The procedure Mother-Father-Son-Hole—Except for some details, the making of the first figure (Mother) of the series is identical to procedure Ten Men.[20] A passage leads then to the second figure, "Father", and finally two other figures are shown: Son and Hole.

1. Ten Men (pictures 22a and 22b).
2. Release the thumbs gently (picture 22c). Then, with both thumbs' pads, hook down distal radial index strings close to each index finger (picture 22d).

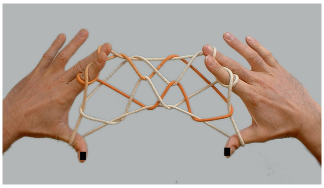
   That last "passage" allows the second figure to be formed (pictures 22e and 22f).



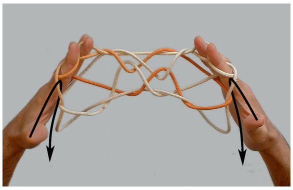
22a



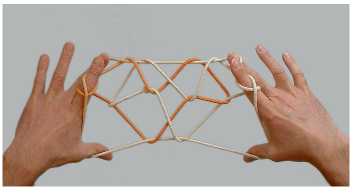
22b – First figure: Mother (Shishido and Noguchi 1987, p. 46)



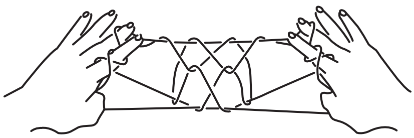
22c



22d



22e

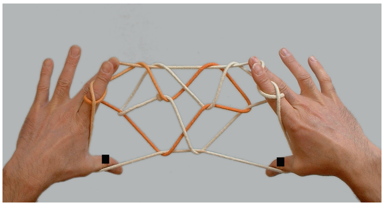


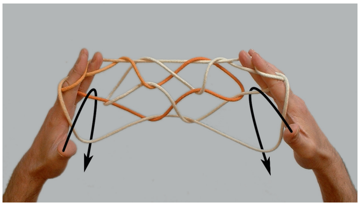
22f – Seconde figure: Father (Shishido and Noguchi 1987, p. 46)

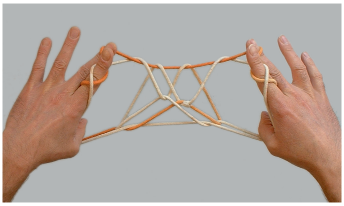
[20]The difference lies in the way the first normal position is reached. Moreover, Ten Men and Mother's first normal positions are not exactly identical. Actually, they differ in a single simple crossing. See the discussion about $Conf(A)$ and $Conf(B)$ in Sect. 6.4.1.

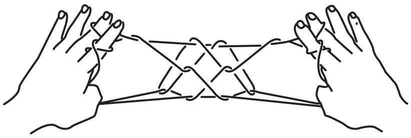
3. Release thumbs gently (picture 22g), then hook down proximal ulnar index strings and distal radial index strings by both thumbs' pads (picture 22h).

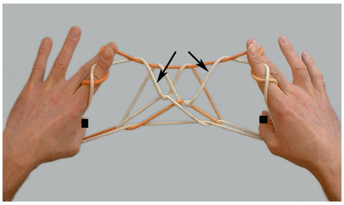
   We thus obtain third figure ("Son") (pictures 22i and 22j).
4. Release thumbs gently, then hook down the strings indicated by ↑ (picture 22k) and distal radial index strings by both thumbs' pads (picture 22l) (Instructions adapted from the original text (Shishido and Noguchi 1987, pp. 45–47)).

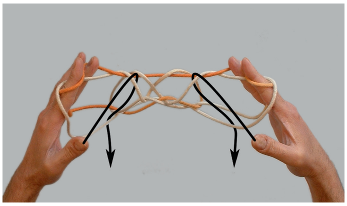

22g


22h

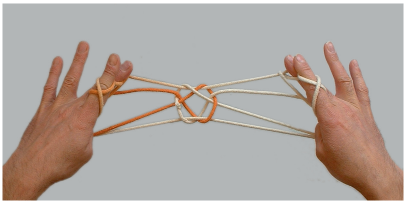

22i

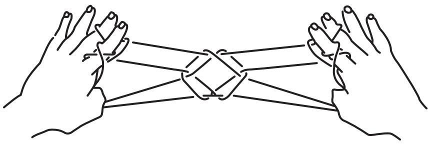

22j – Third figure: Son (Shishido and Noguchi 1987, p. 46)


22k

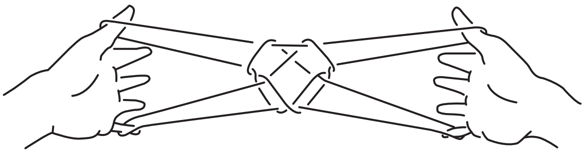

22l

We thus obtain final figure "Hole" (pictures 22m and 22n).


22m


22n – Finale figure: Hole (Shishido and Noguchi 1987, p. 47)

The procedure Mother-Father-Son-Hole can thus be analysed as a succession of transformations. Each one of them allows to transform a figure into another. This last point raises questions: did the creators of these procedures seek to find a passage between different figures that they already knew? Or rather, did they try to transform a given figure, keeping in mind a passage leading to a new form that they deemed worthy of being memorized? At this stage, it is difficult to answer. However, these questions led me to define a final figure's "drawing" as the geometric form that can be extracted from it, regardless of the string's exact path. For instance, the drawing of figure Hole above can be defined as a "double-sided lozenge". It is noteworthy that this drawing appears repeatedly in Shishido and Noguchi's corpus—particularly in procedure Egg's final figure (picture 23).

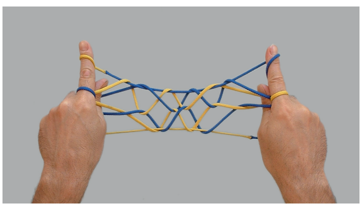


23 – Final figure: Egg (Shishido and Noguchi 1987, p. 50)

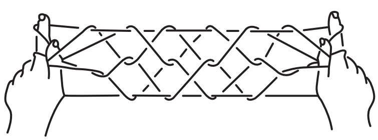
Although the path of the string is not exactly the same in figures Hole and Egg, both clearly show the same drawing (double-sided lozenge). Remember that procedure Mother (or Ten Men) can be found in many corpora from Oceania. It is therefore reasonable to think that Mother-Father-Son-Hole practitioners knew it. Thereafter, a continuation could have been carried out, using figure Mother as a starting point. Practitioners could then have tried to transform it into a double-sided lozenge final figure. This example suggests that the creation of certain string figure procedures could have sometimes occurred while trying to transform a string figure drawing into another. Other examples show that practitioners have sometimes worked out the transformation of a final figure into the exact replica of a string figure (taking the exact path of the string into account) that could already be performed through another method.

3.4.2 Transforming a String Figure into Another

An example of such transformation can be found in a paper by Shishido and Noguchi. Procedure Stars and Moon described in this Papuan corpus (Shishido and Noguchi 1987, p. 54) begins by making a first figure called Stars (pictures 23a and 23b).

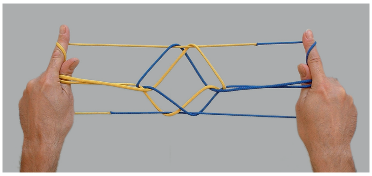


23a

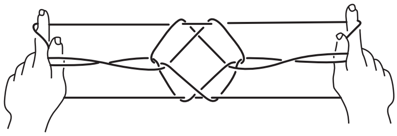


23b – Figure "Stars" (Shishido and Noguchi 1987, p. 54)

Figure Stars has been described as a final figure in many published string figure collections from Oceania. However, in this case, Stars is an intermediate figure which is transformed into another one through a series of elementary operations. A final figure called Moon is obtained in this way. Remarkably, Moon is exactly the same figure (crossings included) than Egg, shown above and described in the same collection (pictures 23c and 23d). We may therefore hypothesize that the second part of procedure Stars and Moon (i.e. Moon from Stars) could have been created in order to transform figure Stars into figure Egg.



23c



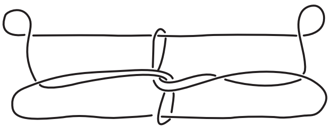
23d – Figure "Moon" (Shishido and Noguchi 1987, p. 55)

Such procedures, allowing to display a series of intermediate figures through a succession of transformations, are present in most of the corpora I have studied so far. Moreover, I was able to see that a procedure of this kind, belonging to a given corpus, passes through intermediate figures (or "drawings") that occur within the same corpus' other procedures. This suggests that practitioners from certain societies could have carried out a systematic search of one figure's possible transformations (or drawing) into another. In order to better understand the impact of the elementary operations involved during these transformation processes, it is necessary to analyse these transformations. We will come back to this point in Part III of this book. A formal analysis of these phenomena will allow to bring some new light on the mechanisms involved in this type of transformation.

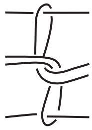
3.4.3 Transformation of Final Figure Geometry: The Concept of Motif

When studying the collection of Solomon string figures published by Honor Maude (1978), one is struck by the fact that the "drawings" of a great number of final figures seem to have been designed through different combinations of a few simple "motifs". To illustrate this point, I shall give two examples of such motifs, and describe the different combinations that occur within this Solomon corpus. At the center of the final figure *Nambiri*,[21] there is a motif that I call "Caterpillar" (translation of the vernacular name *Nambiri*).

[21] See Maude (1978, pp. 58–59). This procedure is very close to *Pilun*, found in the Caroline Islands and described above to illustrate the concept of Normal Position.

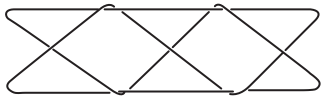


24a – Final figure *Nambiri* (Maude 1978, p. 59)

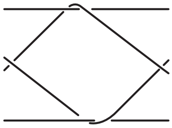


24b – Motif “Caterpillar”

Motif “Lozenge” can be extracted from final figure *Bona* (a bird).



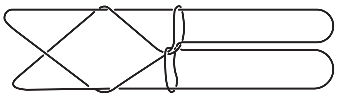
24c – Final figure *Bona* (Maude 1978, p. 57)



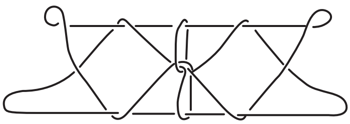
24d – Motif “Lozenge”

Some of the possible combinations between motifs “Caterpillar” and “Lozenge” are shown in the final figures below:

- One lozenge and one caterpillar (picture 24e)
- Two lozenges and one caterpillar (picture 24f)

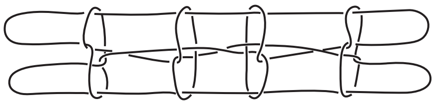


24e – Final figure *Noea* (paddle) (Maude 1978, p. 61)

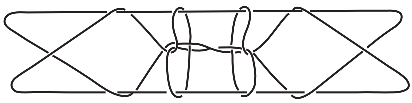


24f – Final figure of *Porouruurumatawa* (legendary man of the seabed) (Maude 1978, pp. 61–62)

The procedure *Whai wane* (shark) leads to a figure composed of four “caterpillars” (picture 24g). According to Maude, this string figure represents four men who gather fruits in a tree (Maude 1978, pp. 63–64). Then it rains, and two of these men climb down from the tree. A transformation is then performed, leading to a figure composed of two lozenges and two caterpillars (picture 24h). Note that this transformation is accompanied by a short story. I will come back below on the relationship between string figure-making and the stories or songs that sometimes come with the string figure procedures.



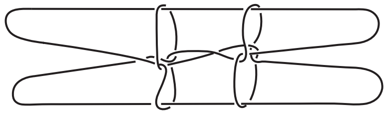
24g



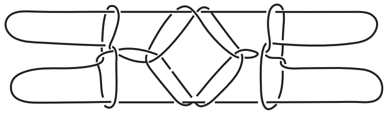
24h – First figure of *Whai wane* (Maude 1978, p. 61)

In the same Solomon collection, procedure *keu Roke nioke* (men carrying sticks) consists in two caterpillars (Maude 1978, p. 68) (picture 24i).

Motifs “Lozenge” and “Caterpillar” are also combined with other motifs: for instance, previously shown motifs “double sided lozenge” and “Caterpillar” put together form the final figure of *Namu* (puddle) (picture 24j).



24i – Final figure of *Roke nioke keu*



24j – Final figure of *Namu*

Analysing motifs involved in a corpus of string figures should be a complementary approach to both modes of conceptualization previously introduced. It is probably intentional that a few motifs suffice to describe a large number of final figures within a given corpus. And therefore, the implementation of elementary operations and sub-procedures by practitioners was certainly guided by an intention to combine these few motifs. Organizing these operations has probably been carried out in relation to their impact on different substrata (strings’ spatial configuration) and the making of these particular motifs. Here we seem to have an activity which can be seen as mathematical at different levels: firstly, an algorithmic practice to organize ordered set of elementary operations, and, secondly, a geometrical practice, since these algorithms aims to create spatial configurations.

I do not know yet whether the concept of “motif” is relevant to all corpora. At first sight, it plays a stronger role in the Oceanian and Latin American corpora than in the Arctic ones. In the corpora from the Arctic that I have studied so far, the motifs are not readily apparent, and are therefore less easy to isolate.

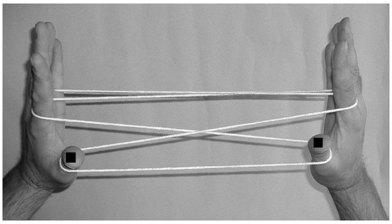
Attempting to link the various motifs and the sub-procedures involved in a corpus of string figure procedures, as in the Solomon corpus, should help us to better understand how these string figures were created. This should also help to better identify the mathematical ideas implemented by the practitioners in this activity. We will come back to this crucial point in Chap. 7.

3.4.4 Transformation Through Iteration

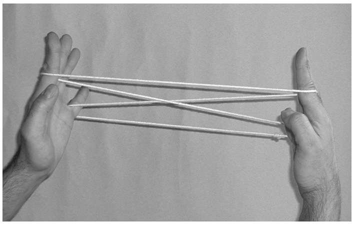
Some string figure procedures aim to display a series of intermediate figures in a remarkable way: during the process, transformations from one figure to the next are implemented through the same sub-procedure which is iterated a certain number of times (in most cases, as many times as allowed by the string’s length). Moreover, the impact of this iterative sub-procedure is to iterate the same motif. The making of these kind of string figures are thus characterized by the implementation of three fundamental ideas: transformation, iteration, and the concept of motif. Describing the making of the Papuan string figure called "Family sickness" will illustrate this point (Shishido and Noguchi 1987, p. 44).

3.4.4.1 The String Figure Procedure "Family Sickness"

1. Opening A. Release thumbs (pictures 25a and 25b).

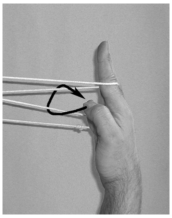


25a

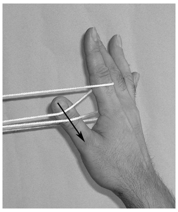


25b

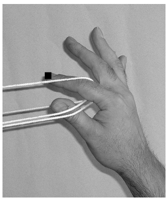
2. Pass thumbs, proximal to index loops (picture 25c), insert into little finger loops, from proximal side, return with radial little finger strings and ulnar index strings (picture 25d); release indices (pictures 25e and 25f).



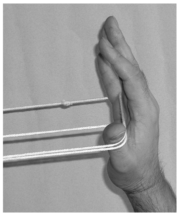
25c



25d

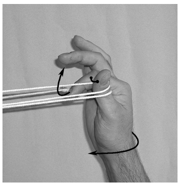


25e

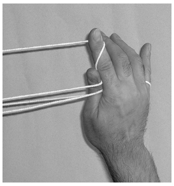


25f

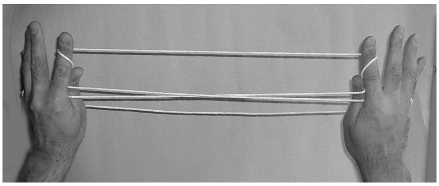
3. Caroline extension (pictures 25g–25i).



25g

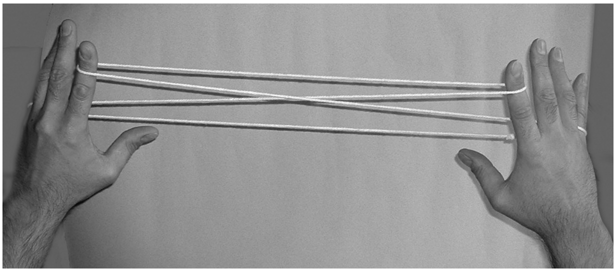


25h



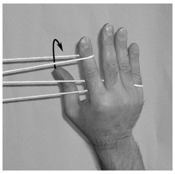
25i

4. Repeat the following movements several times:
   – Release thumbs (picture 25j).

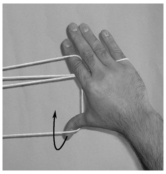


25j

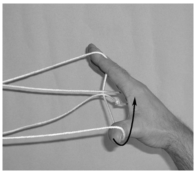
- Pass thumbs proximal to all strings, insert them into index loops, from the proximal side (picture 25k), return with ulnar index strings by rotating thumbs down away from you (picture 25l), towards you and up (picture 25m).
- Release indices (picture 25n).



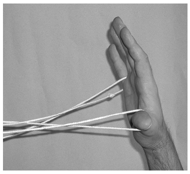
25k



25l

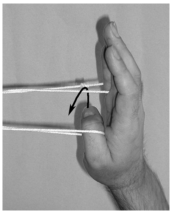


25m

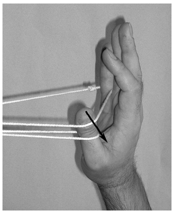


25n

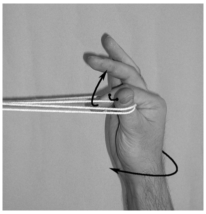
- Insert thumbs into little finger loops from proximal side (picture 25o), return with radial little finger strings (picture 25p). Caroline extension (pictures 25q and 25r) (adapted from Shishido and Noguchi 1987, p. 44).



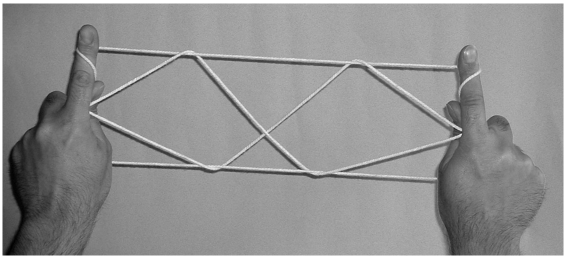
25o



25p

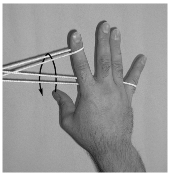


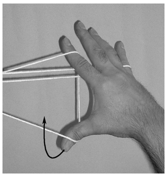
25q

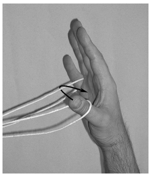


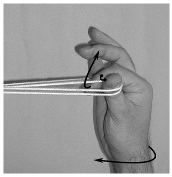
25r

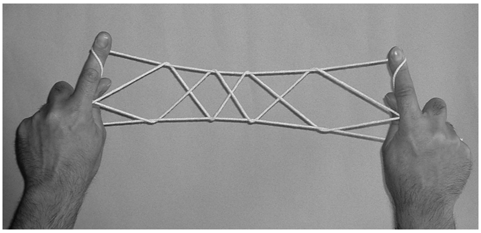
Pictures 25s–25v illustrate the first iteration of the iterative sub-procedure previously described in step 4. One obtains a figure made of four "lozenges" in a row (picture 25x). A second iteration produces six lozenges in a row (picture 25y). The same process may be repeated as may times as allowed by the string's length: at each stage, this sub-procedure's implementation entails the making of two additional lozenges.

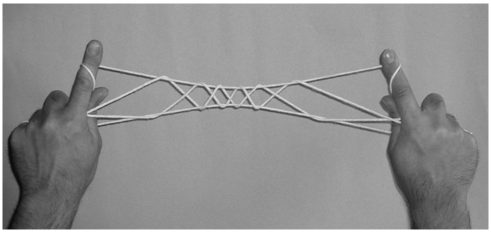

25s


25t

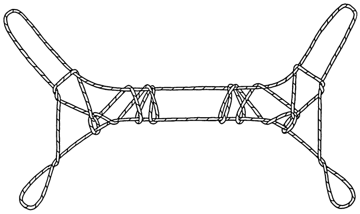

25u


25v

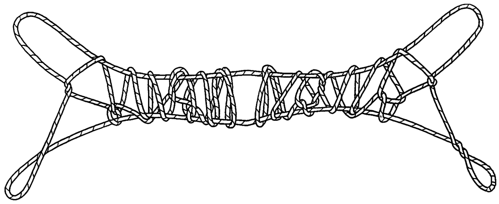

25x


25y

These "transformations through iterations" can be found in many string figures corpora from various areas of the planet. In particular, there is an example of such a procedure in the corpus of Inuit string figures documented by Guy Mary-Rousselière. He describes a procedure called *Kiligvagjûk iglugêk* (The two mammoths—picture 26a). His description of this figure is followed by instructions for making *Kiligvarârît* (two mammoths and their offspring). As a first stage, it consists in making the previous figure *Kiligvagjûk iglugêk*. Then, a few elementary operations allow to reach a configuration from which one can iterate the whole *Kiligvagjûk iglugêk* procedure. At the end, one obtains, on both sides, a "Mammoth" immediately followed by its children (picture 26b). Just as in procedure "Family sickness", this iterative process can be repeated as many times as allowed by the string's length (Mary-Rousseliere 1969, p. 44). Moreover, as in "Mother-Father-Son-Hole", the intermediate figures' names suggest the idea of generation through kinship relation.



26a



26b

3.4.5 Transformation and Recitative

In some societies, string figure-making is accompanied by recitatives or songs. Sometimes, these "oral texts" are recited or sung after the final figure is displayed. In this case, the practitioner often uses this figure to illustrate the story. Although analysing these "texts" can highlight some of this practice's cultural aspects (Senft and Senft 1986), it does not seem easy to link the procedures at work in string figure-making with these accompanying texts. However, such a connection might be relevant when the string figure procedure allow to display a series of intermediate figures (as in "Family sickness" and "Mother-father-son-hole"). In this case, the "text" is often recited or sung in order to punctuate the making of the various intermediate figures. Regarding such a situation, we may hypothesize that the "text" helps the practitioner to memorize the string figure procedure, and, conversely, the procedure helps him/her to memorize the "text". From this perspective, one may suggest that string figure procedures and their associated oral texts can provide genuine memory support for one another. The connections between text and procedure will be further studied in that particular perspective. An in-depth study of these texts will certainly throw light on mental connections between "words" or "rhythm of sentences" and the hands' "movements".

The Solomon string figure *Whai wane* previously mentioned is an example in which the transformation of the first figure into the second one is clearly connected to the "text". Procedure *Whai wane* is accompanied by the story of four men who gather some fruits in a tree. The first figure symbolizes these four men perched in the tree (picture 24g above). The passage is then performed to transform the two motifs ("men") at the extremities of the figure (picture 24h above), forming the second figure. It is then explained that rain forces the two men to climb down from the tree. Here, the story's logic is clearly linked to the transformation's pattern.

Many ethnographical papers contain several procedures accompanied by a recitative. In some cases, it is recited throughout the whole procedure. I have personally collected some of these oral texts and will return to this point in Part IV of this book. A thorough study of the recitatives associated with string figure-making would certainly help to better understand the nature of the "text/procedure" interrelation, and, thus, the function of these "texts" in the memory processes and in the modes of transmission of string figures.

3.4.6 Before Going Further

We have seen that the activity of creating new string figure procedures can be regarded as mathematical at different levels. Their production requires an intellectual task of selecting the elementary operations and organizing them in procedures. There is no doubt that this work has consisted in identifying ordered sets of elementary operations—the sub-procedures—having a noticeable impact on different substrata (configurations of the string). String figures thus appear as the result of genuine algorithms. Based on an algorithmic practice, the production of string figure algorithms is also of a "geometrical" and "topological" order, insofar as it is based on investigations into complex spatial configurations, aiming at displaying either a 2-dimensional or a 3-dimensional figure. The transformations of a figure (or "drawing") into another, and the iteration of sub-procedures, previously brought to light, confirm this point.

These results raise many other questions. How do the "elementary operation" and "sub-procedure" actually operate on the string? Do they allow to get a global view of a string figure procedure in time and space? Can we predict the consequences of the implementation of an elementary operation on the rest of the procedure? Why can a series of elementary operations be applied to different configurations of the string, and thus be seen as a sub-procedure? Does an iterative sub-procedure have a particular form? How are the elementary operations and sub-procedures involved in the form of a given corpus of string figures?

Two directions of research have emerged in order to move forward on these issues. First and foremost, we need to develop mathematical tools enabling to model string figure procedures. We will see, in Chaps. 5–7, that such mathematical modelling allows to make hypotheses on how the practitioners from different societies have explored string figure procedures.

The second direction aims to bring together the latter theoretical approach with an ethnographical research. As we will see in Chaps. 8 and 9, string figure-making is still practiced nowadays in some societies of oral tradition. I met some practitioners in the field, with the intention of documenting my own corpora of string figures. It gave me the opportunity to make some observations about the mental representations and cognitive mechanisms involved in this practice, as well as about modes of transmission and memorization. The meetings with "experts", and the analysis of their own viewpoints, should enable us, in the long term, to model string figure-making, taking into account how the actors themselves perceive this practice.

Before further discussing these two directions of research, let us turn to the work of Walter William Rouse Ball (1850–1925). To my knowledge, as mentioned earlier, this Cambridge professor was the first mathematician who regarded string figure-making as a mathematical activity. In 1911, he published a text which could well be the very first attempt made by a mathematician to demonstrate the connection between mathematics and procedural activities such as string figure-making. It has therefore been of fundamental importance in promoting both awareness of this topic and further research into it.

References

Braunstein J (1992a) Figuras juegos de hilo de los indios maka. Hacia una Nueva Carta Etnica del Gran Chaco III:24–81

Braunstein J (1992b) Figuras de hilo de los mataco orientales. Hacia una Nueva Carta Etnica del Gran Chaco IV:36–66

Braunstein J (1996) Langages de ficelle: Au fil d'une enquête dans le Chaco argentin. Techniques et cultures 27:137–151

Eibl-Eibesfeld I (1987) Trobriander (Ost-Neuguinea, Trobriand-Inseln, Kaile'una)-Fadensspiele Ninikula. Institut fur den Wissenschaftlichen Film Publikationen zu Wissenschaftlichen Filmen, Sektion Ethnologie, Serie 15, Nummer 25, Institut für den Wissenschaftlichen Film, Göttingen

Haddon K (1911) Cat's cradles from many lands. Albert Saifer Publications, Watchung

Haddon K (1930) Artists in strings. AMS, New York. (Reprint edition 1979)

Hornell J (1927) String figures from Fiji and Western Polynesia. Bishop Museum, vol 39. The Museum, Honolulu. (Reprint edition 1971, Germantown, New York: Periodicals Service Co)

Jayne CF (1962) String figures and how to make them: a study of Cat's cradle in many lands. Dover Edition, New York. (A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York)

Jenness D (1920) Papuan cat's cradles. J R Anthropol Inst 50:299–326

Jenness D (1924) Eskimo string figures. Report of the Canadian Arctic expedition 1913–1918, vol XIII, Part B. F.A. Acland, Ottawa

Mary-Rousseliere G (1969) Les jeux de ficelles des Arviligjuarmiut. Bulletin n°233. Musées nationaux du Canada, Ottawa

Maude H (1971) The string figures of Nauru Island. Libraries board of South Australia occasional papers in Asian and Pacific studies, vol 2. Libraries Board of South Australia, Adelaide

Maude H (1978) Solomon Island string figures. Homa Press, Canberra

Maude H, Emory K (1979) String figures of the Tuamotus. Homa Press, Canberra

Maude H, Firth R (1970) Tikopia string figures. Royal Anthropological Instutute of Great Britain and Ireland, Occasional paper, n°29. Royal Anthropological Institute, London, p 63

Maude H, Maude HE (1936) String figures from the Gilbert Islands. J Polyn Soc 45 (Memoir n°13):1–40

Noble PD (1979) String figures of Papua New Guinea. Institute of Papua New Guinea Studies, Boroko

Paterson TT (1949) Eskimo string figures and their origin. Acta arctica, fasc. 3. E. Munksgaard, København, p 98

Rosser WE, Hornell J (1932) String figures from British Guinea. J R Anthropol Inst 62:39–50

Senft G, Senft B (1986) Ninikula Fadenspiele auf den Trobriand Inseln Papua New Guinea. Baessler-Arch 34(1):93–235

Shishido Y, Noguchi H (1987) Some string figures of Highland people in Papua New Guinea. Bull Int String Fig Assoc 14:38–69

Victor P-E (1940) Jeux d'enfants et jeux d'adultes chez les Eskimo d'Angmassalik: Les jeux de ficelle. Meddelelser om Gronland 125(7):1–212. Copenhagen

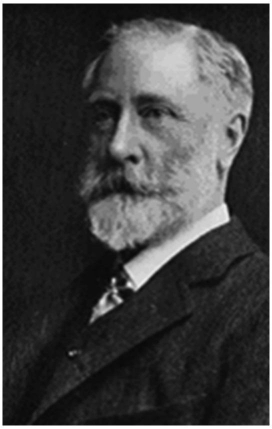
Part II
Mathematics and String Figures

Chapter 4
W.W. Rouse Ball's Mathematical Approach to String Figures

4.1 Ball's Mathematical Recreations

Ball was a professor at Trinity College in Cambridge. As a student, he

> attended University College School and University College London, where he won the gold medal in Mathematics and first-class honours in Logic and Moral Philosophy in 1889. He entered Trinity College Cambridge in 1870, and was Second Wrangler and First Smith's Prizeman in 1874. [. . .] Rouse Ball returned to Trinity College as Lecturer in 1878 and remained until (semi-) retiring in 1905 (Singmaster 2005, p. 658).



27 – William Walter Rouse Ball
(Whittaker 1925, p. 449)

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_4

Ball wrote several books dealing with the history of both mathematics[1] and Trinity College. However he is best known as the author of the very popular book *Mathematical Recreations and Essays* first published in 1892. The success of this book is clearly shown by the nine editions which followed until 1922. From the fifth edition (1911) on, Ball devoted a chapter to string figures. The source material on which he developed his analysis came from publications by anthropologists.

He seems to have become quite familiar with string figures, as he gave at least one lecture on string figures in 1920, at the Royal Institution of London, showing the audience how some string figures were made (Proceedings of the Institution, (Ball 1920b)). Thus it was from a practitioner's point of view that Ball approached this activity.

In his book *Mathematical Recreations and Essays*, the chapter on string figures kept its initial form until the ninth edition (1920). From the fifth edition to the ninth, the book was divided into two parts of an approximate equal length, entitled "Mathematical Recreations" (Part I) and "Miscellaneous Essays" (Part II) respectively. In his preface, Ball draws the readers' attention to the way he chose to classify the different topics addressed in the book.

> The earlier part of this book contains an account of certain Mathematical Recreations: this is followed by some Essays on subjects most of which are concerned with historical mathematical problems. [...] The first part now consists of eleven chapters, in which are described various problems and amusements of the kind usually termed Mathematical Recreations. [...] The second part now consists of twelve chapters, mostly dealing with Historical Questions. It is with some hesitation that I placed among them papers on String Figures, Astrology, and Ciphers, but I think they may be interesting to my readers, even though the subjects are indirectly connected with Mathematics (Ball 1911, pp. v–vi).

According to the author, the first part of the book belongs to the tradition of mathematical recreations, as written by his predecessors.[2] The tables below give the titles of the chapters of the book (fifth edition 1911):

[1]In 1888, Ball published a book entitled *A Short Account of the History of Mathematics* (Ball 1888) which has been republished several times. In 1889, he published another book, *History of the Study of Mathematics at Cambridge* (Ball 1889). He was interested in the works of Newton and he published, in 1891, a paper entitled "A Newtonian Fragment relating to Centripetal Forces" in the *Proceedings of the London Mathematical Society* (Ball 1891), followed by the book *An Essay on Newton's Principia* in 1893 (Ball 1893).

[2]See the article Singmaster (2005) for further details in the historical background.

Part I	
Chapters	Title
1&2	Arithmetical recreations
3&4	Geometrical recreations
5	Mechanical recreations
6	Chess-board recreations
7	Magic squares
8	Bees and their cells
9	Unicursal problems
10	Kirkman's school-girls problem
11	Miscellaneous problems

Part II	
Chapters	Title
12	Calculating prodigies
13	Arithmetical machines
14	Three classical geometrical problems
15	The parallel postulate
16	Insolubility of the algebraic quintic
17	Mersenne's number
18	String figures
19	Astrology
20	Cryptographs and ciphers
21	Hyper-space
22	Time and its measurement
23	Matter and Ether theories

Obviously, most of the second part's essays deal with fundamental mathematical questions and their history. It is also clear that, at the end of the nineteenth century, problems such as *Duplication of the Cube*, *Trisection of an Angle*, *Quadrature of the Circle* developed in Chapter 14, *The Parallel Postulate* (Chapter 16), etc. were not considered by most mathematicians to be mathematical recreations, but pure mathematical problems.[3] This is still true nowadays.

Ball, whose intention in Part I was to deal with subjects in the tradition of Recreational Mathematics, would not have considered chapters on string figures, astrology and ciphers to be fully appropriate for the first part of the book. Furthermore, he expressed the need to justify his idea of devoting chapters to subjects such as string figures in Part II, which deals mostly with pure mathematical questions. He makes it quite clear that he hesitated to do so. Nevertheless, he suggests that the practice of string figures (as well as astrology or cryptography) may be seen as mathematical, or more precisely, that an indirect connection can be found between the practice of string figures and mathematics.[4] Ball does not discuss

[3]As Singmaster pointed out, "Several major mathematical works have devoted much space to problems that are now considered recreational, [. . .]" (Singmaster 2005, p. 654). Singmaster gives the example, among others, of the "Nine Chapters", "The Aryabhata", etc. It shows that there can sometime be a movement from mathematics to Recreational Mathematics. The opposite can also happen. Problems raised in a recreational context sometimes become a mathematical field. This is demonstrated by historian of mathematics Mitsuko Mizuno who brought to light the relationship between the mathematical recreations of mathematician König Dénes (1884–1944) and his work in graph theory (Wate-Mizuno 2010).

[4]The subject of "Cryptography", that Ball suggested to be *indirectly connected to mathematics* raised afterwards some fundamental mathematical questions throughout the twentieth century. See for instance: Oded Goldreich, *Foundations of Cryptography*, in two volumes, Cambridge University Press, 2001 and 2004.

this difficult epistemological problem in the book. Moreover, he clearly avoids the question in the introduction to the chapter devoted to string figures:

> It (String Figure) cannot with accuracy, be described as mathematical, but as I deliberately gave this book a title which might allow me a free hand to write on what I liked, I propose to devote a chapter to an essay on certain string figures (Ball 1911, p. 348).

The lecture given by Ball at the Royal Institution of London was published in 1920. With some additions, this article became a book entitled *An Introduction to String Figures* published in 1920 (Ball 1920c). Therefore Ball decided to "cut down the space" (Ball 1922, p. 321) devoted to this subject in the tenth edition of *Mathematical Recreations and Essays*.

In the following pages, by analysing the way the chapter "devoted to string figures" (from the fifth to the ninth edition) was set out, I will argue that Ball organized it in order to help his reader to perceive a possible connection between string figures and mathematics: I will show that the selection of string figures he made in anthropological papers invites to consider string figures as a system of transformations. Furthermore, by giving access to this system, Ball clearly encourages the reader to create new string figures as a recreational mathematical practice. By doing so, the author may have attempted to implicitly justify the inclusion of the topic in his book on mathematical recreations.

First, I will focus on the papers and books that Ball used as source material for his chapter on string figures: these papers were published, mostly by anthropologists, at the end of the nineteenth century and the beginning of the twentieth century. Then, I will comment on his introduction to the chapter "String Figures" in *Mathematical Recreations and Essays* (from the fifth to the ninth edition). Then, I will describe and analyse the way Ball organized this chapter. Although the text is not divided in clear subsections, I will show that five parts can be drawn from a linear reading of this chapter: five different aspects of the practice of string figure-making emerge, epitomized by five different groups of examples selected in anthropological papers. Finally, I will compare this chapter to the lecture made at the Royal Institution of London in 1920 and to the small booklet published in the aftermath of this lecture. Ball used the same ethnographical sources. Nevertheless he clearly structured these papers in a different way, and with a different point of view.

4.2 Source Material

4.2.1 Haddon and His Successors Until 1911

A few publications dealing with string figures occurred in the decade following the article "A Method of Recording String Figures and Tricks" (Haddon and Rivers 1902). It seems that Haddon and Rivers' methodology stimulated and helped some anthropologists and enthusiasts to collect string figures. In 1903, John

Gray published in the journal *Man* a short article describing a few Scottish string figures (Gray 1903); the same year, Haddon published in the Journal *American Anthropologist* an article detailing the making of some American string figures and tricks (Haddon 1903); then in 1906, in the *Journal of the Anthropological Institute of Great Britain and Ireland*, William A. Cunnington wrote an article on the making of some string figures and tricks in Central Africa (Cunnington 1906), John Parkinson published a paper entitled "Yoruba String figures" (Parkinson 1906) and Haddon described the making of string figures in South Africa (Haddon 1906). In the journal *Folklore*, W. Innes Pocock also published two articles on the subject (Pocock 1906a,b).

As mentioned earlier, Caroline Furness Jayne published in 1906 the first book on the topic entitled *String Figures*, first reprinted in 1962 as *String Figures and How to Make Them: A Study of Cat's Cradles in Many Lands* (Jayne 1962, first edition, 1906). Jayne gives the instructions for the making of 129 string figures that ethnologists had recorded in various traditional societies. It is her brother, the anthropologist William Henry Furness, who introduced Jayne to Haddon. The latter transmitted to the former his interest in string figures (Jayne 1962, p. v).

Gray, Cunnington, Parkinson and Jayne wrote down the descriptions of the figures according to the method devised by Haddon and Rivers. However, Jayne introduced modifications to some terms in their nomenclature. Moreover, the description of each string figure is accompanied by several sketches that show each step of the procedure as it would be viewed by the person making the figure, whereas Haddon and Rivers drew only the final figure at the end of the written description. Haddon and Rivers did not share the same point of view about Jayne's modification to their method of recording string figures. In Haddon's introduction to Jayne's book, he claimed that she had simplified the method in order the make it more accessible:

> A second visit to Torres Strait afforded me the requisite opportunity, and Dr W. H. R. Rivers and I managed to devise a method of recording string figures and tricks which enabled us to write down some thirty string figures. Since then the nomenclature has been adopted for the recording of string figures of other peoples, and now my friend Mrs Jayne has simplified our procedure and has produced this elaborate volume, which will enable anyone to indulge in this fascinating amusement (Jayne 1962, p. xii).

In 1907, Rivers wrote a review of Jayne's book in the journal *Folklore* (Rivers 1907). Even though he clearly had a good opinion of many aspects of the book, Rivers expressed a severe criticism: according to him, Jayne s' modification to their nomenclature would seriously impair the method:

> All the descriptions of the figures have been written according to the method devised by Dr. Haddon and myself, but Mrs Jayne has introduced some modifications which seem to me to impair seriously the exactness and definiteness of the method. The words "near" and "far" applied to a string on the hands are equivocal. They may mean that the string is nearer to, or farther from, the eyes of the person making the figure, or they may mean that the string is nearer to, or farther from, the wrist. Further, the words "upper" and " lower," as applied to strings on the hands or fingers, may cease to be correct if the position of the hands be changed. (Rivers 1907, p. 114)

Jayne's book contains the method for the making of 87 string figures and 10 tricks.[5] It is the main source material to which Ball refers to in his Chapter "String Figures". As far as I know, no significant publications were made after 1906, until Haddon's daughter published, in 1911, a book entitled *Cat's Cradles from many lands* describing 50 string figures and 12 tricks. 15 of these string figures were collected by Haddon and Rivers during the 1898–1899 expedition (Haddon 1911, pp. 7–27).

A footnote at the beginning of Ball's chapter on string figures (Ball 1920a, p. 348) suggests that his interest in the subject arose from his meeting with Haddon. As mentioned above, Ball knew Jayne's book; he also knew most of the publications which followed the 1902 paper by Haddon and Rivers. It was while writing the chapter on string figures that he came across the book by Kathleen Haddon, published in the same year as the fifth edition of *Mathematical recreations & Essays*.

> For my knowledge of the subject I am mainly indebted to Dr. A. C. Haddon, of Cambridge; to String Figures by C. F. Jayne, New York, 1906, and to articles by W. I. Pocock and others in Folk-Lore, and the Journal of the Anthropological Society. Since writing this chapter I have come across another book on the subject by K. Haddon, London, 1911: it contains descriptions of fifty Figures and a dozen String Tricks (Ball 1920a, p. 348).

4.2.2 Ball's Introduction

4.2.2.1 Classification and Transformation

At the beginning of the chapter "String Figures", Ball expresses that he intends to introduce the reader to this "fascinating recreation" without concerning himself with the ethnographical aspects of string figures.

> An amusement of considerable antiquity consists in the production of figures, known as Cat's Cradles, by twisting or weaving on the hands an endless loop of string, say, from six to seven feet long. The formation of these figures is a fascinating recreation with an interesting history.[. . .] The subject is extensive. I propose however merely to describe the production of a few of the more common forms, and do not concern myself with their ethnographical aspects. Should, as I hope, some of my readers find the results interesting, they may serve as an introduction to innumerable other forms which, with little ingenuity, can be constructed on similar lines (Ball 1920a, p. 348).

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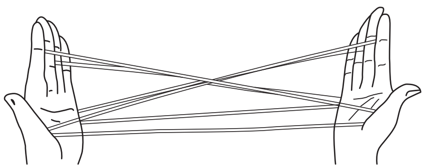
[5]For each string figure described in the book, Jayne precisely mentions her informants. A total of 28 procedures were collected by Jayne in the United States on the occasion of the St. Louis Universal Exposition in September 1904. Twenty two procedures from the book had been taught to Jayne by Haddon, of which five were being published for the first time. Jayne's brother, anthropologist William Henry Furness, allowed her to include 16 string figures he had collected himself in the Caroline Islands. John Lyman Cox collected 16 string figures for her from the Indian School at Hampton, Virginia (Sherman 2003). Finally, Jayne refers to Gray and Boas about two other figures. The interest of Furness and Cox in string figures suggests that besides the few articles published in the period of 1902–1906, some anthropologists or enthusiasts, interested in string figures, devoted some time to this activity even though they did not publish any articles.

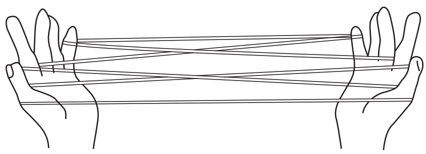
Although Ball does not broach the subject in its ethnographical context, he gives a short description of the classification established by Haddon. Like most of the anthropologists interested in string figures (and influenced by the theory of diffusionism) in the early twentieth century, Haddon was concern with collecting and comparing string figures patterns in order to get evidence of contacts between different societies (see Chap. 2). Referring to the string figures collections published until then, Haddon suggested a classification into two classes which can be defined, according to him, by considering the procedures' origins and geographical distribution. He suggested that string figures could be divided into two main groups called respectively "Oceanic type" and "Asiatic or European type". It seems to me that Ball misunderstood the point in his personal considerations about the final patterns of string figures. As far as I know, such considerations cannot be found in Haddon's demonstration.

> First we must note that there are two main types of the string figures known as Cat's Cradles. In one, termed the European or Asiatic Variety, common in England and parts of Europe and Asia, there are two players one of whom, at each move, takes the string from the other. In this, the more usual forms produced are supposed to suggest the creations of civilized man, such as cradles, trays, dishes, candles,& c. In the other, termed the Oceanic Variety, common among the aborigines of Oceania, Africa, Australasia and America, there is generally (but not always) only one player. In this, the more usual forms are supposed to represent, or be connected with, natural objects, such as the sun and moon, lightning, clouds, animals, &c., and on the whole these are more varied and interesting than the European type (Ball 1920a, pp. 348–349).

Haddon's hypothesis, as expressed in the preface to Jayne's book, was actually that most string figures in Europe and Asia began as the well-known European string game "Cat's Cradle", which is played by two people (Jayne 1962, p. xii). The succession of movements involved at the beginning of this game was called "Cat's Cradle Opening" by Haddon. According to him, the Oceanic type was characterized by the high occurrence of another opening that he (and Rivers) called Opening A: indeed this opening was used for the making of many string figures in Oceania, Africa or America. The configurations obtained after performing either Opening A or Cat's Cradle Opening are shown in pictures 28a and 28b.



28a – Cat's Cradle Opening configuration



28b – Opening A configuration

Ball does not elaborate on Haddon's classification much more than he does in the extract above: very likely, his only purpose was to point out that such a classification is possible. When Jayne wrote her book, only a few anthropological papers on string figures had been puublished. Nowadays, since there has been many publications on the topic, Haddon's hypothesis can be refuted. In particular, it is in contradiction to the high occurrence of Opening A in the corpora of string figures collected in India or Japan.[6] Nevertheless, the conceptual tool "Opening" is still valid when comparing string figures. As we will see in the Part IV of this book, the openings appear to be a relevant criterion in differentiating diverse corpora of string figures collected in various areas. At the end of the paragraph devoted to Haddon's classification, Ball brings up the possible "transformation" of an European type string figure into an Oceanic one:

> We can pass from a figure of European type to one of the Oceanic type and vice versa, but it is believed that this transformation is an invention of recent date and has no place in the history of this game (Ball 1920a, p. 349).

This transformation is described by Haddon in the preface to Jayne's book (Jayne 1962, p. xxi). The point is actually to switch, by applying a few operations, from the Cat's Cradle Opening configuration to the Opening A configuration (pictures 28a and 28b). Haddon mentioned that it was his friend Miss A. Hingston who had worked out this transformation, emphasizing that it had not been observed by ethnographers in the field.

After reading Jayne's book, Ball became interested in the possibility of classifying string figures and transforming one configuration into another. Even though he does not go into greater detail, he points out that the topic can be directly connected to these two fundamental ideas: classification and transformation. Furthermore, Ball structured his chapter according to Haddon's classification. The first part of this chapter is therefore devoted to the description of European type string figures (Cat's Cradle), then the second part is about Oceanic type.

4.2.2.2 Circulation of String Figures

In the introduction to the part devoted to *Oceanic Type* string figures, Ball mentions the question of this practice's circulation throughout the world:

> One or two specimens of this type [Oceanic type] are known in England, but they may be recent importations, perhaps by sailors, and not indigenous (Ball 1920a, p. 350).

The publications on Scottish and English string figures made by Gray (1903) and Pocock (1906a,b) present a relatively small number of figures compared to the large number of figures from Oceania, Africa, America published in the same period by Haddon, Parkinson, Cunnington, etc. Moreover, the procedures described by these authors are generally much more elaborate than the procedures described by Gray and Pocock. Haddon insists on this point in the preface to Jayne's book:

> As a child I had played cat's cradle and had seen various string tricks, but it was not until the year 1888 that I saw in Torres Straits some of those elaborate string figures of savage peoples that put our humble efforts to shame.[...] They can make much more intricate devices than ours and the manipulation is correspondingly complicated [...] Travellers in

[6] See Hornell 1932 and Saito 2004.

> various parts of the world have had similar experience. We are informed that these figures are much more complicated than are ours, and they represent various natural and artificial objects in a state of rest or motion (Jayne 1962, p. xi).

This suggests that the activity of string figure-making was more widely practiced within oral tradition communities than in Europe at that time. This has been confirmed by the huge corpora made up with Inuit or Oceanian string figures after the 1920s.[7] It is thus plausible that some string figures were imported into Europe from remote countries by explorers. However it is difficult to know for certain that a particular string figure comes from elsewhere. In the history of mathematics, many examples show that sophisticated procedures or reasoning can emerge with a similar form within communities which are geographically and culturally distant and which may not have any contact with each other. For the moment, I do not know of any trace of string figures in Europe during the Renaissance or the Middle Ages. The question was asked to medievalist Danièle Alexandre-Bidon (pers. com., December 2009), who is currently carrying out research in games and childhood in the Middle Ages.[8] Up to now, she has never encountered any trace of string games in source material. If this is confirmed by other historians, it would allow us to assume that the majority of complicated string figures known nowadays in Europe were invented in societies of oral tradition in Oceania, America or Africa.

4.2.2.3 Haddon and Rivers Terminology

Ball clearly encourages his readers to become practitioners themselves. Therefore he introduces the Haddon & Rivers terminology which allows the reader to make the figures.

> To describe the construction of these figures we need an accurate terminology. The following terms, introduced by Rivers and Haddon, are now commonly used. The part of a string which lies across the palm of the hand is described as *palmar*, the part lying across the back of the hand as *dorsal*. The part of the string passed over a thumb, finger or fingers is a *loop*. [. . .] The part of the loop on the thumb side of a loop is termed *radial*, the part of the little-finger side is called *ulnar*; thus each loop is composed of a radial string .[. . .] If there are two or more loops on one finger (or other object), the one nearest the root of the finger is termed *proximal*, the one nearest the tip or free end is termed *distal* (Ball 1920a, pp. 349–350).

Ball adopted Jayne's modification of Haddon & Rivers' nomenclature mentioned above:

> If, as is not uncommon, the figure is held by someone, with his hands held apart, palm facing palm, and the fingers pointing upwards, then the radial string of any loop is that nearest from

[7]For instance, Jenness published 153 Eskimo string figures and tricks in 1924 (Jenness 1924), Davidson published 74 Aboriginal string figures and tricks from Australia in 1941 (Davidson 1941).

[8]Cf. Alexandre-Bidon and Lett (2004).

> him; in this case we may use the terms *far* and *near* instead of ulnar and radial.[...] If the position of the hands is unambiguous, it is often as clear to speak of taking up a string from *above* or *below* it as to say we take it from the distal or proximal side (Ball 1920a, pp. 349–350).

Before giving the description of the first string figure, Ball makes some interesting remarks about the difficulty of precisely describing movements by words.

> The following descriptions are I believe sufficient to enable anyone to construct the figures, and I do not attempt to make them more precise. They are long, but this is only because of the difficulty of explaining the movements in print, and the figures are produced much more easily than might be inferred from the elaborate descriptions (Ball 1920a, p. 350).

Even though this precise terminology is efficient in most cases, it is in fact not rare to encounter some difficulties when trying to learn a new string figure by reading anthropological papers. As far as I know, these complicated procedures have been created and practised mostly by people belonging to oral tradition communities, in which the transmission of string figures was made orally and visually, as it is still the case nowadays. String figures are mainly based on a knowledge of gestures: very few words suffice when string figures are taught to the children, who just need to imitate their parents or other elders.

The first part of the Chapter is entitled *Cat's Cradles European Varieties*, and the second *Cat's Cradles Oceanic Varieties*. Ball uses sometimes the term *Cat's Cradles* as an equivalent of "string figures",[9] as it was often the case in the beginning of the twentieth century (Haddon and Rivers 1902, p. 146). But most often, Ball—like Jayne—uses the term "figures" when referring to "string figures". Although Ball starts with the description of *European type* string figures, he recommends "any one desirous of making the Figures and not really acquainted with the subject to commence with the Oceanic Varieties [...] where only one operator is required" (Ball 1920a, p. 350). Let us follow Ball's recommendation and continue our analysis by looking at the way the author introduces his readers to the so-called *Oceanic type* string figures.

4.3 First Descriptions of Oceanic Type String Figures

Before describing some string figures of Oceanic type, Ball defines three sets of operations that are involved several times in the making of these string figures.

[9] As far as I know, the expression "string figure" seems to be due to Haddon and Rivers (1902, p. 147). The name "Cat's Cradle" is still in use nowadays, particularly in the USA, as a generic reference to "string figures".

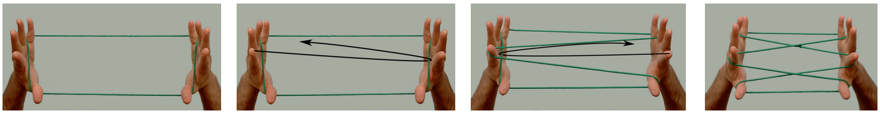
4.3.1 Sub-procedures

In the first part of this book, I have defined a *sub-procedure* as an ordered set of operations applied to the string by the fingers, either shared in a same way for the making of different string figures or iterated several times within the same string figure process. Ball might have shared that perspective on the processes implied in string figure-making, as he gives three examples of what I have called "sub-procedures": the first one is "Opening A". The second is a variation on "Opening A", that he calls "Opening B". And the third is a "sub-procedure" that Ball calls "Movement T".

4.3.1.1 Openings A and B

Ball starts by underlining that these two sets of operations are shared in a same way in the making of a great number of string figures. Then, he describes precisely how to "take up the string in the form of Opening A" (Ball 1920a, pp. 357–358).

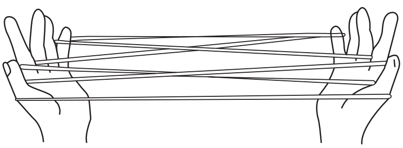
Opening B is obtained as Opening A, "save that, in the second part of the Opening [= after taking up the string in the First Position[10]], the right palmar string is taken up by the left index before the left palmar string is taken up by the right index" [pictures 29a to 29d below] (Ball 1920a, p. 358).



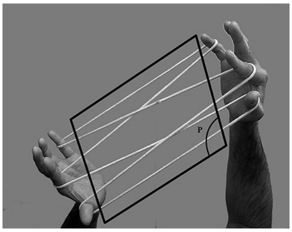
29a – First Position 29b 29c 29d

To illustrate the final configuration obtained through Opening A, Ball gives the following drawing (picture 30a) and explains that the string configuration can be seen as a planar configuration.

> The resulting figure, in a horizontal plane, is shown in the diagram, seen from above [picture 30a] (Ball 1920a, p. 358).



30a



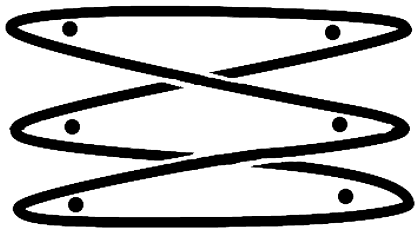
30b – Coplanar loops

[10]The expression "First Position" is due to Jayne (1962, p. 10). The same initial position had been defined as Position I by Haddon and Rivers (1902, p. 148).

At the end of the processes Opening A or B, the loops on the little fingers usually lie close to the palms. Ball deliberately made the drawing with the loops on the tips of the little fingers (picture 30a). Working in this way, he shows that the six loops of the configuration obtained through this opening can be seen in "a horizontal plane" (picture 30b above). Ball does not refer to this planar configuration elsewhere in the chapter. Therefore it is not easy to understand why he wants his reader to perceive the loops' possible coplanarity. However, it is plausible that this viewpoint would have come from his reading of mathematical papers in knot theory, published in the second half of the nineteenth century by mathematicians such as J. B. Listing, T. P. Tait and O. Böddicker, who are quoted by Ball at the end of the chapter:

> I should have liked to add another section to this chapter on knots and lashings. Some references to the mathematics of the subject will be found in papers by Listing, Tait, Böddicker,[11] but its presentation in a popular form is far from easy, and this chapter has already run to dimensions which forbid any extension of it (Ball 1920a, p. 379).

In concluding so, Ball points out that the topic of string figures could certainly be connected to the then nascent knot theory. To study knots, i.e. closed curves in three dimensional space, knot theorists considered the regular plane-projections of a knot. "Regular" means that we look at the projections in which only "simple crossings" (i.e. two lines crossing each other) are allowed. Picture 31 below shows a regular plane-projection of the configuration obtained through Opening A.



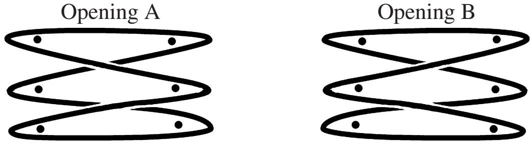
31 – Regular plane-projection of "Opening A"
The *dots* represent the projections of fingers

As far as I know, the expression "Opening B" was not used in anthropological papers in the period 1902–1911, even though some authors, like Jayne, referred to the possibility of reversing the order in the way palmar strings are picked up. Jayne and Ball did not have actually the same point of view about this variation on Opening A. Jayne advises her reader

[11] Ball refers to Listing (1847), Böddicker (1876), and Tait (1898)

> to follow the order just given [for Opening A], and take up, first, the left palmar string with the right index, and then the right palmar string with the left index; it will save trouble, therefore, if this order be always followed, even if it makes no difference in the result. If the reverse of this order is ever required, of course it will be noted in the description (Jayne 1962, p. 12).

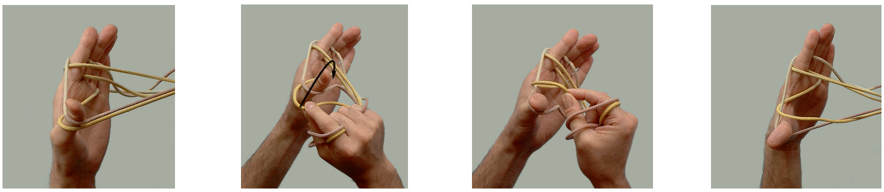
Most of the time, transforming Opening A into Opening B does not actually alter the final pattern in a significant way. More precisely, one can see that the configuration obtained through Opening B is the “mirror image” of the one obtained through Opening A as shown by their regular projections (pictures 32a and 32b). Therefore, the substitution of Opening B for Opening A within a string figure procedure entails the making of the mirror symmetry of the former final figure. I do not know whether or not Ball noticed this property, since he does not refer to it. However, he clearly prompts the reader not to follow Jayne’s advice by pointing out that “in most of the figures described [in the chapter] it is immaterial whether we begin with Opening A or Opening B” (Ball 1920a, p. 358).



32a 32b

4.3.1.2 Movement T Versus *Navahoing*

> There is also another movement which is made during the construction of many of the figures and which I shall described once for all. This movement is when we have on a finger two loops, one proximal and the other distal, and the proximal loop is pulled up over the distal loop, then over the tip of the finger, and then dropped on the palmar side [pictures 33a to 33d]. I term this the Movement T (Ball 1920a, p. 358).



33a 33b 33c 33d

This passage about “Movement T” immediately follows the description of Openings A and B. By writing that “Movement T” is “another movement”, Ball clearly classifies these three sequences as movements. Besides, although Ball does not give any particular explanation, the choice of the letter T might have been due to the perspective he took as a practitioner. I have observed that in most cases this sub-procedure is applied on the loop of the thumbs and is often carried out with the help of the teeth—two good reasons for choosing to call it "Movement T". As previously mentioned (Chap. 3), Kathleen Haddon describes the same movement that she calls "Navahoing" in her book *Cat's Cradle from many Lands*, thus suggesting that a "movement" (sub-procedure) can be culturally characteristic (Haddon 1911, p. 5). Although Kathleen Haddon and Ball do not use the same name, they both refer to the latter sequence of operations as to a "movement". Ball knew of the book written by Kathleen Haddon, which was published in 1911, the year *Mathematical Recreations and Essays*'s fifth edition was published. However, we may think that he had not noticed that Kathleen Haddon had given this succession of operations a different name. Otherwise, Ball would have chosen the same term, as he did for Opening A. In the lecture that Ball gave at the Royal Institution in 1920, a passage confirms that point: after having defined the "movement" in question, he pointed out:

> This movement is not uncommon; it was first discovered among Navaho Indians: hence it is called Navahoing. I describe the process as Movement T (Ball 1920b, p. 93).

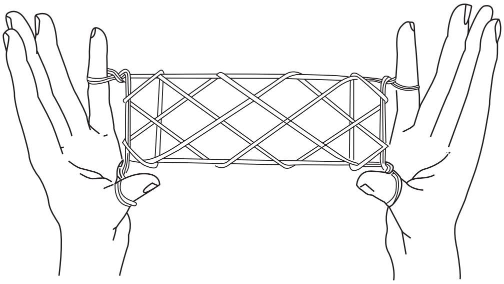
Actually, Ball did not use the term "Movement T" in his lecture (Ball 1920b). The sentence "Make movement T on the thumb loops" became "Navaho the thumb loops". Then in the booklet which followed the publication of the conference, *An introduction to String Figures* (Ball 1920c), Ball did not refer to the term "Movement T" anymore:

> This movement is not uncommon; it was first discovered among Navaho Indians: hence it is called Navahoing the loops (Ball 1920c, Dover Edition, 1971, p. 21).

It is likely that Ball finally chose to refer to this sub-procedure using the term "navahoing" as K. Haddon's work was better known among the authors interested in string figures. The term "navaho" has been the one mostly used until today to refer to this sub-procedure.

4.3.2 A Progressive Learning

Ball begins the section devoted to string figures of Oceanic type with an Apache Indians string figure referring to "a door". He justifies his choice by underlining that it "affords a good introduction to the Oceanic varieties, for it is one of the easiest figures to construct, as the movements are simple and involve no skill in manipulation" (Ball 1920a, p. 358). The description of "The Door" is followed by two other simple procedures. Some more complicated string figures of the so-called "Oceanic type" are then described in detail by Ball.



34 – *The Door* (Ball 1920a, p. 359)

4.4 String Figures as a System of Transformations

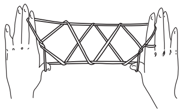
In the next few subsections, I will argue, in a linear analysis of the text, that the string figures described by Ball in his book have been organized into five groups that introduce fundamental ideas on the topic on which he lays stress. We will see that the first group reveals that some "interesting" geometrical designs can be formed at the end of the process. The figures belonging to the second group tend to bring light on the fact that the making of a string figure can be seen as a procedure in which one operation—or more precisely an "elementary operation" (as I have defined it)—can be altered or omitted. Concerning the third and the fourth groups, they consist in string figure procedures that share a common sequence of elementary operations, a sequence that I have defined as a "sub-procedure". Finally, we will see that it is the concept of transformation which is developed in the last group.

4.4.1 First Group: Diamonds

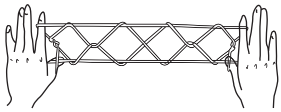
The following group of string figures is explicitly introduced by the author under the title "Diamonds". Ball describes the making of three string figures resulting in a geometrical form obtained through the repetition of the same motif that he calls a "diamond" or "lozenge-shaped figure".

> Numerous lattice-work forms have been collected in which diamonds or lozenge-shaped figures are strung in a row, or in two or more rows, between two parallel strings. I describe a few of these (Ball 1920a, p. 361).

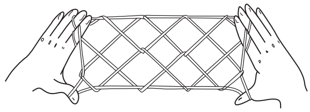
Ball borrowed the three string figures in this group from Jayne's book. However, he chose to rename them "Triple Diamonds", "Quadruple Diamonds" and "Multiple Diamonds", rather than keep the names given by Jayne. His goal was certainly to stress the common characteristic between these three procedures. The first lozenge-shaped figure presented by Ball is "Triple Diamonds" (picture 35a). He followed the instructions given by Jayne, whose brother William Furness had learnt this figure from *Natik* people in the Caroline Islands (Jayne 1962, p. 143). In his description of this figure, Ball underlines that it is not symmetrical (Ball 1920a, p. 361). Let us stress Ball's interest in symmetry. At first glance, the final design, made of three lozenges in a row, seems to be symmetrical (see figure by Ball below). However, if one takes a closer look at the knots and crossings, the figure does not appear symmetrical with respect to a vertical line drawn between the two hands. I will not describe the procedure here, but it is worth mentioning that such an asymmetry of the crossings is due to the fact that the two hands do not perform exactly the same operations.[12] So Ball's intent might have been to emphasize the crossings' asymmetrical configuration that resulted from the asymmetry of the operations (applied to the string).



35a – Triple diamond (Ball 1920a, p. 361)



35b – Quadruple diamonds (Ball 1920a, p. 362)



35c – Multiple diamonds (Ball 1920a, p. 362)

The second lozenge-shaped figure is a well-known figure in America, most often called "Jacob's ladder" nowadays (picture 35b). It was shown to him "by a friend who was taught it when a boy in Lancashire. It is the same as one described by Mrs. Jayne (pp. 24–27), which was derived by her from Osage Red Indians" (Ball 1920a, p. 362). The third string figure of this first group is called "Multiple Diamonds" by Ball, and was also collected by William Furness among the Caroline Islanders (picture 35c). As previously mentioned, I have noticed, either during my fieldwork or going through the collections of string figures, that knowledge of this figure is widespread throughout the Pacific.[13] By presenting this figure, Ball underlines that the "diamonds" are here in three rows, whereas the preceding figures are in a single row (Ball 1920a, p. 363).

[12] See Ball (1920a, pp. 361–362). The same procedure is known under the name *Meta* (trap) in the Trobriand Islands. The reader will find the instructions for making this string figure in the accompanying website (*kaninikula* Corpus).

[13] Jaynes describes this figure as Ten Men. See Sect. 3.2.2.1. See also the procedure 52. *Salibu* (*kaninikula* corpus) in the accompanying website.

4.4.2 *The "Many Stars" Group*

4.4.2.1 Procedure Many Stars

After having described the figure "Multiple diamonds", Ball introduces the description of the "somewhat similar" figure "Many Stars" collected and published under this name by Haddon (1903, p. 222) and by Jayne (1962 [1906], pp. 48–53).

> *Many Stars*. [This] figure-see figure x-is made by the Navaho Mexican Indians, and by the Oregon Indians. The Oregon method is much the more artistic, since the movements are carried out by both hands simultaneously and symmetrically, and the one hand is not used to arrange the strings on the other hand. But I give the Navaho method partly because it is easier to perform and partly because, by slightly varying the movements, it gives other interesting figures (Ball 1920a, p. 364).

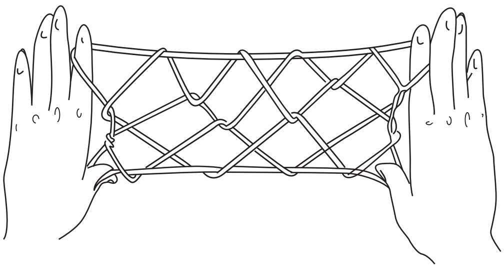


Figure x. Many Stars.
36 – Ball's drawing of "Many Stars" (Ball 1920a, p. 364)

It is noticeable that Haddon and Jayne only refer to this figure as a Navaho one. Ball does not specify where he learnt the "Oregon" method for that figure and does not describe it.[14]

Although figure Many Stars appears indeed to be quite similar to figure Multiple Diamond, their methods of construction are different. So Ball's presentation tends to underline that quite similar final figures can be obtained through different methods. In this passage, Ball also underlines that, by slightly altering a few operations applied to the string, one may obtain, according to him, "other interesting figures". As we will see below, he further develops this point through the examples that follow his description of Many Stars, while prompting the reader to explore the string configurations by varying the operations. According to me, this kind of investigation

[14]The reason put forward by Ball for choosing the Navaho method is rather obscure to me. According to him, the Oregon method would be more artistic because of its simultaneous and symmetrical movements. But Haddon and Jayne have described the Navaho "Many Stars" with a succession of operations performed by both hands most of the time simultaneously and symmetrically. The one hand is used "to arrange the string on the other hand" only for performing Movement T (Navahoing). Furthermore, Ball modified Jayne and Haddon's description by substituting a few non-simultaneous operations to symmetrical and simultaneous ones (see the description of Many Stars).

on the string configurations appears to be of "topological" order. Ball thus focuses here on that particular aspect of this activity. This dimension might have retained his attention while reading Jayne's book: Jayne indeed concludes the description of Many Stars by asserting that

> [this string figure can be seen] as the first of a series of ten Navaho figures, which are all done in much the same way, but come out in characteristic patterns in the end. They all start with *Opening A*, or modification of it; after that, however, some go as "Many Stars", but end differently, while others begin and end as "Many Stars", but have different intermediate movements" (Jayne 1962, p. 52).

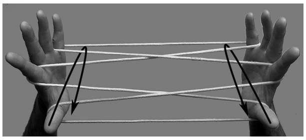
In order to understand how to obtain the other figures that Jayne compares to Many Stars, we need to go further into the description that Ball gives of this latter figure. Although Ball had learnt many string figures from Jayne's book, he did not adopt her way of presenting the procedures. Jayne illustrates each step of the making of a string figure with an accurate drawing, whereas Ball does not give any intermediate drawings, but presents only a sketch of the final figure after a textual description of the procedure, as Haddon and Rivers had done before him (1902). The fact that Ball chose this manner to explain the making of a string figure prompts me to think that he was interested in the possibility of transcribing concisely in words the whole process of a string figure. By giving the instructions in this manner, Ball compels even more the reader—keen to grasp the ideas developed in the chapter—to make the figures all by himself.

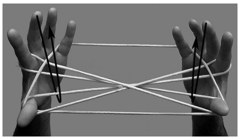
In order to facilitate the understanding of the instructions given by Ball, I will systematically include pictures illustrating the descriptions quoted in the following. Nevertheless, I encourage the reader (as Ball does) to perform these string figures. Indeed, it might be difficult to perceive the complexity of the procedures without manipulating the string.

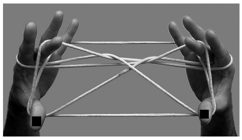
> *Many Stars* [. . .] It is produced thus.
> *First*. Take up the string in the form of Opening A.
> *Second*. Pass each thumb away from you over three strings (viz. the far thumb and both index strings) and pick up from below on its back the near little-finger string, and return [picture 37a].

As mentioned above, Ball adopted Jayne's modification of Haddon & Rivers' nomenclature. It consists in substituting the common terms *near/far* and *below/above* to the four terms *radial/ulnar* and *proximal/distal*, when the string is held by the palms facing each other.

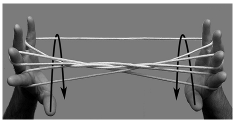
> *Third*. Bend each middle-finger down towards you over two strings (viz. both the index strings) and take up from below on its back the far thumb string, and return [picture 37b].
> *Fourth.* Release the thumbs [picture 37c].

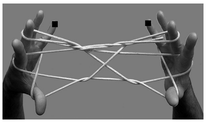

37a

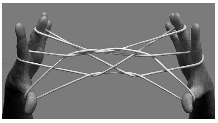

37b

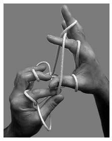

37c

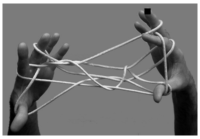
> *Fifth*. Pass each thumb away from you over one string (viz. the near index string), under the remaining five strings, and pick up on its back the far little-finger string, and return [picture 37d].
> *Sixth*. Release the little-fingers [picture 37e].
> *Seventh*. Take the far string of the right middle-finger loop, pass it under the near string of that loop, and then, taking it over the other strings, put it over the tips of the right thumb and index, so as to be the distal loop of them [pictures 37f and 37g].
> Release the right middle-finger [pictures 37h and 37i].
> Make a similar movement with the other hand [picture 37j] (Ball 1920a, p. 365).

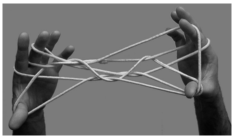

37d

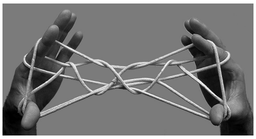

37e


37f


37g

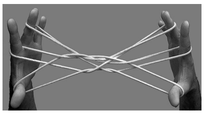

37h

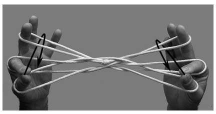

37i

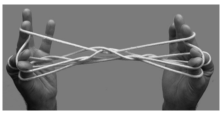

37j

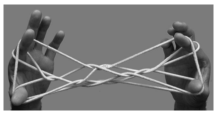
Although her knowledge of the topic allowed her to make relevant remarks about the possible modifications of the procedures, Jayne always rendered the instructions accurately, as the result of the ethnographical collections made by herself or other anthropologists. Ball was not guided by such purpose. He was focused on—what I call—the "topological" aspect of string figures more than on their cultural dimension. He did not hesitate to modify ethnographical sources, sometimes rewriting a procedure to give an equivalent result. For instance, the seventh step is not described in the same way by Haddon, who had first showed this figure to Jayne. Haddon's description is:

> Transfer the middle-finger loop of each hand to the thumb and index by passing these digits to the proximal side of the middle-finger loop, and then round the ulnar middle-finger string to insert them from the distal side into the middle-finger loop. Release middle fingers [pictures 1 to 4 below] (Haddon 1903, p. 222).


Picture 1

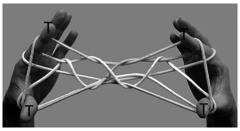

Picture 2


Picture 3

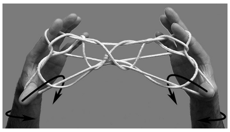

Picture 4

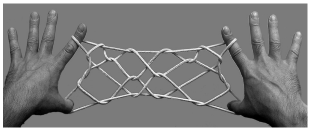
The latter sequence is not technically easy to do. It might be the reason why Ball chose to replace it by a sequence leading to the same configuration (picture 37j and picture 4 above) but easier to perform. Let us finish the making of Many Stars according to Ball's instructions.

> *Eighth*. Make movement T on the loops on the thumbs and index-fingers (picture 37k). There is now on each hand a string passing from the thumb to the index, and on each of these strings are two loops, one nearer you than the other.
> *Ninth*. Bend each thumb away from you over the upper string of these nearer loops.
> *Lastly*. Rotate the hands so that the palms face away from you, the finger point up, and the thumbs are stretched as far from the hands as possible [pictures 37l and 37m] (Ball 1920a, p. 365).



37k


37l


37m – Many stars

Like Jayne did, Ball numbered each stage in the making of a string figure, whereas Haddon & Rivers wrote continuous texts without numbering the different stages. This choice suggests that Ball wanted to emphasize that a string figure process can be seen as a sequence made up of a succession of steps.

4.4.2.2 String Figure as a "Formula"

At the end of each procedure of the Oceanic type, Ball gives a brief summary of the making of the string figure. His description of Many Stars is for instance followed by this short paragraph:

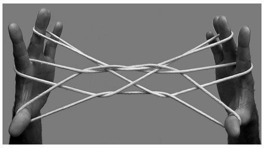
> *More briefly thus*. Opening A. Each thumb over 3 and picks up one. Each middle-finger over 2 and picks up one. Release thumbs. Each thumb over one, under 5, and picks up one. Release little-fingers. Take up near string of each middle-finger loop, turn it over, and transfer it to tips of corresponding thumb and index-finger. T to loops on thumbs and index-fingers. Place thumbs on upper strings of near loops. Rotate and extend (Ball 1920a, p. 365).

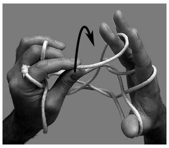
Ball uses whole numbers to denote the number of strings that a given finger has to travel over or under. To my knowledge, this method was original (and, in any case, not used in anthropological studies). Ball asserts that this synthetic approach might be helpful to remember quickly the making of a string figure, when one has forgotten how to perform it.

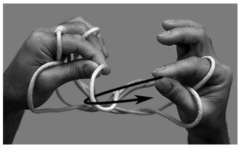
> Once a figure has been constructed or the rule given for making it understood, the brief description of the method (which in many cases I insert after the exposition of the rule) will suffice for the reproduction of the figure (Ball 1920a, p. 357).

By using the term "rule", Ball stresses on the fact that a string figure is the result of a step-by-step construction. It is also noticeable that by giving instructions such as "each thumb over 3 and picks up one" (quotation above), Ball proposes a synthetic version of the described operation in a summary which might help to remember the whole process (while avoiding long and detailed explanations). As it retains essential ideas relating to the process, this summary can be seen as the "core" of the "rule". The technical terms that Ball uses in the short descriptions mentioned above are the same as in the detailed ones that he gives: Opening A, picking up or taking up, extending, releasing, etc.. But the expression "Make movement T on..." is simply written as "T on . . .". As far as I know, this way of summarizing operations on the string was not inspired by ethnographical literature and seems to be an original contribution by Ball to the subject. Although he does not mention it, his attempt to present the string figures' processes in a synthetic form might have expressed his understanding of string figures as successions of operations that can be reduced to a formula. Ball's work might have been thus the first step towards a formal approach to string figure procedures, which was further developed by a few mathematicians and ethnolinguists in the second half of the twentieth (Amir-Moez 1965; Storer 1988; Braunstein 1996).

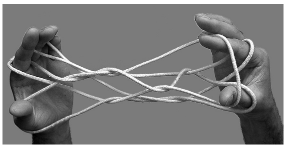
In Ball's formal description of Many Stars, the sentence "Take up near string of each middle finger loop, turn it over, and transfer it to tips of corresponding thumb and index finger" synthesizes the seventh step of Many Stars shown above. Notice that this step is not described in the same way in the synthetic version as it is in the previous description of Many Stars but it corresponds exactly to a variation of the seventh step suggested by Haddon in a footnote (see pictures 38a–38e) (Haddon 1903, p. 222).


38a


38b


38c


38d

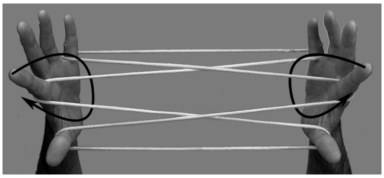

38e

By giving the latter variation on the seventh step, Ball helps his reader to perceive the effects of the operations—applied to the string by fingers—on the motions of the loops. In this particular case, the consequence of Many Stars' seventh step is to rotate middle finger loops anticlockwise (for an observer located to the left side of the practitioner) and to transfer them to the thumbs and indices, as it appears in pictures 38a–38e above. Although referring to the operations applied to the strings ("Takes up near string of each middle finger loop . . ."), it is thus clear that Ball intends to show the motion of the middle finger loops during the process. This remark is of fundamental importance since "the motion of loops" has later been the starting point of an original formalization of string figures by mathematician Thomas Storer (1938–2006) in the 1980s—whom I will introduce in the next chapter.

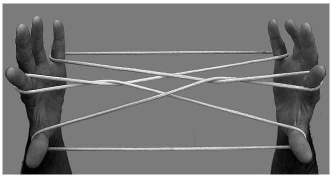
4.4.2.3 Variations on Many Stars

Let us focus on what I call the "variations" on Many Stars that Ball selected from Jayne's book and grouped under the title "Owls". Jayne learnt these string figures from the Navaho and described them as "Second Owl" and "Third Owl" (Jayne 1962, pp. 54–56). Ball underlines the connection between these figures and the previous Many Stars, writing that they "can be produced like Many Stars save for interpolation or alteration of one movement" (Ball 1920a, p. 366). The first figure "Owl" described by Ball is obtained from Opening A by twisting both indices anticlockwise, and then by continuing with the subsequent steps of Many Stars.

> Immediately after taking up the string in the form of Opening A, give a twist to the index loops by bending each index down between the far index string and the near little-finger string and, keeping the loop on it, bring towards you, up between the near index string and the far thumb string [pictures 39a to 39b].

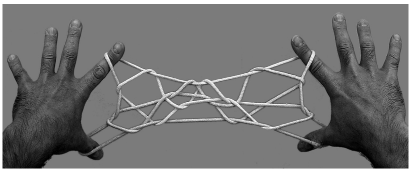


39a

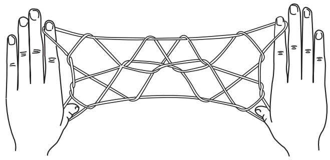


39b

> Continue with the second and the subsequent movements described in Many Stars (pictures 39c and 39d) (Ball 1920a, p. 366).



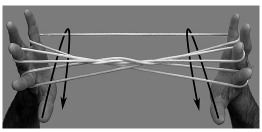
39c



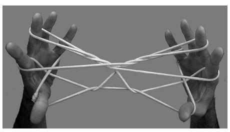
39d – An Owl (Ball 1920a, p. 365)

Ball mentions the second figure "Owl" (taken from Jayne's book) by stressing the fact that it can be produced by altering Many Stars' fifth step.

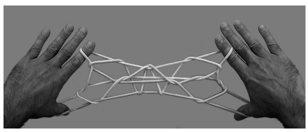
> In another example (Jayne, pp. 55–56) all the movements are the same as in Many Stars, save that in the fifth movement the far little-finger string is drawn from above, instead of below, through the thumb loops [pictures 40a to 40c] (Ball 1920a, p. 366).



40a



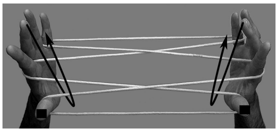
40b

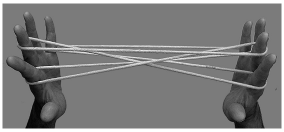


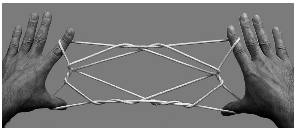
40c – Second Owl

According to Ball, “other figures [. . .] can be produced like Many Stars save for the alteration or omission of one movement” (Ball 1920a, p. 366). In the next example, called “Single Stars” by Ball, it is actually the procedure’s second to fourth steps that are altered and replaced by a single step:

> The example of the Single Stars which I select is termed the North Star, and is produced thus (Jayne, p. 65). Replace the second, third, and the fourth movements in Many Stars by the following. Bend each middle-finger towards you over the index loop, and take up from below on the back of the finger the far thumb string. Release the thumbs, and return the middle-fingers. The effect of this is to transfer the thumb loops to the middle fingers [pictures 41a and 41b].
>
> This is followed by the fifth and the subsequent movements described in Many Stars. This figure may at our attention be regarded as a single or double diamond [picture 41c below] (Ball 1920a, p. 366).

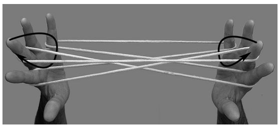

41a

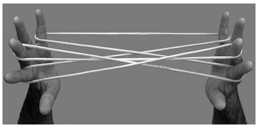

41b

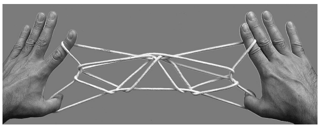

41c – Single Star

Ball proposes to alter the second step of Single Stars by adding a twist of the middle fingers to obtain “another elegant design”—called *W.W* by the author—since it forms “two interlaced W’s” (Ball 1920a, p. 366).

> This figure is made in the same way as North Star, except that after transferring the thumb loops to the middle-fingers, a twist is given to each middle finger loops by bending each middle finger down on the far side of the far middle-finger string and (keeping the loop on it) bringing it towards you up between the near middle-finger string and the far index string [pictures 42a to 42c] (Ball 1920a, p. 366).


42a


42b


42c – The figure W.W

This figure seems to be an original creation by Ball, since he does not refer to any ethnographical source. We may also notice that *W.W* are Ball’s first names initials.

We have seen that Ball constantly prompts his reader to be inventive and create new figures. With the figure *W.W*, which apparently came up from his own practice of string figures, he clearly suggests how to use the descriptions given in his chapter as a base for personal investigations. This appears explicitly when Ball asserts:

> The reader who has followed me in my descriptions of the movements for producing Many Stars will find it easy to make other modifications which lead to other figures (Ball 1920a, p. 367).

Adding, altering or omitting one operation in the process, and then observing the consequence of such an action, is certainly an efficient method for exploring the procedures. As many other examples described in ethnographical papers tend to suggest, this might have been a method largely used by the "creators" and the "practitioners" of string figures in different societies. However, with a little practice, one realizes that it is not so easy to introduce, into a string figure procedure, changes that lead to obtaining a configuration extendable into a 2 or 3-dimensional design (presented between parallel lines). Most of the time indeed (particularly when one starts with Opening A), experimenting variations on the procedure results in an impasse, namely a set of entanglements that cannot be extended. This suggests that those skilled in creating or making string figures had a good knowledge of the various consequences of some particular operations on the spatial configurations of strings. Ball did not mention this difficulty. He probably did not want to discourage his readers from exploring these complex configurations on his own. Ball encouraged those interested in making string figures to become creators themselves rather than being mere practitioners. In inviting his reader to do so, Ball suggests that these are the explorations across complex spatial configurations of strings that can be seen as recreational mathematics. Ball's comments invite furthermore to reflect upon the ways string figures have been originally created, which is an interesting anthropological problem that so far remains unsolved.

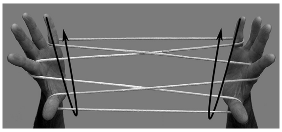
Here Ball also prompts his readers to consider ethnographical data as a new type of relevant material in the field of "mathematical recreations". In his chapter on string figures, he organized the new materials collected by anthropologists. Ball's work further shows that these ethnographical data can be used as a basis, or a model, from which one can give free rein to his imagination. Ball did not however hesitate to modify some of these ethnographical sources. According to his own words ("The example of the Single Stars which I select is termed the *North Star* ..." (Ball 1920a, p. 366)), he selected for instance both figures "Owls" and figure "Single stars" from a set of eight presented by Jayne as figures connected to Many Stars (Jayne 1962, pp. 48–65). Ball thus reclassified the ethnographical material he used in order to focus on certain aspects that he considered to be of major importance in the analysis of string figures. His identification of the first group, "Diamonds", was based for instance on his focus on the final form of the string figure's process. For the next group, "Many Stars", his point was more to insist on the potential offered by alteration, omission or addition of a few elementary operations. As we will see now, the selection made by Ball for the identification of the last two groups aimed at revealing a certain type of "movement" (that I define as "sub-procedure").

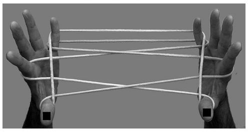
4.4.3 Lem Group

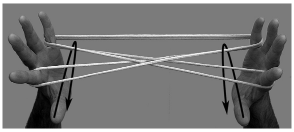
4.4.3.1 *Lem* Sub-procedure

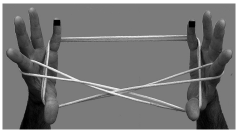
The sub-procedure called *Lem* Opening by Haddon and Rivers is a sequence of several operations which begins by taking up the string in the form of Opening A. This name was chosen by Haddon because the string figure *Lem Baraigida* (setting sun) he had collected from Murray Islanders included this sequence of operations (Haddon and Rivers 1902, p. 150). Ball describes it as follows:

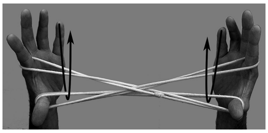
> *First*. Take up the string in the form of Opening A.
> *Second*. Pass the little-fingers over four strings (viz. the radial or near little-finger string, the index loops, and the ulnar or far thumb string), insert them into the thumb loops form above, take up with the backs of the little-fingers the near thumb string, and return [picture 43a].
> *Third*. Release the thumbs [picture 43b].
> *Fourth*. Pass the thumbs under the index loops, take up from below the two near strings of the little fingers loops and return, passing under the index loops [picture 43c].
> *Fifth*. Release the little-fingers [picture 43d].
> *Sixth*. Pass the little-fingers over the index loops, and take up from below the two far strings of the thumb loops and return. This arrangement is known as Lem Opening [pictures 43e and 43f] (Ball 1920a, p. 367).

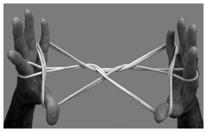

43a


43b

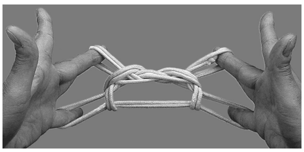

43c

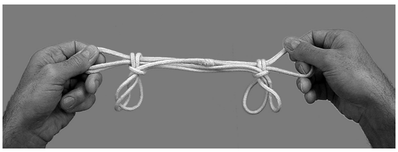

43d


43e


43f

In the terminology I have borrowed from linguist José Braunstein (see Chap. 3), the sequence called *Lem* Opening by Haddon cannot be seen as an opening but rather as Opening A immediately followed by a “passage” (or a sub-procedure). More precisely, the *Lem* Opening sequence can thus be described as a succession of an Opening A and three passages, which lead to the three normal positions showed above in pictures 43c, 43e and 43f respectively. In my sense, these “passages” can be grouped and considered all together as a sub-procedure that I will call *Lem* sub-procedure. Ball describes the method used for making two string figures, respectively called “The Setting Sun” and “The Head Hunters”, that were collected by Haddon and Rivers in the Murray Island (1902, pp. 150–151). These figures both start with Opening A and are followed by the *Lem* sub-procedure.


44a – The Setting Sun


44b – Head Hunters (Haddon and Rivers 1902, p. 150)

Ball begins the description of The Setting Sun by the six steps of the *Lem* Opening and gives the name of this sequence. As for figure The Head Hunters, Ball simply explains:

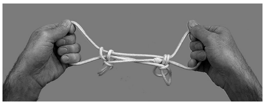
> *First*. Make the Lem Opening, which involves six movements. Continue thus. *Seventh* [. . .] (Ball 1920a, p. 367).

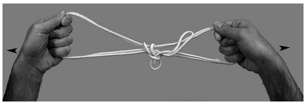
In describing these two string figures successively, Ball shows, as he did for openings or Movement T, that an identical series of operations can be found within different string figure-making process. Although he did not explicitly introduce it, Ball has thus shed light on the concept of sub-procedure.

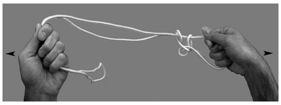
4.4.3.2 Introspection into "The Head Hunters"

Although Ball does not want to concern himself with the cultural aspects of string figures, he makes an interesting remark about The Head Hunters:

> The Head Hunters is another and more difficult example, in which the Lem Opening is used. It too is derived from the Torres Straits, and is interesting because it is a graphical illustration of a story [. . .]
>
> [If the two hands are drawing slowly apart then the two small hanging loops] will approach each other and become entangled [pictures 45a to 45c].


45a


45b


45c

> One represents a Murray man, and the other a Dauar man. They "fight, fight, fight," and, if worked skilfully, one loop, the victor, eventually remains, while a kink in the string represents all that is left of the other loop. The victorious loop can now be drawn to one hand along the two strings, sweeping the kink in the front of it: it represents the victor carrying off the head of his opponent (Ball 1920a, p. 368).

The description above is adapted from Haddon and Rivers (1902), who give the following instructions just after describing the making of *Ares*.

> Insert the four fingers into the little finger loops and draw slowly apart. The two index loops [In fact, these two loops are the index loops which have been just released. They correspond to the small hanging loops – my comment] will approach each other and become entangled. One represents a Murray man, and the other a Dauar man: they fight, fight, fight, and one loop eventually remains. When done carefully this loop can now be drawn to one hand along the two strings, it represents the Murray man carrying off the Dauar man's head (Haddon and Rivers 1902, p. 151).

Ball interprets the above, writing:

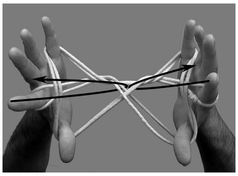
> In the hands of the Murray man who showed the figure to Dr. Haddon, the result of the fight always led to the defeat of the Dauar warrior (Ball 1920a, p. 368).

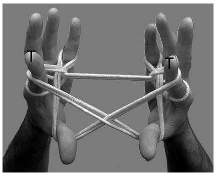
Unlike Haddon, Ball tries to understand why sometimes the figure does not untangle in the same way.

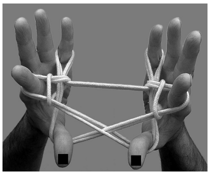
> Sometimes, if the two index loops are twisted exactly alike, they both break up, representing a duel fatal to both parties (Ball 1920a, p. 368).

To understand Ball's idea, we must go a little further into the description of The Head Hunters. After having operated the six steps of the *Lem* Opening (Opening A—*Lem* sub-procedures), Ball gives the following description:

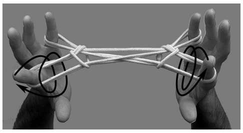
> Insert the index-fingers from below into the central triangle and take up on their backs the near thumb strings [picture 46a].
>
> Loop the lowest or the proximal index string of each hand over the two upper or distal strings and over the tip of the index on to its palmar aspect [It is Movement T; but curiously Ball does not mention it]. Release the thumbs [pictures 46b and 46c].

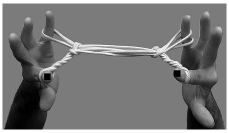

46a

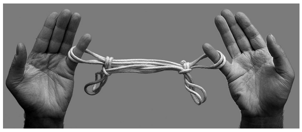

46b


46c

> Take the index loops off the right hand, twist them tightly three or four times, and let the twist drop. Similarly form a twist out of the loops on the left index (Ball 1920a, p. 368) [pictures 46d to 46f, I have adopted the method given by Haddon & Rivers which consists to twist both indices symmetrically before dropping their loops].


46d

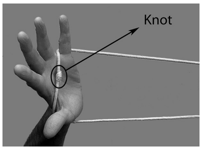

46e


46f

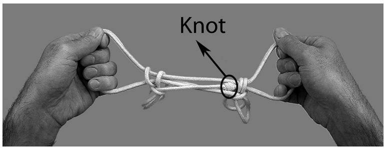
So, when Ball says that "if the two index loops are twisted exactly alike", he refers to the twists of both indices shown in picture 46d above. Then, in this situation, the two double loops representing the fighters can be sometimes entangled at the same time. Ball tries to investigate further:

> It is not easy to make the figure so as to secure a good fight. For the benefit of any who wish to predict the result I may add that if, in the first position, there be a knot in the right palmar string the left loop will be usually victorious over the right loop, and vice versa (Ball 1920a, p. 368).

The knot in question may be the one made for tying up the loop of string as shown below (picture 47a). For instance, if when starting the figure (in Position I) the knot is in the left palmar string (picture 47a), the same knot would be found at the end of the process, and just before fighting, near the right cluster which represents one of the men. The consequence seems to be that most often the right cluster will be untangled faster than the left one, due to the knot's friction against the cluster's strings (picture 47b).



47a – Knot in the right palmar string



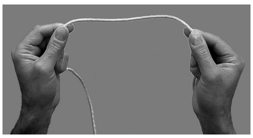
47b – Knot near the right cluster

Ball introduces the paragraph about The Head Hunters by pointing out that this procedure "is interesting because it is a graphical illustration of a story". Although he does tell us shortly about this story, his main intention is to investigate the transformations of the figure during the process. We will see later that string figures accompanied by a story telling were chosen by Ball as a basis for another interesting classification.

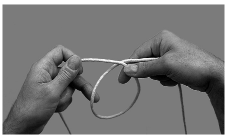
4.4.4 Navaho Opening Group

At the end of the section on string figures of Oceanic type, Ball "gives two examples which do not start from *Opening A*" (1920a, pp. 369–371). Indeed, the starting sequence of some string figures is as follows:

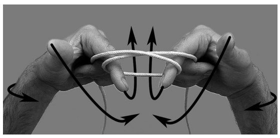
> *First*. Hold the string in one place between the tips of the thumb and index-finger of the right hand and in another place between the tips of the thumb and index finger of the left hand, so that a piece passes between the hands and the rest hangs down in a loop [picture 48a].
> With the piece between the hands make a ring, hanging down, by putting the right-hand string away from you over the left-hand string [picture 48b].
> Next, insert the index-fingers towards you in the ring and put the thumbs away from you into the long hanging loop [picture 48c].
> Separate the hands, and turn the index-fingers upward with the palm of the hands facing away from you [picture 48d].
> Then, turn the hands so that the palms are almost facing you, and the thumbs and the palms come towards you and point upward. You now have a long crossed loop on each thumb and a single cross in the centre of the figure [picture 48e] (Ball 1920a, p. 367).



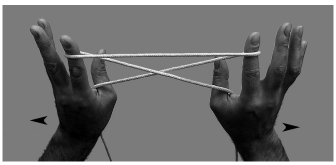
48a



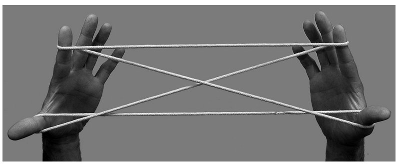
48b



48c

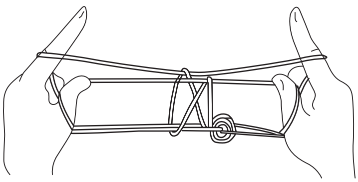


48d

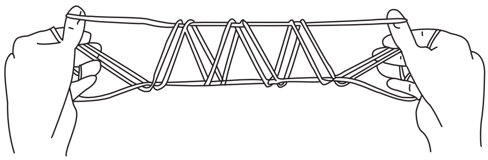


48e

Ball identified this sequence as an opening and named it the “Navaho Opening”. It seems that neither Haddon and Rivers nor Jayne had used this term. Ball might have chosen that name himself, since the sequence is part of several Navaho string figures described by Jayne (1962, pp. 212–232). His intent in using that term was probably to refer to the “actors” who made these string figures. The first string figure presented by Ball and starting with a Navaho Opening is “Lightning”. This figure was collected by Haddon from two Navaho elders in 1901, and later published by Jayne (1962, p. 216). The second one is “Butterfly”, which Jayne “obtained from two Navaho girls at the St. Louis Exposition” (1962, p. 219).



49a – Butterfly (Ball 1920a, p. 369)



49b – Lightning (Ball 1920a, p. 369)

Following Jayne’s presentation, Ball chose to describe these string figures successively. However, unlike Jayne, he named (“Navaho”) the opening that these two procedures have in common. The goal was certainly to show his readers that string figures do not necessarily begin with Openings A or B. By using the term “Navaho” to name this opening, he highlights that certain openings can be characteristic of a cultural group, thus suggesting that they might be the result of a local investigation.

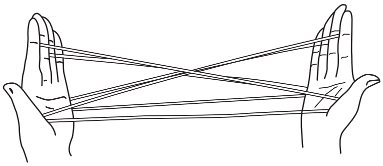
Between the descriptions of the two previous groups that I have called “*Lem* group” and “Navaho Opening group”, Ball also gives an instance of a string figure called “The Parrot Cage”. This figure had been collected by John Parkinson among the Yoruba of the Gold Coast, in West Africa (Parkinson 1906, p. 136). Ball asserts that this figure’s “construction and design are not interesting in themselves”, but are worth to be noticed because “the method used is somewhat different to those employed in the foregoing examples” (Ball 1920a, p. 368). By selecting this figure, Ball seems once again to point out that the methods of construction may significantly vary depending on the cultural areas. Immediately after The Parrot Cage, Ball gives an example adapted from Haddon’s introduction of Jayne’s book (1962, p. xiii). The string figure called “See-Saw” begins with Opening A, thus belonging to the Oceanic type according to Haddon’s classification, although it is performed by two players. Ball’s intent might have been here to highlight that the making of a figure of Oceanic type sometimes requires two partners, as for the “Cat’s Cradle”, which belongs to the Asiatic or European class. Also, as we will see in the next section, the final figure See-Saw can be produced by starting with Cat’s Cradle Opening (Ball 1920a, p. 369). As already mentioned Ball had indeed noticed the possible transformation of the “Opening A” configuration into a “Cat’s Cradle Opening”.[15] Therefore, what is emphasized here is the possibility of obtaining the same final figure by starting with two different openings.

[15] See above Sect. 4.2.2.1 (Classification and transformation).

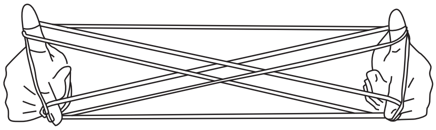
4.4.5 Cat's Cradle Group

According to Ball (1920a, p. 350), Cat's Cradle is "played by two persons, [...], each of whom in turn takes the string off the fingers of the other." This string figure thus consists in the production of a series (or sequence) of figures shown alternatively by two partners. I shall not quote Ball's full description of Cat's Cradle (Ball 1920a, pp. 350–356). The operations involved are much easier than the ones we have seen in the previous groups. We will focus on the series of intermediate figures successively shown during the process, as Ball has sketched them.

> The initial figure is termed the Cradle; from this we can produce Snuffer-Trays [pictures 50a and 50b] (Ball 1920a, p. 351).



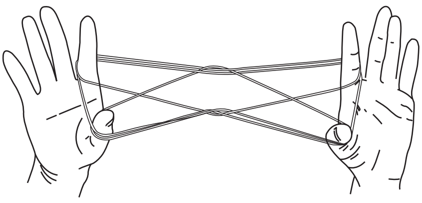
50a – Opening figure: The Cradle (Ball 1920a, p. 351)



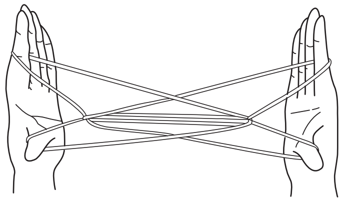
50b – Snuffer-Trays (Ball 1920a, p. 352)

In 1906, the main ethnographical sources about the "Cat's Cradle" procedure could be found in publications by Jayne (pp. 324–336) and Pocock (1906a), who both called "Cradle" the first figure of the series. They had however referred to the second figure of this series as "Soldier's bed" (Pocock giving also two other names: "Dolly's Bed" or "Church Window"), whereas Ball refers to the term "Snuffer-Trays". Ball does not mention where this term comes from. But he carries on his presentation by showing that from "Snuffer - Trays", three directions can be taken, each of them leading to three different configurations: "Pound-of-Candles", "Cat's-Eye" and "Trellis-Bridge". By doing so, Ball highlights that Cat's Cradle can be represented by an arborescence.

> From Snuffer-Trays we can obtain forms known as a Pound-of-Candles, Cat's-Eye and Trellis-Bridge. From each of these forms again we can proceed in various ways. I will describe first the figures produced when the string is taken off so as to lead successively from the Cradle to Snuffer-Trays, Cat's-Eye, Fish-in-a-Dish. This is the normal sequence [pictures 50c and 50d] (Ball 1920a, p. 351).



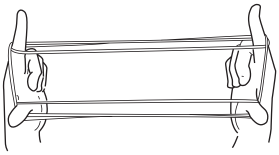
50c – Cat's Eye (Ball 1920a, p. 352)



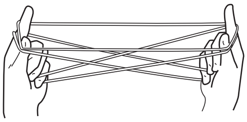
50d – Fish in a Dish (Ball 1920a, p. 353)

The series chosen as the "normal sequence" is the one we find in Jayne as well as in Pocock, who both describe the following succession of figures: Cradle—Soldier's

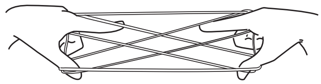
Bed (Ball's Snuffer Trays)—Pound of Candles—Manger—Diamond (similar to Soldier's Bed)—Cat's Eye—Fish in a Dish (pictures 50e–50g by Jayne).



50e – Pound of Candles (Jayne 1962, p. 328)

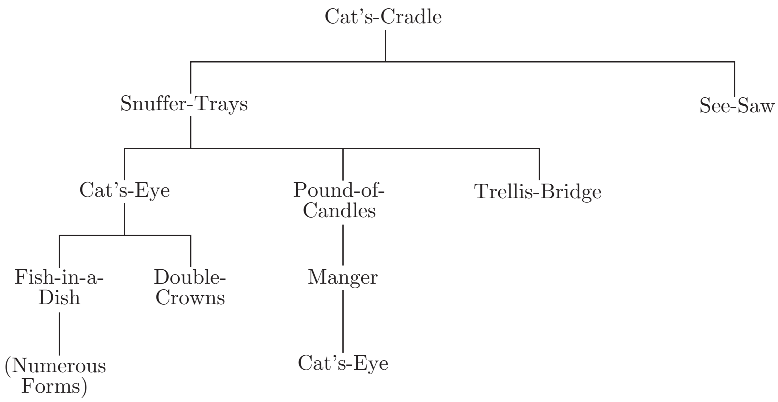


50f – Manger (Jayne 1962, p. 330)



50g – Diamond (Lattice work for Ball) (Jayne 1962, p. 331)

Ball also gives this sequence. But it is worth noticing that each of these three authors has developed a different approach with regard to this sequence. Jayne starts by giving the full sequence, detailing in the end a few possible jumps or returns between two figures of the sequence; in particular, she explains how to obtain Cat's Eye directly from Soldier's Bed (Jayne 1962, p. 336). Pocock describes the full sequence, showing (at each step of the transformation) possible variations that enable to jump directly from one figure to another without following the usual sequence of figures (Pocock 1906a). Ball prefers to begin with offering a global view of the different sequences of figures which can be performed by starting with figure Cat's Cradle. At the end of the section, he thus presents a tree diagram which shows various possible variations on the "normal sequence" of Cat's Cradle (1920a, p. 356). The three figures that can be obtained from Snuffer-Trays (as Ball asserts in the quotation above) can be seen at the third level of this diagram (picture 51).



Picture 51 – Tree diagram: Arborescence of the "Cat's Cradle"

This diagram clearly shows that figure Cat's Eye can be reached by following two different paths, one longer than the other. Ball therefore indicates that a same (final) figure can sometimes be obtained through different procedures.

After having detailed the sequence Cradle—Snuffer Trays—Cat's Eye—Fish in a Dish (i.e. the first branch of the tree diagram), Ball describes the variations in an exhaustive way (Ball 1920a, pp. 350–356). Finally, he indicates a possible method for creating some of the "numerous forms" which can be derived from Fish-in-a-Dish

(Ball 1920a, p. 355). Just as with *Oceanic* type string figures, Ball prompts his reader to imagine new figures, by completing the tree diagram of Cat's Cradle.

Ball ends the chapter "String Figures" by describing some "tricks" (see Footnote 4). I shall not go further into the description of these tricks. Although Ball proposes the beginning of a classification, the point is definitely not to reveal a systematic way of generating these "tricks", which seem to be freely presented here.

4.4.6 Recapitulation

In selecting the procedures to be described in his chapter on string figures, Ball seems to have successively focused on five different aspects:

1. The particular geometrical form of the final figure and its transformations (Diamonds group).
2. The variations that can be produced on string figures either by modification or omission of a few operations (Many Stars group).
3. The "Movement" (sub-procedure) which can be found identically within several string figure processes (*Lem* group).
4. The "Openings" that sometimes appear to be characteristic of a cultural area (Opening A or B, Navaho Opening in Navaho group).
5. The existence of a series of figures and its variations (Cat's Cradle group).

Ball's analysis of the string figures tends to highlight that the creation of such objects can be seen as a "system of transformations". He shows that many procedures can be derived from a single one, either by modifying or by omitting a few operations (which lead to the transformation of the final figure and/or to another "interesting" procedure). Ball also gives the idea that "openings" are the starting point of many possible procedures.

Throughout the whole chapter, the author clearly encourages the reader to experiment this system of transformations, by performing some procedures himself. Ball's intent to make understandable the way a string figure's procedure can be altered aims at encouraging individual investigations that might lead to the creation of new figures. For Ball, it is mainly this potential of creation of original figures that is linked to the notion of *recreational mathematics*.

4.5 The 1920 Lecture

4.5.1 Introduction to the Lecture

The text of the lecture that Ball gave on string figures at the Royal Institution of Great Britain was first published in 1920 in the Proceedings of the Institution.[16]

[16] It was first republished in 1920 in a small booklet entitled *An introduction to string figures* which was to be republished, with some additions, several times under different titles (Ball 1920c). The

Ball started the lecture by presenting “String Figures” as “a world-wide amusement of primitive man” and “being in themselves interesting for most people”. Then, he clearly expressed his intention to demonstrate to his audience “how such figures are actually made”. But before “coming to that”, he said “something about their nature and history” (Ball 1920b, p. 77). After showing the main “movements” involved in the making of string figures,[17] Ball focused on the “nature” of this activity rather than on its “history”. In particular, Ball mentioned its fascinating and theatrical aspects—which he had personally experienced—and he encouraged the audience to do the same:

> These figures, when shown to a few spectators in a room, always prove, as far my experience goes, interesting alike to young and old: but their attractiveness, their fascination I might almost say, is not permanent unless people can be induced to construct them for themselves. I can hardly propose—and that is a difficulty inherent in lecturing on the subject—that for the first time, now and here, without individual help, you should make the designs you will see later. To enjoy the occupation, however, you must be able to make them, and, bold though I may seem, I venture to assert that once you acquire this knowledge you will find pleasure in applying it (Ball 1920b, p. 78).

Finally, Ball claimed that the making of string figures is a pleasant and cheap hobby which can help to pass the time. Moreover,

> the figures are easy to weave, they have a history, and they are capable of numerous varieties. Thus even in England the game may prove well worth the time spent in learning to play it; and admittedly to the very few who travel among aborigines it may sometimes be a real service (Ball 1920b, p. 78).

That last sentence was probably inspired by what Kathleen Haddon had written about this aspect of the question:

> It is moreover, an excellent method of becoming friendly with natives, for who could suspect of guile a man who sits among the children playing a piece of string? (Haddon 1911, p. xvi).

This time, Ball addressed the subject in a different manner than he did in the chapter “String Figures”. In the lecture, he limited his comments to general points concerning the nature of this practice, whereas in the chapter he moves very quickly towards technical aspects such as geographical distribution throughout the world or the terminology worked out by anthropologists. In both cases, Ball used roughly the same ethnographical sources material.[18] But indeed, it is how he laid emphasis on

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1920 lecture was also republished in 1960, in a book entitled *String Figures and other Monographs* (Ball 1920b).

[17] Some comments have been added in square brackets in the text of the lecture published in the *Proceedings of the Royal Institution of Great Britain*. They show that Ball repeatedly illustrated his talk by demonstrating the making of string figures to the audience.

[18] In the 1920 lecture and the Appendix published in the *Proceedings of the Royal Institution of Great Britain*, Ball refers to Haddon and Rivers (1902), Jayne (1962 [1906]), Compton (1919), Landtman (1914), Gordon (1906), Haddon (1911), and also his own sister A. E. Hodder, who collected some string figures in Asia. In the booklet *An Introduction to String Figures*, Ball refers mostly to Jayne and Kathleen Haddon—and sometimes to Compton. He justified his choice by

certain aspects of this practice that makes the difference between the two texts very clear. I have argued that Ball laid stress, in the Chapter "String Figures", on five different technical points directly connected to the procedures and their possible alterations. In the 1920 lecture, Ball suggested three other criteria of classification.

4.5.2 Another Viewpoint on String Figure-Making

As far as I know, Ball is the author of the following criteria of classification. He proposed to divide string figures into three "classes" defined as follows:

> These figures may be divided into three classes α, β, γ according as (α) the production of a design, or (β) the illustration of some action or story, or (γ) the creation of a surprise effect is the object desired; it will be desirable to begin by giving one or two examples of each class (Ball 1920b, p. 78).

In the lecture, Ball did not use the distinction between "string figures" and "tricks", a distinction which is clearly mentioned in the chapter "String Figures". Nevertheless, Class α is actually composed of "string figures", according to Haddon and Rivers' definition (representation of "certain objects or operations" (Haddon and Rivers 1902, p. 147)). To illustrate Class β, Ball chose two procedures called "Man climbing a tree" and "The Yam Thief", both also described in the Chapter "String Figures" and defined as a string figure and a trick respectively. Also, to illustrate Class γ, Ball gave an example of a trick (Lizard twist). Tricks, according to Haddon & Rivers' definition, "are generally knots or complicated arrangements of the string which run out freely when pulled out" (Haddon and Rivers 1902, p. 147). Therefore, they often produce a "surprise effect". So, according to Ball's classes, a trick would often be placed in Class γ. However, although Ball did not mention it explicitly, he gave some examples which demonstrate that these three classes are not mutually exclusive (see below the example of "Lightning").

Even as Ball demonstrated to his audience how some string figures were made, he was mainly concerned with the significance of the figures and the surprise effect that such a procedure may sometimes produce, rather than with the technical operations involved in the making of these figures. Stories which sometimes go with string figures were chosen by Ball as criteria of classification (Class β). String figure "The Head Hunters", introduced above (Sect. 4.4.3.1 *Lem* group), belongs to class β. Ball did not give this example during the lecture to illustrate this class. However, I have pointed out above that, when describing this procedure in his book on recreational mathematics, Ball chose to focus on how the knot is untangled instead of the connection between the story and the string figure. This suggests that "figures" do

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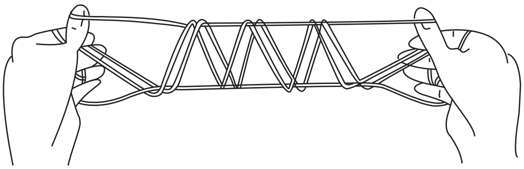
writing: This works by Jayne and Haddon, both excellent, mentioned in my lecture, are more accessible than the articles in which the discoveries of these figures were first announced, and accordingly, I refer, by choice, to these books (in which the sources of information are quoted) rather than to the original memoirs (Ball 1920c, p. 21).

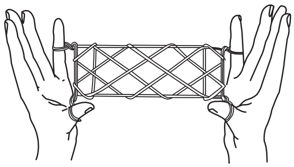
not seem to have the same status in both cases. In the Chapter "String Figures", figures are introduced as the result of a process on which one can act, whereas in the lecture it is the interpretation of the figures that is more precisely discussed.

Ball gave some examples to illustrate string figures of each class. For Class α, he began with string figure "Lightning", which is also described in the Chapter "String Figures" (see above Sect. 4.4.4). By choosing this example, Ball showed that the criteria of classification α, γ are not mutually exclusive. In this case, as the author mentioned, the "production of the design" leads to a "surprise effect".

> The Construction is simple and no digital skill is involved. You see the final result appears suddenly, almost dramatically, and I regard this as an excellent feature of it. Observe also that the production of the figure is rapid. Timing myself, I find I take under ten seconds to make it (Ball 1920b, p. 78).



52a – Lightning (Ball 1920b, p. 78)



52b – A Tent Flap (Ball 1920b, p. 80)

The second example in Class α was "A Tent Flap", which is similar to the figure described as "The Door" in the Chapter "String Figures".[19] However, in his lecture, the speaker introduced this figure (and also the previous one) in a very different manner than he did in his book on recreational mathematics. In the lecture he started with a few ethnographical considerations about the way string figures circulated from one group to another:

> The next diagram as of a design, known as a Tent-Flap or Door due to the Apache Red Indians. [. . .]. The Apache are now almost extinct, but the figure is familiar to the Mexican Indians, who are said to have learnt it from Apaches living on the Reservation Lands maintained by the United Sates Government. This also is a figure in class α (Ball 1920b, p. 80).

In the chapter "String Figures", even though the author mentioned that this figure was known by the Apache, he moves on quickly to technical aspects.

> The first example I will give is a Door [. . .] which comes from the Apache Red Indians. It affords a good introduction to the Oceanic Varieties, for it is one of the easiest figures to construct, as the movements are simple and involve no skill in manipulation (Ball 1911, p. 358).

In the lecture, after explaining the cultural context of the making of this figure, Ball gave a demonstration to the audience. In the published version of the lecture's text, Ball wrote down the same instructions for making it that he had very probably given orally during the lecture (Ball 1920b, p. 80). It is interesting to note that he

[19] See Sect. 4.3.2.

did not use Haddon & Rivers' nomenclature, though he mentioned it later in the course of lecture. The instructions are given without using specific terms, except "Opening A", whereas in the chapter "String Figures" he begins with the description of Haddon & Rivers' terminology and uses it from the very first description. The next four figures displayed during the lecture were described without using technical terms, like the Door had been. This seems to indicate that Ball's intention was definitely different in the lecture than in his book of recreational mathematics: the chapter "String Figures" was aimed at readers interested in mathematical ideas, whereas the lecture (and its published version) was aimed at a wider audience.

The descriptions of Lightning and A Tent Flap were followed by three other procedures, illustrating the criteria of classification β and γ defined above. Then, Ball gave a full historical account of anthropological studies on string figure-making which had been carried out until then. He explained Haddon & Rivers' terminology as related to this history. We have seen that, in the introduction of the chapter "String Figures", Ball proposes "to describe the production of a few of the more common forms", without concerning himself "with their ethnographical aspects" (Ball 1911, p. 348). It is obviously not the case in the lecture's text, from which several anthropological questions arose, as shown in the following extract:

> Of course from the beginning of the study of these figures the question arose of their possible relation to historical and religious traditions. Up to now, however, with the exception of a few isolated facts, no evidence of such connection has been found. Indeed the only traces of it so far recorded are that in New Zealand the forms are associated with mythical heroes, and the invention of the game is attributed to Maui, the first man; that various designs common to many of the Polynesians are often made to the accompaniment of ancient chants; that the Eskimo, too, have songs connected with particular patterns, have a prejudice against boys paying the game for fear it should lead to their getting entangled with harpoon lines and hold that such figures, if made at all, should be constructed in the autumn so as to entangle the sun in the string and delay the event of the long winter night. Further, Boas asserts that among the Kwakiutl of Vancouver Island the form known as "Threading a closed loop" is used instead of a password by members of a certain secret society to recognise fellow-members (Ball 1920b, p. 88).

Nevertheless, according to Ball, in spite of these testimonies, there was (at that time) "no substantial evidence that the construction of string figures is other than a recreation", even though "new discoveries may at any time alter our views on this question" (Ball 1920b, pp. 88–89). Although Ball referred several times to string figures as a "hobby", a "pastime", or an "amusement", he used the term "recreation" only once in the lecture. Of course, it is difficult to say what "recreation" exactly means here. However, we have seen that the "recreational aspect of string figures making" (i.e. learning how to make some "interesting" and complicated figures, searching for and creating new procedures) was absolutely central in *Mathematical Recreations and Essays*.

In the tenth and eleventh editions of the book, Ball did not prompt the reader to try to create new string figures anymore: in these two editions, the chapter devoted to string figures was written down in the spirit of the 1920 lecture, in a very different manner from than in the previous editions.

4.6 To Conclude

4.6.1 The Tenth and Eleventh Editions

In the tenth edition of *Mathematical Recreations and Essays*, Ball decided to "cut down the space" devoted to string figures.

> In the five editions of this work issued between 1911 and 1920 I devoted a chapter of some length to describing the production of string figures. In 1920 I gave an account of the subject in a lecture in London, and this, with the addition of a good many examples, has been issued as a small booklet. That being now available, I propose in this edition to cut down the space devoted to the subject and merely explain the construction of a few typical string forms which may serve as an introduction to that amusement and will, I would fain hope, induce my readers to go further on it (Ball 1922, p. 321).

In this shortened chapter, Ball described some string figures and tricks including Lightning and A Tent Flap. In describing these figures he did not mention nor use Haddon & Rivers' nomenclature. Furthermore, he did not structure this text in the same way as in the first version of this chapter. In fact, Ball no longer focussed on operational aspects of string figures, preferring to concentrate on the division into classes α, β, γ introduced in the 1920 lecture. It was much more a summary of the lecture than a summary of chapter "String Figures" as previously written. So, by "cutting down the space", Ball removed the fundamental mathematical ideas developed in the previous editions (see the Recapitulation above), thus entirely changing his viewpoint. As explained in the above extract, the 1920 lecture was issued as a booklet entitled *An Introduction to String Figures* (Ball 1920c) and republished several times. The booklet develops the lecture's viewpoint on string figures based on classes α, β, γ. As far as I know, the first version of the chapter "String Figures" analysed above was never revised or republished.

After Ball's death, the famous English geometer H.S.M Coxeter edited four posthumous editions of *Mathematical Recreations and Essays*. In the editor's preface to the eleventh edition (Ball 1939), Coxeter explained how he supplemented and reorganized the whole text of the tenth edition:

> In revising Rouse Ball's delightful book, it has been my aim to preserve its spirit, adding the kind of material that he himself would have enjoyed. After consultation with several mathematicians, I have felt it desirable to strike out the fifth, eighth, and fifteenth chapters of the tenth edition (For String Figures, the reader is referred to the ninth or the tenth edition, or the Rouse Ball's little book on that subject.) The twelfth chapter has been broken up and distributed among the first, third, fourth and eleventh chapters (Ball 1939, p. vii).

The fifth chapter of the tenth edition is entitled *Mechanical Recreations*, the eighth, *Bees and their cells*, the twelfth, *Miscellaneous Problems (Continued)* and the fifteenth, *String Figures*. By stressing that the choice of striking out these four chapters resulted from discussions with several mathematicians, Coxeter leads us to think that he selected the chapters which he thought insufficiently connected to mathematics. As for string figures, Coxeter refers to the ninth and the tenth editions in his preface. So he knew that these two editions did not include the same texts on string figures. Did Coxeter read closely the chapter "String Figures" of the ninth edition? We will probably never know. Anyway, the eleventh edition was clearly based on the tenth. In the latter, four chapters had been removed, chapter 12 had been split and divided among other chapters, a new chapter 5 had been added and chapter 14—which deals with cryptographs and ciphers—had been rewritten (Ball 1939, p. vii). As mentioned above, in revising the ninth edition, Ball left out mathematical ideas about string figures. We may assume that Coxeter was not fully aware of the nature of this chapter's previous version, and that it was his reading of the chapter in the tenth edition—in which it has no connection to mathematical ideas—that led him to strike out the chapter on string figures.

4.6.2 String Figures as Recreational Mathematics

The chapter "String Figures" written by Ball seems to be the first attempt made by a mathematician to demonstrate the connection between mathematics and procedural activities such as string figures. Ball does not raise the question, but his presentation is structured in order to make his reader perceive this connection. I have argued that this can be seen on two levels. On the one hand, by focusing successively on different aspects of this practice, Ball shows that string figures deal with concepts such as classification, operation, sub-procedure (movements), and transformation: in this way, he implicitly suggests that this practice can be considered as mathematical. At the other hand, Ball also encourages his reader to practice and create string figures, thus emphasizing the recreational dimension of this practice.

4.6.3 Mathematicians and String Figures

After Ball, a small number of mathematicians worked on the subject of string figures in the twentieth century. In 1965, American algebraist Ali Rina Amir Moez (1919–2007) published a book entitled *Mathematics and String Figures* (Amir-Moez 1965). In this work, Moez studied, using a symbolic approach, a few procedures leading to lozenges in a row.

In the 1990s, a Japanese-Malaysian team of computer scientists—Yamada Masashi, Burdiato Rahmat, Itoh Hidenori and Seki Hirohisa—published some articles on string figures (in Japanese, they are called *Ayatori*). Their aim was to implement different algorithms in order to show the making of string figures on a computer screen, and compare the efficiency of these algorithms. They also established a connection between the making of string figures and knot theory (Yamada et al. 1997).

These formal studies call for description and analysis, which I shall carry out in later works. However, both works by Moez and the Japanese-Malaysian team concentrate on very particular situations and do not seem easy to generalize. Therefore, for the moment, these two formal approaches to string figures do not lead to efficient mathematical tools for studying string figure corpora with the methodology introduced in Part I of this book. To analyse different corpora of string figures in a comparative way, I felt it absolutely necessary to focus on sub-procedures, in an attempt to approach and compare the various methods invented by the practitioners within different societies to create new string figures. My aim has been to reach a better understanding of the way sub-procedures operate on particular states of the string and to be able to describe and analyse the phenomenon mathematically. Working in this direction, I was acquainted with the works of American mathematician Thomas Storer (1938–2006). In 1988, he published a long article on the subject of string figures in which he developed several different mathematical approaches. One of these, the heart-sequence of a string figure, will be of great use to us in the analysis of string figure algorithms.

References

Amir-Moez AR (1965) Mathematics and string figures. Edwards Brothers, Ann Arbor

Alexandre-Bidon D, Lett D (2004) Les Enfants au Moyen Âge, Ve-XVe siècles, Hachette littérature, Paris, 281p

Ball WWR (1888) A short account of the history of mathematics. Macmillan, London. (Fourth edition of 1908 reprinted by Dover publication, 1960)

Ball WWR (1889) The history of the study of mathematics at Cambridge. Cambridge University Press, Cambridge. (Reissued by the Publisher, 2009)

Ball WWR (1891) A Newtonian fragment relating to centripetal forces. Proc Lond Math Soc s1–23:226–231

Ball WWR (1893) An essay on Newton's principia. Macmillan, London/New York. (Reedited by University of Michigan Library, Ann Arbor, 2005)

Ball WWR (1911) Mathematical recreations and essays, 5th edn. Macmillan, London

Ball WWR (1920a) Mathematical recreations and essays, 9th edn. Macmillan, London

Ball WWR (1920b) String figures. Proc R Inst G B 23:77–110. (Reprinted in "String Fgures and other Monographs", Chelsea Publishing, New York, pp 1–72, 1960)

Ball WWR (1920c) An introduction to string figures. W. Heffer and Sons, Cambridge. (Reprinted by W. Heffer and Sons as String Figures, 1921 (2nd edn), 1928 (3rd edn). Reprinted by Dover publications, as Fun With String Figures, New York, 1971, 80p. Reprinted in String Figures and other Monographs, Chelsea publishing, New York, 1960, pp 1–72)

Ball WWR (1922) Mathematical recreations and essays, 10th edn. Macmillan, London

Ball WWR (1939) Mathematical recreations and essays, 11th edn. Macmillan, New York. (Revised by HSM Coxeter)

Ball WWR (1971) Fun with string figures. Dover, New York

Böddicker O (1876) Erweiterung der Gauss'schen Theorie der Verschlingungen. W. Spemann, Stuttgart

Braunstein J (1996) Langages de ficelle: Au fil d'une enquête dans le Chaco argentin. Techniques et cultures 27:137–151

Compton RH (1919) String figures from New Caledonia and Loyalty islands. J R Anthropol Inst G B Irel 49:204–236

Cunnington WA (1906) String figures and tricks from central Africa. J R Anthropol Inst G B Irel 36:121–131

Davidson D (1941) Aboriginal Australian string figures. Proc Am Philos Soc 84:763–901
Gordon GB (1906) Notes on the western Eskimo. Univ Pa Free Mus Sci Art Trans Dep Archaeol II(Part. I):87–97
Gray J (1903) Some Scottish string figures. Man 3:117–118
Haddon AC (1903) A few American string figures and tricks. Am Anthropol 5(2):213–223
Haddon AC (1906). String figures from South Africa. J Antropol Inst G B Irel 36:142–149
Haddon AC, Rivers WH (1902) A method of recording string figures and tricks. Man 2:146–149
Haddon K (1911) Cat's Cradles from many lands. Albert Saifer Publications, Watchung
Hornell J (1932) String figures from Gujarat and Kathiawar. Mem Asiat Soc Bengal 11(4):147–164
Jayne CF (1962) String figures and how to make them: a study of Cat's Cradle in many lands. Dover, New York. (A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York)
Jenness D (1924) Eskimo string figures. Report of the Canadian Arctic Expedition 1913–1918, vol XIII, Part B. F.A. Acland, Ottawa
Landtman G (1914) Cat's cradle of the Kiwaï Papuans, British New Guinea. Anthropos 9:221–232
Listing JB (1847) Vorstudien zur Topologie, part x. Die Studien, Gottigen
Parkinson J (1906) Yoruba string figures. J Anthropol Inst G B Irel 36:132–141
Pocock WI (1906a) Cat's cradle. Folklore 17(n° 1):73–93
Pocock WI (1906b) Some English string tricks. Folklore 17(3):351–373
Rivers WHR (1907) String figures. A study of Cat's-Cradle in many lands. Folklore 18:112–116. (By Caroline Furness Jayne. New york: Charles Scribners's sons, 1906)
Saito T (2004) Ayatori: the traditional string figures of Japan. Bull Int String Fig Assoc 11:1–286
Sherman M (2003) A tribute to John Lyman Cox (1866–1955). Bull Int String Fig Assoc 10:288
Singmaster D (2005) 1892 Walter William Rouse Ball, mathematical recreations and problems of past and present time. In: Grattan-Guinness I (ed) Landsmark writings in western mathematics 1640–1940. Elsevier, Amsterdam, pp 653–663
Storer T (1988) String figures, volume 1. Bull String Fig Assoc 16(Special Issue):1–212
Tait PG (1898) Collected scientific papers, vol. I. Cambridge University Press, Cambridge, pp 273–347
Wate-Mizuno M (2010) Les oeuvres de Konig Dénes (1884–1944) dans le domaine des récréations mathématiques et son traitement de problèmes récréatifs dans se travaux de théorie des graphes. PhD thesis, Paris Diderot University
Whittaker ET (1925) Obituary: W. W. Rouse Ball. Math Gaz XII(178):448–454
Yamada M, Burdiato R, Itoh H, Seki H (1997) Topology of Cat's Cradle diagrams and its characterization using knots polynomials. Trans Inf Proc Soc Jpn 38(8):1573–1582

Chapter 5
Thomas Storer and the Concept of Heart-Sequence

5.1 Storer's Interest in String Figures

Thomas Storer spent most of his career at the University of Michigan in Ann Arbor, teaching mathematics and carrying out research in Combinatorics. Storer was a native American Navajo. He was known as one of the first native American to earn a Ph.D. degree in mathematics and to reach the position of full professor in a major university. Storer was also a string figure enthusiast, member of the International String Figure Association (ISFA, already mentioned above). He learnt his first string figures during his childhood, from his grandmother and friends, and became well acquainted with the subject as is shown by the following extract[1]:

> [. . .], in 1958 – having learned some 20 string-figures from my grandmother (all she knew!) and perhaps, another dozen from my friends while growing up – i discovered the little pamphlet by Rohrbough (ed.): FUN WITH FOLKLORE, with its two figures, Takapau and Brush House, taken from J.C. Andersen: MAORI STRING FIGURES. I could hardly believe my good fortune-that very educated and learned people had actually written about such things-and I devoured all the literature i could get my hands on (Storer 1988, p. iii).

Notice how surprised he is to discover that "very educated and learned people" had written about string figures, even though Storer did not dwell furthermore on that fact. However it is clear that this literature intensified his interest on the subject. Storer strove to acquire a good bibliographical knowledge of the topic. And so, in 1985, he published the first edition of *String Figure Bibliography* in the *Bulletin of ISFA*.[2] His interest in string figures made him endeavour to get a better understanding of the phenomenon.

[1]For unknown reason, Storer wrote "i" instead of "I" as the first personal pronoun.

[2]Two other editions followed in 1996 and 2000.

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_5

> After learning my thousandth or so figure, i began searching for a book or article which spoke to the beautiful "system" which i dimly apprehended underlying these disparate string-figures - to no avail. The wordy ramblings of collectors were too imprecise to satisfy, and topological Knot-Theorists apparently dismissed the entirety of the string figures of the world as "trivial". And, although i learned a great deal from both groups of writers, i hungered for an approach which was neither too weak to be effective, nor so powerful that it identified (and as "trivial", at that) all the objects of my insatiable interest. And, since such work still does not exist, to my knowledge, i have decided to write one, chronicaling my development of such a system over the ensuing years (Storer 1988, p. iii).

During a sabbatical year in 1988, Storer spent hours to carry out such approach on string figures.[3] This led him to publish a long paper entitled *String-Figures* in the *Bulletin of the String Figure Association* (Storer 1988). As the foreword to the article clearly shows, Storer was convinced of the existence of a "structure" underlying the set of all string figures. His project was obviously to work out formal tools to bring some light on this underlying "Structure".

> The purpose behind these researches is twofold: 1). To explicate the "structure" underlying the set of all string-figures by exploring their interrelations, and 2). "to conserve" string figures uniquely, in a manner not heretofore possible, through the development of an unambiguous formal language for their discussion (Storer 1988, p. i).

To carry out this project, the mathematician developed different formal approaches on string figures. Storer has created three conceptual tools which are presented in the first part of his paper under the title "Systemology". Then, in the next four parts, using these conceptual tools, Storer carries out a deep analysis of the making of four string figures. For each of them, he explores their interrelations with other string figure procedures. Working in this way, Storer introduces a methodology which could help us, in the long term, to "explicate the *structure* underlying the set of all string-figures".

5.2 Storer's Systemology

Storer's formal approach on string figures tackles two different problems.

> In order to discuss string-figures in an unambiguous way, we must address two problems: 1) Description of the final (and intermediate) positions [of the string], and 2) Method of construction, i.e. how to proceed from one position to the next. The former [problem], itself, has two aspects: 1a. The string's interrelationships to itself, i.e. internal crossings, loopings, etc., and 1b. the string's relationship to the supporting frame (usually the hands). (Storer 1988, p. 1)

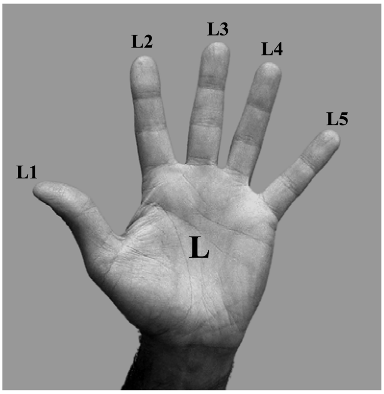
[3]This point is not mentioned in the article (Storer 1988); it was written by Storer's wife, Karen Storer, in her introduction to the article "Someone who Loved the String: A tribute to Tom Storer" (Sherman 2007) by Mark Sherman.

Storer tackles the problem of the description of the string's final (and intermediate) positions during the process by using "Diagrams of Knots". Moreover, he introduces a methodology called "Crossing-Analysis" to carry out a step-by-step analysis of the crossings' creation. Concurrently, the mathematician creates a formal language, called "Calculus for string figures", which allows to write down symbolically the complete process of the making a string figure, from the Opening to the final figure. Storer describes his calculus as a "functional language" since it is based on "the classical function notation of Mathematics/Symbolic Logic" (Storer 1988, p. ii).

In the following sections, I will describe briefly Storer's Crossing-Analysis and the associated concept of "Linear-Sequence". Then, we will turn to a brief description of the Calculus for string figures. Finally, I will show how Storer adapted this formal language to introduce the concept of "Heart-sequence" of a string figure.

5.2.1 Labelling the Functors

In Storer's "Systemology", fingers are numbered from 1 (thumb) to 5 (little finger). R, L and B indicate "right hand", "left hand" and "Both hands" respectively. In this way, $R1$ is the notation of the right thumb, whereas $L2$ denotes the left index.



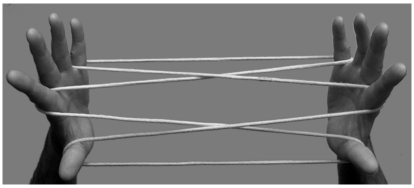
53 – Fingers numbered from 1 up to 5

The ten fingers are sometimes helped by the mouth (M), a big toe (T) or a wrist (W). They are all termed "Functors" by the mathematician.

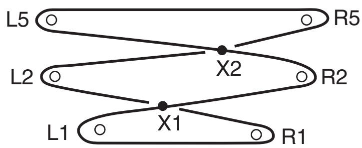
Summary table—functors	
Symbols	Definition
1	Thumb
2	Index
3	Middle finger
4	Ring finger
5	Little finger
Ri	ith finger of the right hand
Li	ith finger of the left hand
R, L, B	Right hand, left hand, both hands
M	Mouth
T	Great toe
W	Wrist

5.2.2 Crossing-Analysis and Linear-Sequence

Storer was certainly inspired by the methods of knot theory when he gave a method for describing string figure-making, using plane-projections of the main intermediate positions of the string during the process. For each step of the procedure, Storer draws the regular plane-projection of the knot which is formed around the fingers represented by dots. The projection is "regular" i.e. it does not contain any double-point. Picture 54b show the regular projection of the configuration obtained after Opening A.



54a – Configuration obtained thanks to Opening A

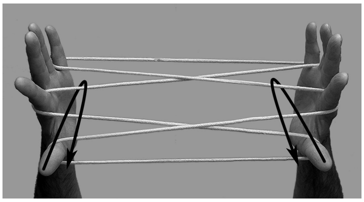


54b – Projection of the configuration obtained after Opening A. x1 and x2 are the crossings (Storer 1988, p. 30)

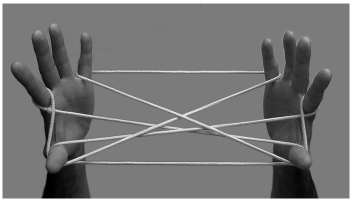
To each regular plane-projection Storer associates a "linear-sequence": the idea is to follow the string, starting from a dot (say $L1$), noting every crossing and dot encountered during the "tour". At every crossing, it is indicated whether we are on the string either "Over" ($\varnothing$) or "Under" (U) the other crossing string. For instance, the linear-sequence of the configuration obtained through Opening A is the following:

$$L1 : x1(\varnothing) : R2 : x2(\varnothing) : L5 : R5 : x2(U) : L2 : x1(U) : R1$$

Storer begins to observe how the associated linear-sequence changes from one step to another. For instance, let us consider the regular projection of the configuration obtained under the first step of the Solomon string figure *Niu* already described in Chap. 3 (Sect. 3.1.1). Remember that this first step consists in picking up the ulnar index string with the thumbs and return to position (pictures 55a and 55b).

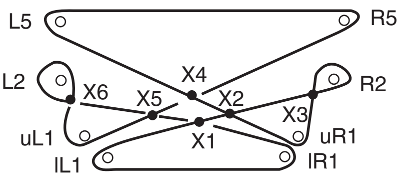


55a – Thumbs pick up the ulnar index strings

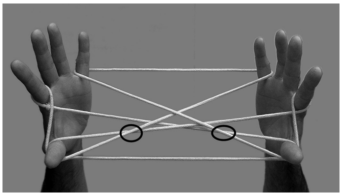


55b – Thumbs return to position

Picture 55c below shows the regular projection sketched by Storer.



55c – The regular projection of Niu-Step 1 (Storer 1988, p. 31)



55d – Crossings which do not appear in the projection drawn by Storer

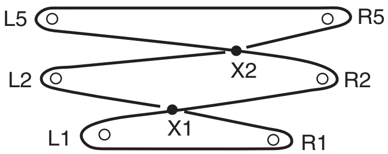
Storer doubles the dots when two loops are carried by a single finger: one dot corresponds to the "lower" (ℓ) loop and the other to the upper (*u*) one. This convention is the reason why certain crossings between the strings of the lower loop and the upper one "disappear" in the projection. For instance, in the case of the projection of *Niu*—step 1, there are two such crossings indicated in picture 55d above. The linear-sequence of this configuration becomes:

$\ell L1 : x1(\varnothing) : x2(U) : x3(U) : R2 : x3(\varnothing) : uR1 : x2(\varnothing) : x4(\varnothing) : L5 : R5 : x4(U) : x5(\varnothing) : uL1 : x6(\varnothing) : L2 : x6(U) : x5(U) : x1(U) : \ell R1$

By drawing the projections and writing the associated linear-sequences of the main intermediate configurations in a string figure-making process, Storer shows that one can observe, at each successive stage, the appearance or cancelation of the simple crossings xi. This is called "crossing-analysis". Moreover, the mathematician demonstrates that a simple crossing can be either

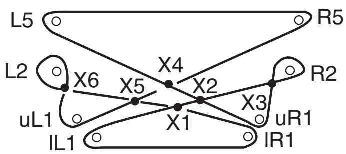
– Extension cancellable, in the sense that it disappears under an extension of the string.
– Constructional crossing (C-crossing), in the sense that it is necessary for the construction but "disappears" during the process (Storer makes the analogy with the "scaffolding of a building under construction").

– Structural crossing (S-crossing), in the sense that it "appears" in an intermediate string-position that maintains himself to the final string-position in the sequence i.e. the final figure's regular projection.



56a – Fig. I

→



56b – Fig. II

Storer's figures above show the appearance of four new crossings (pictures 56a and 56b). A crossing may have different names from one stage to another. For instance, from Fig. I to Fig. II, we see that $x1$ is invariant and $x2$ becomes $x4$.

Fig. I	→	Fig. II
$x1$	→	$x1$
$x2$	→	$x4$

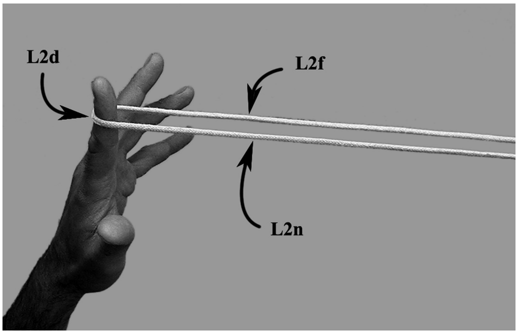
Storer demonstrates that, in some cases, it is possible to yield the linear-sequence of the regular projection at a step n by operating on and transforming the linear-sequence of the previous step $n - 1$. In particular, he states some results about cancellable crossings that can be formally identified by reading the linear-sequence.

The viewpoint "regular - projection, crossing-analysis and linear-sequence" offers certainly an interesting direction to follow. However, for the moment, it is not a relevant tool to study string figure corpora in a comparative way. Indeed the "crossing-analysis" is made thanks to many hand-made drawings. Therefore, Storer himself did not use this method systematically, but only on some well-chosen string figures. It is most likely that the automation of regular-projection sketching, using computers, could help to investigate the corpora of string figures. However, the conception of such a program raises many complex technical questions, and I shall explore it in a future publication.

5.2.3 Labelling the Objects

Storer's Calculus for string figures is based on the functional notation $F(x)$. F represents the Functors which are either fingers $\{R1, \ldots, R5, L1, \ldots L5\}$, mouth (M) or great toe (T). The Functors operate on x which symbolizes either strings or loops, called "Objects". Before turning to the description of the Calculus we need to see how the Objects are symbolized. The Objects are separated into two groups: Strings and Loops.

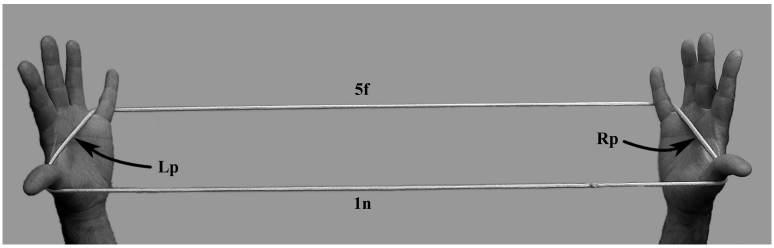
Storer denotes a loop by using the symbol "∞". When $i \in \{1, 2, 3, 4, 5\}$, $Li\infty$ symbolizes a loop made on the ith finger of the left hand (for example, the loop in picture 57 is noted $L2\infty$). In the same way, $Ri\infty$ defines a loop made on the ith finger of the right hand. The string making the loop is divided into three parts. The one which lies on the "dorsal" side of the finger is written symbolically Rid or Lid for a loop made on the ith finger. The "near" string of a loop is the string closest to the practitioner. The other one is referred to as the "far" string. The notations are the following:



57 – $L2\infty$ and its strings

- Rin: right near string on the ith finger
- Rif: right far string on the ith finger
- Lin: left near string on the ith finger
- Lif: left near string on the ith finger

In "Position I", a left and right palmar string (string which lies on the palm of the hand) are created (picture 58). These two palmar strings will be denoted Lp and Rp.



58 – Position I

As shown in picture 58, the string connecting $L5f$ to $R5f$ and the one between $R1n$ to $L1n$ are simply noted $5f$ and $1n$ respectively.

Summary table—objects	
Symbols	Definition
Loops	
$Li\infty$	Loop carried by ith finger of the left hand
$Ri\infty$	Loop carried by ith finger of the right hand
$W\infty$	Loop on the wrist
Strings	
Lif	Far string of the loop carried by the finger Li
Rin	Near string of the loop carried by the finger Ri
Lid	Dorsal string of the loop carried by the finger Li
if	Entire string encompassing the connected Lif and Rif
in	Entire string encompassing the connected Lin and Rin
Rp	Right palmar string
Lp	Left palmar string

It frequently happens that several loops are carried by the same finger. In such a case, Storer uses the following notations: "If, in a given string position the generic finger, F, has the generic natural number n loops we name these—beginning at the base of F and proceeding to the tip—as follows:" (Storer 1988, p. 21). Then, the following table is drawn.

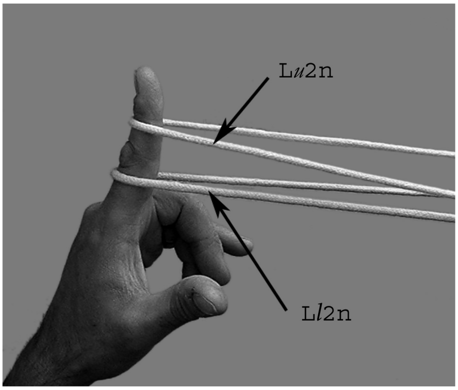
$\underline{n}$	$\underline{F\infty's}$
1	$F\infty$
2	$lF\infty, uF\infty$
3	$lF\infty, mF\infty, uF\infty$
4	$lF\infty, m_1F\infty, m_2F\infty, uF\infty$
5	$lF\infty, m_1F\infty, m_2F\infty, m_3F\infty, uF\infty$
.	
.	
.	
n	$lF\infty, m_1F\infty, m_2F\infty, \ldots, m_{n-2}F\infty, uF\infty$

59 – Three loops on $L2$

The symbols *l, u, m* are used as the abbreviation of *lower*, *upper* and *median* respectively. However, I did not find, neither in the anthropological literature nor in my own fieldwork findings, a configuration in which a finger carries more than 3 loops. Storer makes the same observation:

> We remark that we know of no string-position arising from a native culture in which $n > 3$ and the loops must be kept distinct; with $n = 3$, [...]. The notation above, however, is sufficiently general to allow for that possibility, or to allow for modern invention (Storer 1988, p. 22).

Storer utilizes the same symbols *l, u* and *m* to differentiate the different strings that run from one given finger. For instance, when the index finger $L2$ carries two loops, two different near strings start from this finger. They will be noted $Ll2n$ and $Lu2n$ (picture 60).



60 – Lower and upper left index near strings

Objects and Functors are now well defined. The Calculus for string figures consists in a symbolization of the elementary operations seen as a given Functor (fingers, mouth, feet) operating on one Object (string, loop). Functional notation $F(x)$ is then used to stress that it is Functor F which operates on Object x.

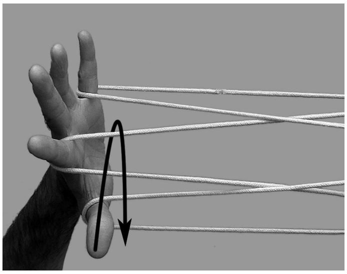
5.2.4 A Functional Language: The Calculus for String Figures

5.2.4.1 Elementary Operations "Picking Up"

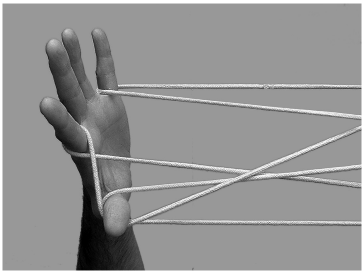
The operation "Picking up" is encoded by applying the following definition:

- $\overrightarrow{F}(\underline{s})$ means: pass the functor F (one particular finger) away from you and over all intermediate strings (if any)—action symbolized by $\overrightarrow{F}$—and pick up from below the string s.

The fact that string s is picked up from below is symbolized by the bar under the letter s. Very often the functor returns to position after operating: # is the symbol used by Storer for the operation "replacing hands in normal position, palms facing one another, fingers pointing up". In the example illustrated below, the left thumb $L1$ passes over the left index near string $L2n$ and picks up from below the left index far string $L2f$. Then, the left thumb $L1$ returns to position (pictures 61a and 61b). This sequence is noted $\overrightarrow{L1}(\underline{L2f})$ #.

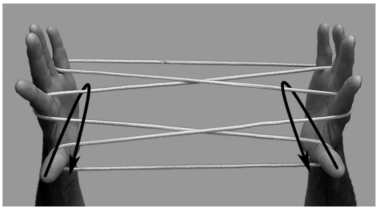


61a – $L1$ passing over $L2n$ then picking up $L2f$

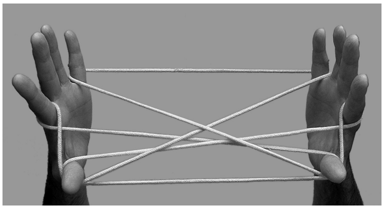


61b – $L1$ returning to position

Since the same operations are very frequently done simultaneously and symmetrically by the right and left hands, Storer gives a symbolic notation for this situation. In pictures 62, the symmetrical and simultaneous operations on the left and the right hands are then noted $\overrightarrow{L1}(\underline{L2f})$ # and $\overrightarrow{R1}(\underline{R2f})$ # respectively. These operations are simply written $\overrightarrow{1}\,(\underline{2f})$, considering that "1" indicates both right and left thumbs operating simultaneously and symmetrically.



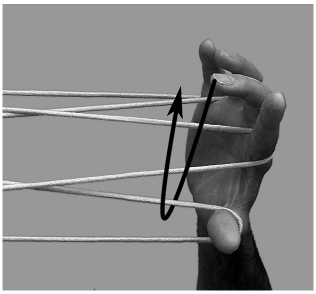
62a – 1 passing over $2n$ then picking up $2f$



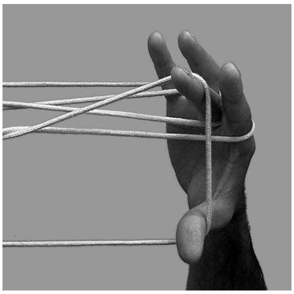
62b – 1 returning to position

- $\overleftarrow{F}\,(\underline{s})$ means: pass the functor F towards you over all intermediate strings (if any)—action symbolized by $\overleftarrow{F}$—and pick up from below the string s.

For instance, in pictures 63a and 63b, the right middle fingers can be seen coming towards the practitioner, passing above both $R2f$ and $R2n$ (so above $R2\infty$), picking up $R1f$ and then returning to initial position.



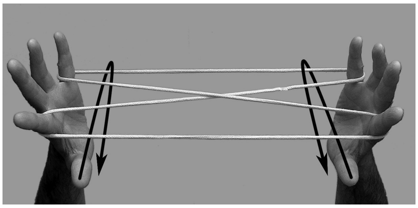
63a – $R3$ passing above 2∞ and picking up $R1f$



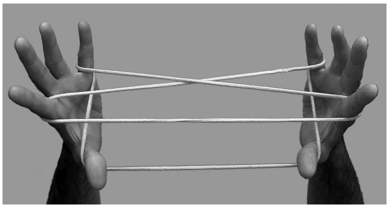
63b – $R3$ returning to position

Storer encodes this succession of operations $\overleftarrow{R3}(\underline{R1f})$ #. Once again, if this operation is applied to both hands simultaneously, the sequence is simply written down $\overleftarrow{3}\,(\underline{1f})$ #.

In the same way, $\underset{\rightarrow}{F}\,(\underline{s})$ and $\underset{\leftarrow}{F}\,(\underline{s})$ mean: pass the functor F under all intermediate strings (if any) away from you or respectively towards you, and pick up from below the string s. For instance, in pictures 64a and 64b, $R1$ and $L1$ pass under 2-loops ($R2\infty$ and $L2\infty$ respectively) then under the $5n$-strings ($R5n$ and $L5n$ respectively), and pick up $5f$-string from below returning to initial position: symbolization will be $\underset{\rightarrow}{1}\left(\underline{5f}\right)$ #.

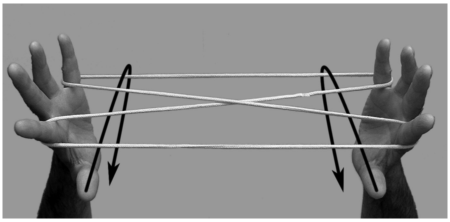


64a – 1 passing under 2∞ and 5n then picking up $5f$

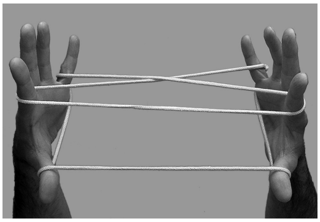


64b – 1 returning to position

When a string is taken up from above, a bar is placed over the letter s. This corresponds to the elementary operation that anthropologists have usually termed "hooking up". In pictures 65a and 65b, the thumbs pass under 2-loops and $5n$-strings, then hook up from above $5f$-strings. In this situation the encoding will be $\underset{\rightarrow}{1}\left(\overline{5f}\right)$ #.



65a – 1 passing under 2∞ then hooking up $5f$



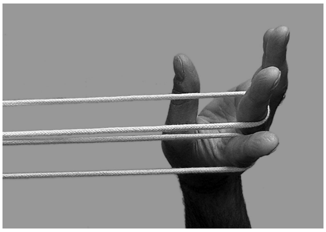
65b – 1 returning to position

5.2.4.2 Operation "Passing a Functor over or Under Several Strings"

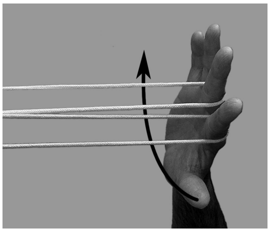
When a given functor F has to pass either *over* or *under* several strings, Storer adopts the following symbolism:

$\overrightarrow{F}(s)$, $\underset{\rightarrow}{F}(s)$, $\overleftarrow{F}(s)$ and $\underset{\leftarrow}{F}(s)$, derived from the one previously used for the operations "picking up", by deleting the bar over or under the Object s.

For instance, $\underset{\rightarrow}{F}(s)$ means: pass the functor F away under all strings up to and including the string s. In pictures 66a and 66b, the right thumb $R1$ passes under all strings up to and including $R3f$. This operation is encoded $\underset{\rightarrow}{R1}(R3f)$.



66a – $R1$ passing under all strings up to and including $R3f$



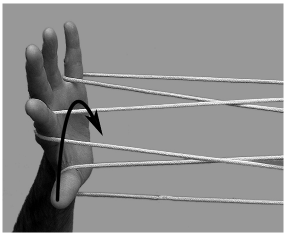
66b – Done

5.2.4.3 Operation "Inserting"

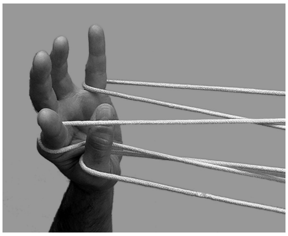
Operation "inserting" (a finger into a loop) is written down as follows:

- $\overrightarrow{F} \downarrow (\infty)$ means: pass the functors away from you—over all intermediate strings (if any)—and insert it downwards into the loop (action symbolized by the arrow $\downarrow$ pointing down).

In the next example (pictures 67a and 67b), the left thumb is inserted from above into the left index loop: $\overrightarrow{L1} \downarrow (L2\infty)$.



67a – $L1$ inserted from above into $L2\infty$

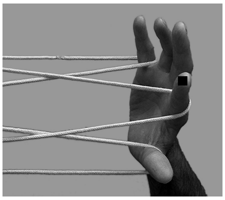


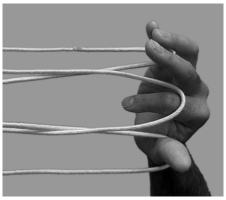
67b – Done

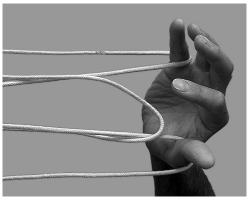
Obviously, there are seven more situations given by: $\overrightarrow{F} \uparrow (\infty)$, $\overleftarrow{F} \downarrow (\infty)$, $\overleftarrow{F} \uparrow (\infty)$, $\underset{\rightarrow}{F} \uparrow (\infty) \ldots$

5.2.4.4 Operation "Releasing"

When the ith finger of the right or left hand carries a single loop, the operation of "releasing" this loop is symbolized by $\square Ri\infty$ or $\square Li\infty$.


68a – Releasing $R2\infty$


68b


68c – Done

As with operations "picking up", "hooking up" and "inserting", not indicating Left or Right (L or R) means that the same operation has to be done simultaneously on both hands. In such a way, $\square i\infty$ indicates the release of both Ri and Li single loops.

When the ith finger of a hand carries more than one loop, the release of a specific loop is written $\square xRi\infty$ or $\square xLi\infty$ with $x \in l, m, u$. Moreover, the notation $\square F$ is used when a functor F (including Mouth, Great toe, Wrist) has to release all of its loops. So, $\square F$ and $\square F\infty$ are equivalent when F carries exactly one loop.

5.2.4.5 Operation "Extending"

The bar "|" indicates that the hands have to move apart in order to absorb the slack on the string. This movement corresponds to an operation that I have called "extending" (the string).

5.2.4.6 Openings

The openings are noted $\underline{O}$. For instance, Opening A is encoded $\underline{O}.A$.

5.2.4.7 Recapitulation

Summary table

Operations	Symbols	Definition
Picking up	$\overrightarrow{F}(\underline{s})$	Pass F away from you—over all intermediate strings (if any) and pick up from below the string s
Passing over/under	$\underleftarrow{F}(s)$	Pass F towards you under all strings up to and including the string s
Returning	#	Replace the hands in normal position, palms facing one another, fingers pointing up
Inserting	$\overrightarrow{F}\downarrow(i\infty)$	Pass F away from you–over all intermediate strings (if any) and insert it downwards into $i\infty$
Releasing	$\square i\infty$ *or* $\square i$	Release both loops $i\infty$
Extending	|	Extend the string

5.2.5 String Figure Process as a Single Formula: The Example of Niu

In order to illustrate the use of this formal language, Storer refers to a string figure named Brokhos which could be, according to him, the oldest string figure known in Western literature.[4]

> The oldest known string figure in western literature is attributed to the Greek Heraklas, about the first century A.D., in a manuscript entitled "Brokhos". And, although the original work did not survive, it is extensively cited in the medical treatise "Iatrikon Synagogos" by one Oribasius of Perganum[5] (Storer 1988, p. 49).

The string figure chosen by Storer is indeed very close to the Solomon string figure *Niu* previously introduced in Chap. 3. Therefore, I shall continue my discussion by writing down Storer's Calculus formula of this particular string figure. I will not quote again the exact instructions given by Honor Maude. Instead I will introduce a more formal nomenclature based on it and largely inspired by the terminology used by members of the International String Figure Association (ISFA).[6] The idea is roughly to make the instructions more concise, using Storer's notation of "functors" and "objects". This way to present instructions for string figure-making is explained in detail in the accompanying website.

Step 1: Opening A (picture 69a).

Storer's Calculus: $\underline{O}.A$

Note on the terminology: Remember that Honor Maude used the expression "distal to" and "proximal to" as abbreviations of "from distal side of" and "from proximal side of" respectively. These two expressions later became the adverbs "distally" and "proximally". Here (when fingers are pointing up), "distally" is equivalent to "from above".

Step 2: Distally, insert 1 into 2 loops. 1 pick up $2f$. 1 return to position (picture 69b).

---

[4]I will not discuss here this hypothesis. The reader will find interesting discussions about this hypothetical oldest description of a string figure, in a paper by Lawrence G. Miller entitled "The Earliest(?) Description of a String Figure" (Miller 1945), and in an article by Joseph D'Antoni entitled "Plinthios Brokhos, The Earliest Account of a string figure construction" (D'Antoni 1997). In these papers, both authors interpreted a description of a Brokhos (Greek word for bandage noose) called Plinthios, which is a knotting procedure leading to a rhomboidal shape. The discussion is based on a literal translation of Bussemaker and Daremberg's French translation (Bussemaker & Daremberg, *Oeuvre d'Oribase*, Paris, 1862, 6 volumes) of the original Greek text by Oribasius, of which the oldest extant copy is the Laurentian Library MS. 74.7, sometimes called Codex of Nicetas. Storer asserts that "we cannot know [for certain] Heraklas' method of construction" and does not actually follow the interpretation of these authors. Therefore, Storer gives another construction which leads to a similar rhomboidal design that he certainly thought more accurate for his discussion.

[5]Storer refers to C.L. Day, Quipus and Witches Knots, p. 124, where this figure appears as n°13, the "4-loop Plinthios Brokhos" or "4-loop bandage noose".

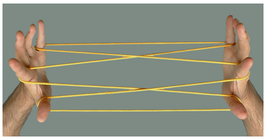
[6]See the web site of the association: http//www.isfa.org

Storer's Calculus: $\overrightarrow{1}\left(\underline{2f}\right)\#$

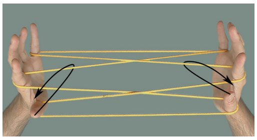
Storer used a colon to connect two consecutive operations. So, the two previous stages putting together will be encoded $\underline{O}.A : \overrightarrow{1}\left(\underline{2f}\right)\#$

Step 3: Proximally, insert 3 into proximal 1 loops.[7] 3 pick up proximal $1f$. 3 return to position (picture 69c).

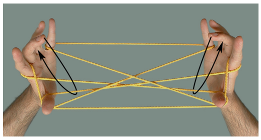
Storer's Calculus: $\overleftarrow{3}\left(\underline{l1f}\right)\#$



69a



69b



69c

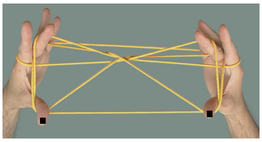
Step 4: Release 1 and extend (picture 69d).

Storer's Calculus: $\square\, 1\ \ |$. These third and fourth steps put together can be written: $\overleftarrow{3}\left(\underline{l1f}\right)\# : \square\, 1\ \ |$

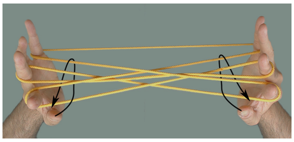
Step 5: Distally, insert 1 into 2 loops. 1 pass proximal to 3 loops. Proximally, insert 1 into 5 loops. 1 pick up $5n$ and return to position (picture 69e).

These operations are symbolized by: $\overrightarrow{1} \downarrow (2\infty)\ :\ \underset{\rightarrow}{1}\ (\underline{5n})\ \#$

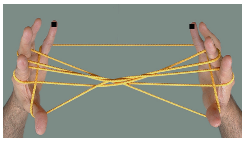
Step 6: Release 5 and extend (picture 69f).



69d



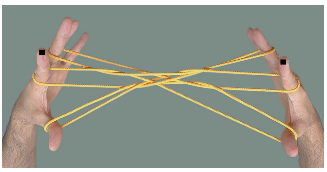
69e



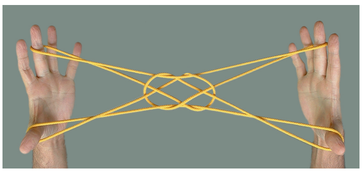
69f

Step 7: Release 2 and extend (pictures 69g and 69h).

The last two stages are noted: $\square\, 5\ |\ \square\, 2\ \ |$



69g



69h – Final figure of *Niu*

[7]The expression "Proximal 1 loops" means "both (right and left) lower 1 loops" symbolized $l1\infty$ by Storer.

The complete formula of *Niu* is then given by:

$$\underline{O}.A\ :\ \overrightarrow{1}\left(\underline{2f}\right)\#:\ \overleftarrow{3}\left(\underline{l1f}\right)\#:\square 1\mid\ \overrightarrow{1}\downarrow(2\infty)\ :\ \underset{\rightarrow}{1}\,(\underline{5n})\ \#:\square 5\mid\square 2\ \mid$$

José Braunstein's viewpoint on string figures (see Chap. 3), can be connected to the Calculus for string figures. I argued that Braunstein sequential viewpoint can be related to the way practitioners often give rhythm to string figure-making process. Moreover—and perhaps for that reason—the "passages" between two returns in "normal position" often correspond to the "steps" of construction noted by the ethnographers in their publication (e.g. Steps 1–7 in the case of *Niu* above). Remember that "|" indicates that the hands are extended to absorb the slack on the string and "#" means "return to position". Therefore both symbols | and # in Storer's Calculus formulae indicate the return in normal position.

$$\underbrace{\underline{O}.A}_{Step\ 1}\ :\underbrace{\overrightarrow{1}\left(\underline{2f}\right)\#}_{Step\ 2}:\ \underbrace{\overleftarrow{3}\left(\underline{l1f}\right)\#}_{Step\ 3}\ :\ \underbrace{\square 1\mid}_{Step\ 4}\underbrace{\overrightarrow{1}\downarrow(2\infty):\underset{\rightarrow}{1}\,(\underline{5n})\ \#}_{Step\ 5}:\ \underbrace{\square 5\mid}_{Step\ 6}\underbrace{\square 2\ \mid}_{Step\ 7}$$

Let us now turn to the third formal tool introduced by Storer. The functional form of the Calculus for string figures was used "by direct analogy", according to Storer's own words (Storer 1988, p. 27) to create another formal language allowing to write down what he called the "Heart-sequence" of a string figure.

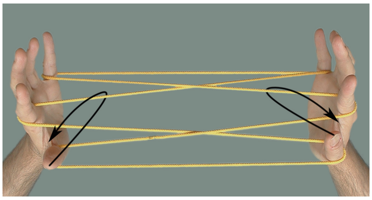
5.2.6 *Heart-Sequence of a String Figure*

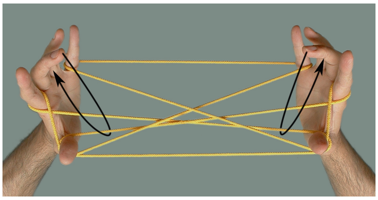
The idea is to focus on the movements of the "loops" without taking into account the way the fingers operate on them. Storer points out that many string figures all over the world can be seen as the result of sequences of operations implemented on the "loops", such as the insertion of a loop into another, or the rotation of a loop. In other words, if one had the opportunity to perform a string figure in the dark with a fluorescent string, the movements of the string could be summarized in a certain number of such operations on the loops. By focusing on these movements during the process, and by converting them into a mathematical formula, the heart-sequence gives, in that sense, a "topological" view of a string figure algorithm. This conceptual tool turned out to be of fundamental importance in shedding light on certain phenomena which occur frequently in the corpora of string figures. Before turning to that point (in Part III), let me precisely introduce Storer's heart sequence.

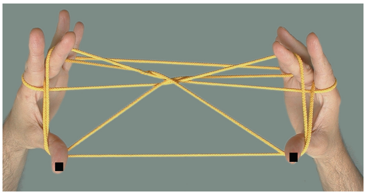
5.2.6.1 Heart-Sequence of *Niu*

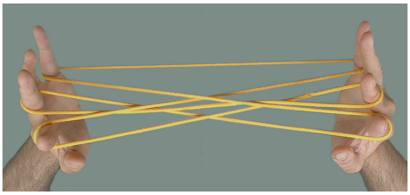
As seen above, procedure *Niu* begins with Opening A. The symbolism $\underline{O}.A$ introduced in the Calculus for string figures is also used for the writing of Heart-sequences. Let us remind the four first steps of *Niu*:

Step 1: Opening A
Step 2: 1 pick up 2 and return (picture 70a).
Step 3: 3 pick up proximal (lower) 1 far and return (picture 70b).
Step 4: Release 1 and extend (pictures 70c and 70d).

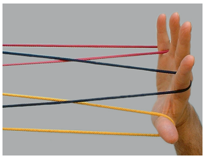

70a

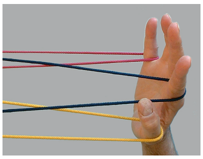

70b

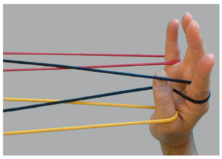

70c

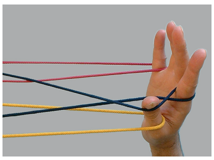

70d

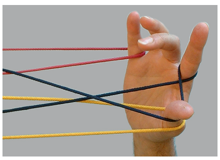
In steps 2–4 taken together (pictures 70a–70d), focusing on what happens to the previous thumb loops (1∞), it can be seen that these loops pass from above through the index loops (2∞), and are transferred to the middle fingers. Pictures 71a–71i show this passage, displaying the movements of the right hand loops. We can distinctly see that the operations performed by $R1$ and $R3$ on the string causes the passage of $R1$ loop (yellow one) from above through $R2$ loop (black one).

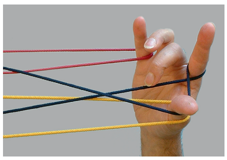

71a

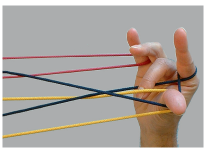

71b

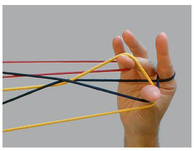

71c

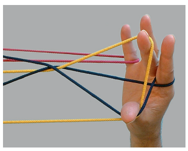

71d

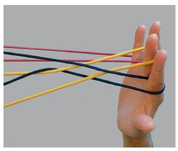

71e


71f


71g


71h


71i

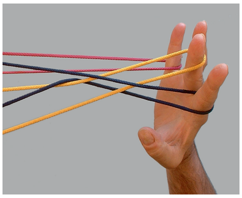

71j

The release of the thumbs in step 4 (pictures 71c and 71d) entails that the yellow thumb loops (1∞) are finally transferred to the middle fingers (pictures 71i and 71j). So, we observe that the previous $R1$ loop (yellow) has been passed from above through $R2$ loop (black) and it is carried by and is transferred to $R3$ at the end of the process. The yellow loop's motion can be summarized by the diagrams in pictures 72a and 72b:

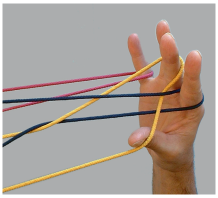
72a – Initial Position

72b – Done

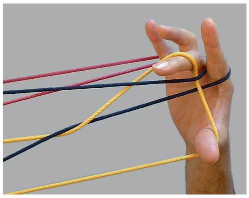
To convince the reader that such is the case, let us pass $R3$ loop (yellow one) from below through $R2$ loop using $R1$, as shown in pictures 73a–73e, thus showing that it is the inverse operation, in the sense that it will take us back to the position following Opening A.



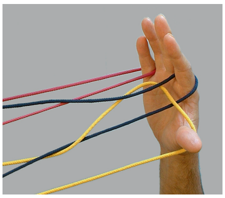
73a



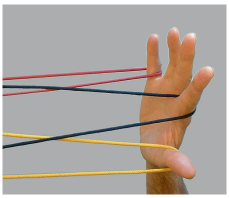
73b



73c



73d



73e

The movement of passing 1∞ from above through 2∞ is noted: $\overrightarrow{1\infty} \downarrow (2\infty)$, using a similar symbolism than the one introduced above for the insertion of a finger (functor) into a loop. In the formula, the functor has been replaced by a loop (1∞)

which operates on another loop (2∞). Furthermore, the arrow pointing right over the symbol 1∞ will mean that loops 1∞ pass "away from" the practitioner and "over" all intermediate strings (none here). Moreover, the arrow pointing down indicates the insertion from above of 1∞ through 2∞.

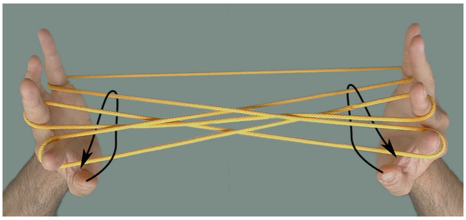
To indicate that 1∞ is finally transferred to the middle fingers, Storer notes $\underrightarrow{1\infty} \to 3$ which is defined as follows: "pass 1∞ *away* and *under* all intermediate strings (if any) and place it, as a loop, directly upon 3". The arrow pointing right under the symbol 1∞ is chosen here since just after the insertion through 2∞ (black), 1∞ (yellow) have to pass under (proximal to) the far index strings $2f$ before being transferred to the middle fingers. So, focusing on the motion of 1∞ the four first steps of *Niu* can be summarized as:

$$\overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \to 3$$

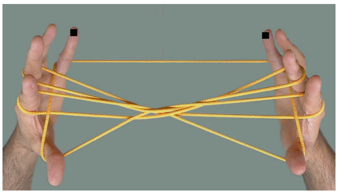
5.2.6.2 The Three Next Steps of *Niu*

With the same point of view, the fifth and the sixth steps show a displacement of little finger loops 5∞. It can be seen that the loops carried by the little fingers go through the index loops (this time from below), then is transferred to the thumbs.

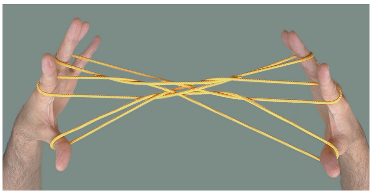
Step 5: Distally, insert 1 into 2 loops. 1 pass proximal to 3 loops. Proximally, insert 1 into 5 loop and pick up $5n$ and return (picture 74a).
Step 6: Release 5 (pictures 74b and 74c).



74a

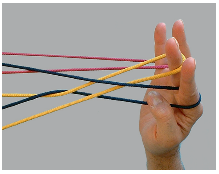


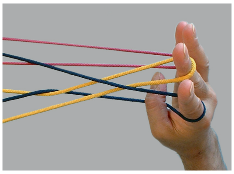
74b

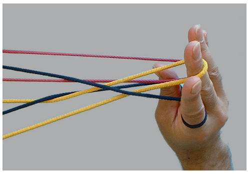


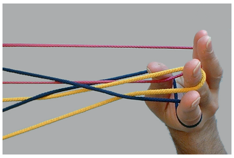
74c

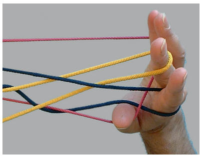
Let us focus on what happens to the original little finger loops (5∞) (red one—pictures 75a–75g).

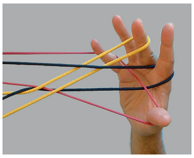

75a

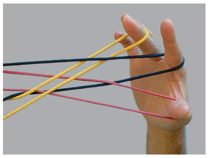

75b


75c


75d


75e


75f


75g

We can see that the loops carried by the little fingers (5∞) pass towards the practitioner under all intermediate strings (here $3n$ and $3f$) and go from below through the index loops. This will be encoded: $\underleftarrow{5\infty} \uparrow (2\infty)$.

In the latter formula, the arrow pointing left under the symbol 5∞ indicates that both 5∞ have to move towards the practitioner and under all intermediate strings (if any). Furthermore, the arrow pointing up indicates the insertion from below of 5∞ through 2∞.

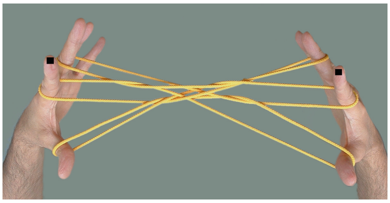
After this passage, the loops 5∞ are finally transferred to the thumbs. Storer gave the notation $\overleftarrow{5\infty} \longrightarrow 1$ which means: "pass 5∞ towards you over all intermediate strings (if any) and place it, as a loop, on 1." Here, the arrow pointing left over the symbol 5∞ indicates that after the insertion of 5∞ (red) into 2∞ (black), 5∞ pass over ("distal to" or "distally") the near index strings $2n$ before its transfer to the thumbs.

Finally, focusing on the motion of 5∞, the steps 5 and 6 of *Niu* can be summarized as:

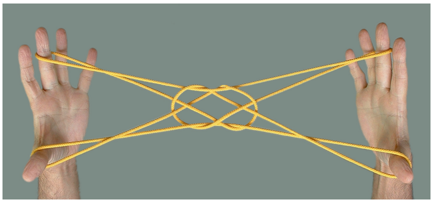
$$\underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1$$

5.2.6.3 Last Step of *Niu*

At this point, in order to reach the final figure, the indices are released and the figure is extended gently (step 7—pictures 76a and 76b).



76a



76b

Once again, as with his notation for openings, Storer uses the symbolism of his Calculus: the last operations will be coded $\square 2\ |$.

The heart-sequence of the procedure *Niu* is then given by the following formula:

$$\underline{O}.A : \left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) \ : \ \underrightarrow{1\infty} \to \ 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow \ 1 \end{array} \right\} : \square\, 2\ |$$

A Heart-sequence formula always begins with an opening ($\underline{O}.A$ in the case of *Niu*) that aims to create a certain number of loops on fingers. This leads to the first "normal position". It is from this normal position that the analysis of loops's movements can be written.

The presentation in columns has been chosen by Storer to indicate that sub-procedures in which the heart-sequences are $\overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \to 3$ and $\underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1$ respectively could be performed simultaneously. Of course, in practice, it is difficult to do so. In other words, we can visualize theoretically these simultaneous movements of loops without usually being able to perform them with our fingers.

5.2.7 *Before Going Further*

5.2.7.1 A Few Remarks on the Heart-Sequence Conceptual Tool

The concept of Heart-sequence, which allows a deeper understanding of the sub-procedures and hence of the string figure algorithms, will be central in this book. The analysis of string figures through the concept of Heart-sequence will bring some new light to certain phenomena that I mentioned in Part I. In particular, this conceptual tool is efficient to investigate how different procedures can lead to the same "final figure" or "motifs", how one figure can be transformed into another, or how a few "motifs" can be combined to make various final figures. As I will show in the following, this new reading on such phenomena, when applying systematically and comparatively on various string figure corpora, lead to some fundamental results.

However, working in this way, we shall not lose sight of the fact that writing down the heart-sequence of a string figure implies a loss of information. This loss can be of two kinds. The first occurs systematically: it is obviously generated by the focus on the object “loop”, causing a loss of information about the way the functors (fingers, feet, mouth) operate. The second concerns the order by which the movements of loops happen during the course of the algorithm. Following the process of *Niu* that is rigorously described by Storer’s Calculus formula, *Niu*’s heart-sequence should be written as follows:

$$\underline{O}.A : \overrightarrow{1\infty} \downarrow (2\infty) \; : \; \underrightarrow{1\infty} \rightarrow \; 3 : \overrightarrow{1\infty} \downarrow (2\infty) \; : \; \underrightarrow{1\infty} \rightarrow \; 3 : \Box\, 2 \;|$$

according to the fact that the movement of 1∞ occurs first, before the movement of 5∞. The latter formula respects the loops’ order of displacements, resulting from the elementary operations’ order within the string figure algorithm *Niu*. When writing down a part of the *Niu*’s heart-sequence as the simultaneous sequence

$$\left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) \; : \; \underrightarrow{1\infty} \rightarrow \; 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow \; 1 \end{array} \right\}$$

one loses the order of displacements of loops 1∞ and 5∞. As I have just demonstrated, it can be decided not to use such simultaneous sequence writing. Furthermore, we will see that we are often forced to do so: in many cases, the order of displacements of the loops has to be taken into account to write down the accurate heart-sequence of a given string figure algorithm.

Storer did not raise the question of the relationship between the two conceptual tools “Calculus” and “Heart-sequence”. It would be helpful to obtain formally the heart-sequence of a string figure from its Calculus’ formula. Unfortunately, I have not been able so far to figure out this transformation. This point led me to make the choice of not using the Calculus’ codes in this book. Moreover, given that the similarities between the two formal languages, using both of them in this work would have probably generate some confusion.

In his article (1988), Storer carries out his study mostly through Crossing-analysis and Calculus for string figures. He introduces the Heart-sequence concept but seldom uses it. Although there is no evidence, I believe that the main reason for this lies in the difficulty of making intelligible demonstrations for the notation of heart-sequences. As demonstrated above, the use of pictures showing movements of coloured loops allows to make such demonstrations clear. Such a methodology would have been difficult to use two decades ago, before the development of certain digital devices. However, Storer was convinced that the Heart-sequence concept could be essential to explore string figure corpora:

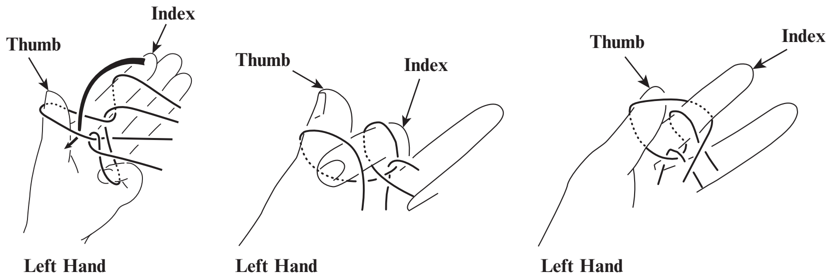
> We view the concept of “heart-sequence” as a Gedanken experiment of fundamental importance in the deeper understanding of the string figures of the world (Storer 1988, p. 35).

Before going further and demonstrating the efficiency of this concept when analysing and comparing string figure algorithms, let us focus on an example found in the ethnographical literature. This example suggests that sometimes the view of string figure-making through the prism of the movements of loops could have been the conceptualization used by the creators or practitioners themselves.

5.2.7.2 Heart-Sequence and Actors' Conceptualization

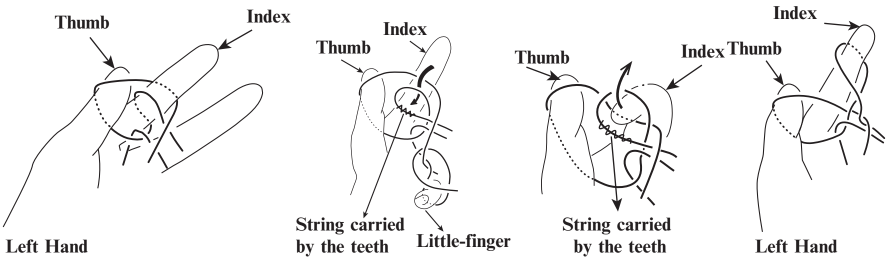
A few examples given in anthropological papers suggest that viewing a string figure algorithm through its heart-sequence is sometimes the conceptualization used by the practitioners themselves. In his work on the Arviligjuarmiut string figures (1969), Mary-Rousselière explains that the expression *Anitidlugo* meant "to pass one (loop) into another" (1969, p. 5). Although he does not mention it, the use of brackets seems to indicate that the word "loop" was implicit in the context of string figure-making. Unfortunately, Mary-Rousselière does not further comment this term. Nevertheless, we may reasonably think that *Anitidlugo* referred to a succession of operations often described in the corpora of Arctic string figures. In particular, Paul-Emile Victor describes it in his paper on the string figures from Ammassalik, Greenland (pictures 77a–77g below, adapted from (Victor 1940, pp. 155–157)). Indeed, the aim of these operations is to pass $L2\infty$ from above into $L1\infty$, and replace $L2\infty$ on the left index.

First, one may insert left index $L2$ from above into left thumb loop $L1\infty$ (picture 77a). Then, the left index $L2$ picks up the string $L1n$ and returns to position (pictures 77b and 77c).



77a 77b 77c

Teeth pick up near left index string $L2n$ (picture 77d). Then, left index $L2$ is released and reinserted from below into the loop carried by the teeth (pictures 77e and 77f). Teeth release their loop and left index returns to position (picture 77g).



77d 77e 77f 77g

This example seems to indicate that some creators or practitioners in the Arctic would have identified the sub-procedure "Passing one (loop) into another" as central in the making of string figures. However, we cannot be sure that they saw the whole process through this viewpoint. Furthermore the actors' viewpoint is very likely to differ from a cultural area to another. This will be confirmed in Part IV of this book, in which I will describe and analyse my own data findings about string figures in the Trobriand Islands, Papua New Guinea and Chaco, Paraguay. Before demonstrating the usefulness of heart-sequences in order to get a better understanding of the previously noted phenomenon of transformation (of a figure into another), let us tackle some problems raised by the writing of such sequences.

5.3 Some Questions Raised by the Concept of Heart-Sequence

Two fundamental questions naturally come to mind while working with this conceptual tool:

- Can several different string figure algorithms share exactly the same heart-sequence?
- Can a string figure algorithm be reconstructed from a given heart-sequence?

The following demonstration will give an example of such reconstruction and at the same time will answer positively to the first question.

5.3.1 Reconstructing a String Figure Algorithm from Its Heart-Sequence

5.3.1.1 The Procedure *Another Niu*

Let us consider the heart-sequence of *Niu*:

$$\underline{O}.A : \left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) \ : \ \underrightarrow{1\infty} \rightarrow \ 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow \ 1 \end{array} \right\} : \Box\, 2 \mid$$

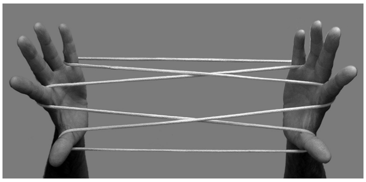
We have seen that the sub-procedures whose heart-sequences are $\overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \rightarrow 3$ and $\underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1$ can be, in theory, performed simultaneously. Therefore, they can also be performed (in theory) by changing the original order, that is to say, by beginning with the motion of 5∞. This leads to raise the following question: can we reconstruct an algorithm in which the operations entail 5∞ to move first. In order to show that it is possible, we may try to imagine a procedure whose heart-sequence is *Niu*'s one but, in which, the movement of 5∞ is done first before moving 1∞. In the following, I will call this procedure *Another Niu*.

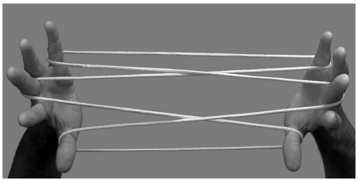
As with *Niu*, the first step will be Opening A. The next few steps should imply the insertion of 5∞ from below through 2∞ ($\underleftarrow{5\infty} \uparrow (2\infty)$). We will use the indices to do so, but we first need to set them free. Therefore, the indices will be transferred to the middle-fingers (step 2).

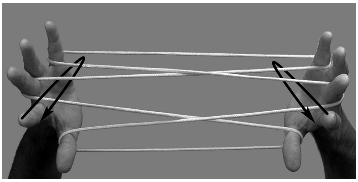
Storer's coding: $\overrightarrow{2\infty} \longrightarrow 3$.

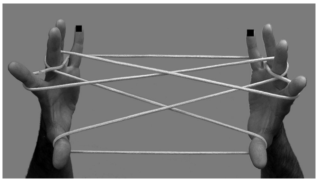
Another Niu

Step 1: Opening A (picture 78a).
Step 2: Transfer 2 loops to 3 (picture 78b).
Step 3: Distally insert 2 into 3 loops. 2 pick up $5n$ and return (picture 78c).
Step 4: Release 5 (picture 78d).

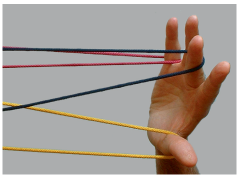

78a

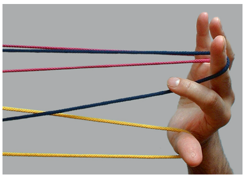

78b

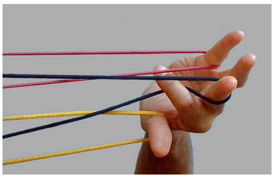

78c

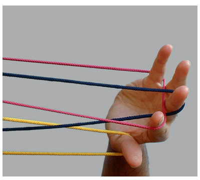

78d

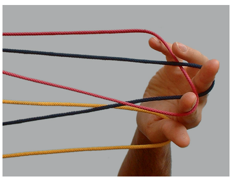
As shown in the pictures 79a–79f, the purpose of steps 3 and 4 taken together is clearly to pass 5∞ (red one) from below into 3∞ (black), previously 2∞. These loops are then transferred to the indices. This will be encoded $\underleftarrow{5\infty} \uparrow (3\infty)$: $\overleftarrow{5\infty} \longrightarrow 2$.

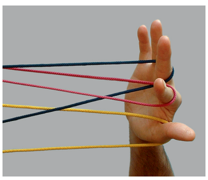

79a


79b


79c

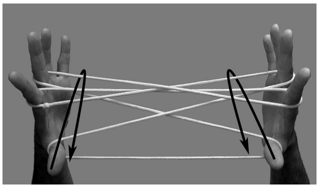

79d


79e

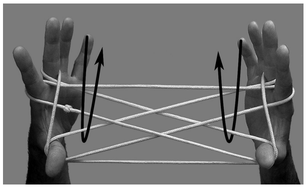

79f

Then, from this point, thumb loops (1∞) have to pass over all intermediate strings and through the middle loops (3∞). This can be performed by the elementary operations involved at the beginning of *Niu*.

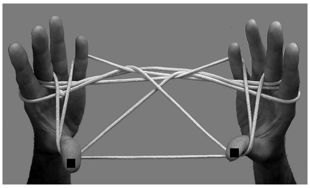
Step 5: Distally, 1 pick up $3f$ and return (picture 80a).
Step 6: Distally, 5 pick up lower $1f$ (picture 80b).
Step 7: Release 1 (pictures 80c and 80d).



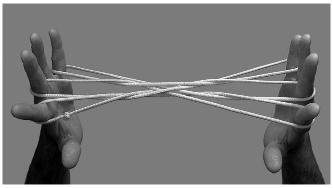
80a



80b

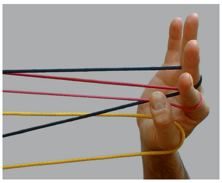


80c

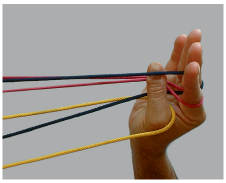


80d

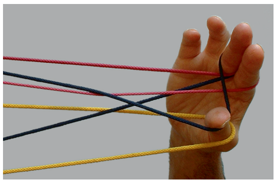
Pictures 81a–81h will convince the reader that during the previous steps (5–7) taken together, 1∞ (yellow) pass over all intermediate strings and through 3∞ from above. Formally, this will be written: $\overrightarrow{1\infty} \downarrow (3\infty)\ :\ \underrightarrow{1\infty} \to\ 5$.



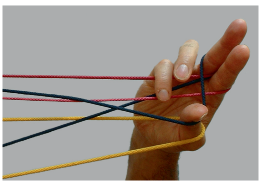
81a



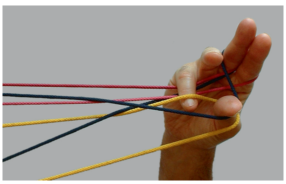
81b



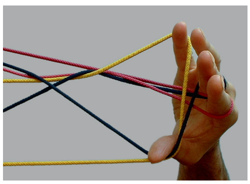
81c



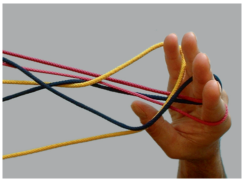
81d



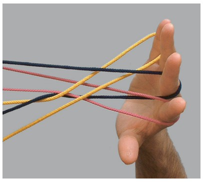
81e



81f



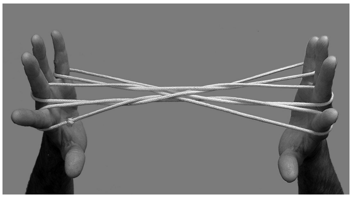
81g



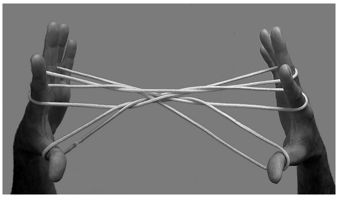
81h

Then, the last two steps (8 and 9) will allow to reach *Niu*'s final figure.

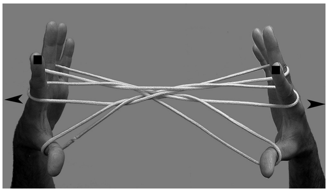
Step 8: Transfer 2, 3 and 5 to 1, 2 and 3 respectively (pictures 82a and 82b).
Step 9: Release 2 and extend (pictures 82c and 82d).



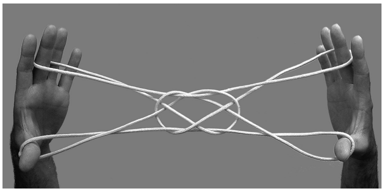
82a



82b



82c



82d

The three transfers of step 8 could be performed (in theory) simultaneously, and can thus be encoded as follows:

$$\left\{\begin{array}{l} \overleftarrow{5\infty} \longrightarrow 3 \\ \overleftarrow{3\infty} \longrightarrow 2 \\ \overleftarrow{2\infty} \longrightarrow 1 \end{array}\right\}$$

Finally, the heart-sequence of *Another Niu* can be written as follows:

$$\underline{O}.A : \overrightarrow{2\infty} \longrightarrow 3 : \left\{\begin{array}{l} 5\infty \uparrow (3\infty) : \overleftarrow{5\infty} \longrightarrow 2 \\ \overset{\longleftarrow}{\overrightarrow{1\infty}} \downarrow (3\infty) : \underrightarrow{1\infty} \rightarrow 5 \end{array}\right\} : \left\{\begin{array}{l} \overleftarrow{5\infty} \longrightarrow 3 \\ \overleftarrow{3\infty} \longrightarrow 2 \\ \overleftarrow{2\infty} \longrightarrow 1 \end{array}\right\} : \square 2 \mid$$

Formally, operations $\overrightarrow{2\infty} \longrightarrow 3$ and $\overleftarrow{3\infty} \longrightarrow 2$ cancel out. A formal consequence of this cancelation is that 2∞ must be substituted for 3∞ into the first parenthesis. The previous heart-sequence formula is then equivalent to:

$$\underline{O}.A : \left\{ \begin{array}{l} \underline{\underleftarrow{5\infty}} \uparrow (3\infty) : \overleftarrow{5\infty} \longrightarrow 2 \\ \overrightarrow{1\infty} \downarrow (3\infty) \; : \; \underrightarrow{1\infty} \rightarrow 5 \end{array} \right\} : \left\{ \begin{array}{l} \overleftarrow{5\infty} \longrightarrow 3 \\ \overleftarrow{2\infty} \longrightarrow 1 \end{array} \right\} : \square 2 \mid$$

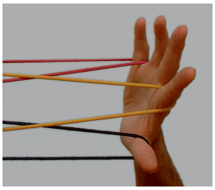
The single operation $\overleftarrow{5\infty} \longrightarrow 1$ can also be substituted for the two operations $\overleftarrow{5\infty} \longrightarrow 2$ and $\overleftarrow{2\infty} \longrightarrow 1$ taken together. In a similar way, the sequence ($\underrightarrow{1\infty} \rightarrow 5$ and $\overleftarrow{5\infty} \longrightarrow 3$) is equivalent to $\underrightarrow{1\infty} \rightarrow 3$. We can conclude that the heart-sequence of *Another Niu* is given by:

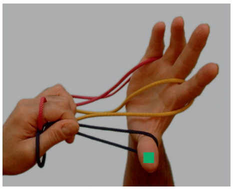
$$\underline{O}.A : \left\{ \begin{array}{l} \underline{\underleftarrow{5\infty}} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \\ \overrightarrow{1\infty} \downarrow (2\infty) \; : \; \underrightarrow{1\infty} \rightarrow 3 \end{array} \right\} : \square 2 \mid$$

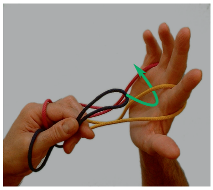
which is exactly the heart-sequence of *Niu*. The above demonstration proves that although *Niu* and *Another Niu* are two different string figure algorithms, they share the same heart-sequence. At the same time, we have seen that when a heart-sequence is given, it is theoretically possible to reconstruct a string figure algorithm, even though the solution is not unique and the succession of elementary operations is sometimes not easy to find out.

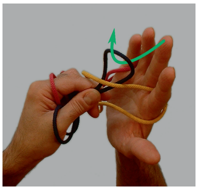
5.3.1.2 Heart-Sequence Versus Music Score

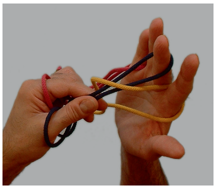
By analogy with the practice of a musical instrument, a heart-sequence could be seen as a music score. The reconstruction of a corresponding string figure algorithm would be thus analogous to the search of an accurate "fingering" to "play the music" on the instrument i.e. to implement a given heart-sequence with our body. Several fingerings are then possible. A string figure algorithm could thus be seen as the result of the connection between a "heart-sequence" and a "fingering" to implement it. I mentioned above that I have not been able to figure out the formal transformation of the Calculus' formula into its heart-sequence so far. This new reading of a string figure algorithm (heart-sequence + fingering) shows that the difficulty certainly lies in the various "fingerings" that one can work out to implement the same heart-sequence.

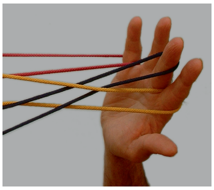

83a


83b


83c


83d


83e


83f

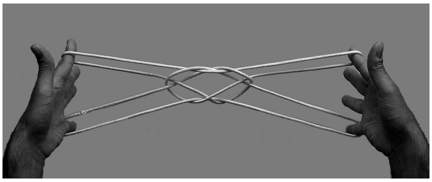
I will call "basic fingering" the method which, so as to implement a given heart-sequence, consists in manipulating the loops of one hand, using the opposite one. For instance, to implement the sub-sequence $\overrightarrow{1\infty} \downarrow (2\infty) \ : \ \underset{\longrightarrow}{1\infty} \rightarrow \ 3$ that we find within *Niu*, one can grasp $R1\infty$ (black) with the left hand (pictures 83a–83c), then insert it from above into $R2\infty$ (yellow—pictures 83c and 83d), and place it on the middle finger (pictures 83d–83f). Finally, the same operations can be repeated on the opposite side.

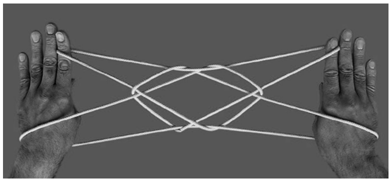
As far as I know, this kind of fingering rarely occurs in practice when making string figures. However, basic fingering has been a useful tool to validate the heart-sequences that I will refer to in the following. Working in this way, I first find out the heart-sequence of a procedure from the original algorithm, so that afterwards I was able to validate step by step the formula that I worked out, implementing it through a basic fingering.

The formal transformation of the heart-sequence of *Another Niu* made above unveils a weak point in the notation created by Storer. The way a loop is noted may change during the process, in terms of the different transfers of this loop from one finger to another. These transfers are directly connected to the "fingering" of the algorithm and are not intrinsically essential for the heart-sequence. The transformation above consisted in reducing the number of transfers in order to modify as least as possible the notation of the loops throughout the formula's implementation. And indeed, it is not easy to keep in mind the identity of the loops during the process. This difficulty led me to illustrate the formulae with pictures of coloured loops, thus giving an unambiguous identity to each loop involved in the heart-sequence.

5.3.2 Heart-Sequence and Symmetry

I will say that two final figures "look alike" if they show the same "drawing"[8] and if they differ only on some (or all) "simple crossings". If the two final figures A and B look alike, I will also say that the figure A is a B "lookalike". In that sense, both final figures in pictures 84a and 84b "look alike", for instance.


84a – *Pu kava* (Marquesas Islands)

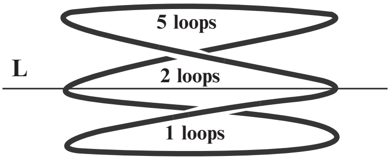

84b – *Kapiwa* (Trobriand Islands)

While comparing string figure algorithms I have often noticed that the final figures which "look alike" can be obtained through very different procedures. One typical case is when a final figure A is the "mirror image" of a final figure B. This situation is described by Storer in a discussion about the heart-sequence of "Brokhos" (*Niu*).

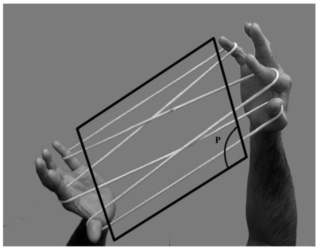
5.3.2.1 Symmetrical Sequences

In this discussion Storer makes clear why the two insertions $\overrightarrow{1\infty} \downarrow (2\infty)$ and $\underleftarrow{5\infty} \uparrow (2\infty)$ can bee seen as "analogous" in the context of $\underline{O}.A$. First, he noticed that "an imaginary line L connecting $L2d$ to $R2d$ is a line of reflection for the 2-dimensional schema of the string-position $\underline{O}.A$" (Storer 1988, p. 35) (picture 85a). With this point of view, 5∞ becomes the L-reflection of 1∞. Moreover, Storer points out that the movement $\overrightarrow{1\infty} \downarrow (2\infty)$ can be seen as the L-reflection, in the 3-dimensional space, of the movement $\underleftarrow{5\infty} \uparrow (2\infty)$. I shall add that this result is correct if the loops start moving from a string position of $\underline{O}.A$ for which the three loops 5∞, 2∞ and 1∞ are coplanar (picture 85b). In practice, this is usually not the case. But of course, in theory, the loops can always be considered in such a position. This remark suggests that the heart-sequence conceptual tool should be helpful in order to study formally the symmetrical movements of the loops involved in the making of a string figure, with respect to a line, in the 3-dimensional space. Indeed, the symbolism $\overrightarrow{1\infty} \downarrow (2\infty)$ and $\underleftarrow{5\infty} \uparrow (2\infty)$ suggests this type of symmetry.

[8]See the definition of "drawing" of the final figure in Sect. 3.4.1. The point is to extract the geometric design of a final figure without taking into account the exact path of the string.



85a – 2-dimensional schema of Opening A and its reflection-line symmetry



85b – Coplanar loops

5.3.2.2 Mirror Image Sequences

Before going further, let me operate a tiny modification to the heart-sequence of *Niu* in order to simplify the following discussion about symmetry. Let us consider that, at the end of *Niu*, the loops carried by the middle fingers are transferred to the little fingers. Then, within the heart-sequence the transfer $\underrightarrow{1\infty} \to 3$ becomes $\underrightarrow{1\infty} \to 5$. The consequence is that three fingers (1, 2 and 5) and three loops (1∞, 2∞ and 5∞) are needed to write down the heart-sequence instead of four fingers (1, 2, 3 and 5) and three loops:

$$\underline{O}.A : \left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) \; : \; \underrightarrow{1\infty} \to 5 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\} : \square\, 2 \mid$$

Consider the heart-sequence of a procedure X starting with Opening A. In the context of the analysis of "Brokhos" (*Niu*), Storer explains how to deduce the heart-sequence of a procedure "pseudo-X", within which the loops' movements are the mirror images of those occurring within procedure X. In other words, a pseudo-X procedure can be deduced from X by performing the mirror moves of the loops, as if the practitioner was looking at himself in a mirror while making string figure X.

Referring to "Brokhos" (*Niu*), Storer asserts: "Perform $\underline{O}.A$ on the hands and imagine yourself viewing this string-position from the far (little finger) side of the hands." From this perspective, the heart-sequence for "Brokhos" appears to be

$$\underline{O}.A : \left\{ \begin{array}{l} \overleftarrow{5\infty} \downarrow (2\infty) : \underleftarrow{5\infty} \to 1 \\ \underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \longrightarrow 5 \end{array} \right\} : \square\, 2 \mid \text{(Storer 1988, p. 36)}$$

The heart-sequence of *Pseudo-Niu* can be found by swapping the roles of the thumb and little finger loops. Starting with Opening A, from the perspective of "the far side of the hands", the move of 1∞ i.e. $\overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \to 5$ becomes the move of 5∞, inserted from above into index loops, and then transferred to the thumbs.

This is symbolized (with the practitioner's point of view i.e. same as with *Niu*) by $\overleftarrow{5\infty} \downarrow (2\infty) : \underleftarrow{5\infty} \rightarrow 1$. In a same way, the motion of 5∞ within *Niu* i.e. $\underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1$ becomes the one of 1∞ and can be encoded $\underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \longrightarrow 5$.

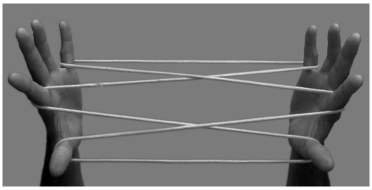
Storer does not describe any procedure of *Pseudo-Niu* whose heart-sequence is the one above. He states only: "we content ourselves with alternate construction of "pseudo-Brokhos", popularly known as the Eclipse" (Storer 1988, p. 37), and he refers to Ball's book "*Fun with string figures*"[9] while giving the instructions using his own calculus. I will show later why Eclipse actually cannot be considered as a *Pseudo-Niu* (or *Pseudo-brokhos*) procedure. Before returning to this, let us now reconstruct a procedure *Pseudo-Niu* whose heart-sequence is the one given above. This will allow to show that implementation of the heart-sequence of *Pseudo-Niu* ("mirror image" of the one of *Niu*) leads to the mirror image of *Niu*'s final figure.

5.3.2.3 *Pseudo-Niu*: A Mirror Process of *Niu*

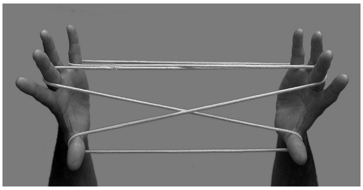
After Opening A, the second step of *Pseudo-Niu* aims to transfer index loops to the middle fingers.

Step 1: Opening A (picture 86a).
Step 2: 2 loops are transferred to 3 (picture 86b).

Storer's coding: $\underline{O}.A : \overrightarrow{2\infty} \longrightarrow 3$.
The latter transfer frees the indices now ready to operate.



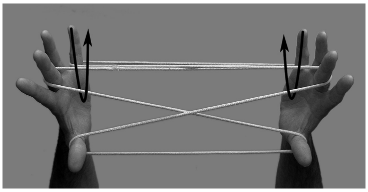
86a

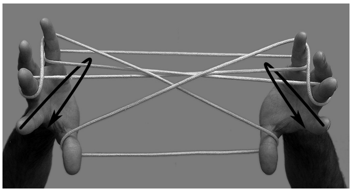


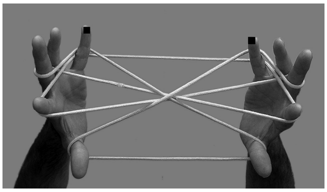
86b

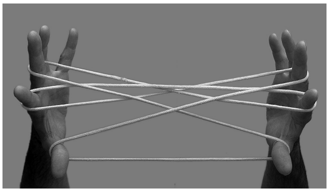
Step 3: Distally, 5 pick up $3n$ and return (picture 86c).
Step 4: Distally, 2 pick up $5n$ and return (picture 86d).
Step 5: Release 5 (pictures 86e and 86f).

[9] See Ball (1971, p. 35). Walter W. Rouse Ball probably found the instructions for this string figure in an article by anthropologist W. A. Cunnington about string figures from Central Africa. See figure number 16, named "Mwezi" (the moon) (Cunnington 1906, p. 129).

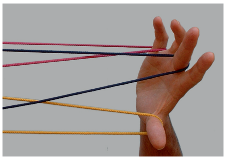

86c

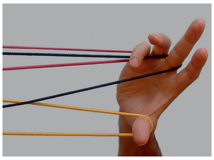

86d

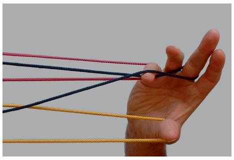

86e

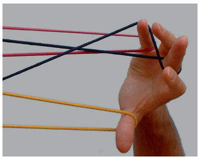

86f

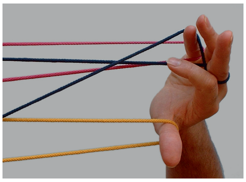
As shown in pictures 87a–87j, the purpose of steps 2–5 is to pass little finger loops 5∞ (red one) from above into the middle finger loops 3∞ (black one). 5∞ are then transferred to the indices. This will be encoded $\overleftarrow{5\infty} \downarrow (3\infty) : \underleftarrow{5\infty} \longrightarrow 2$.

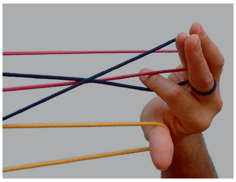

87a

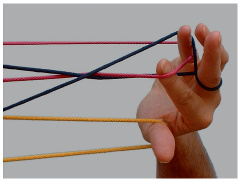

87b

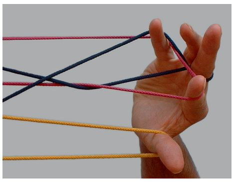

87c

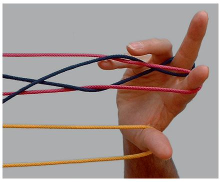

87d

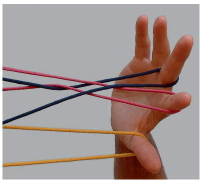

87e


87f


87g


87h

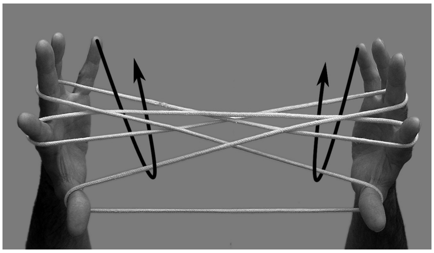

87i


87j

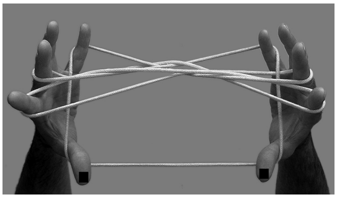
The procedure may continue as follows:

Step 6: Insert 5 through 3 loops from above. Then proximally, pick up $1f$ and return (picture 88a).

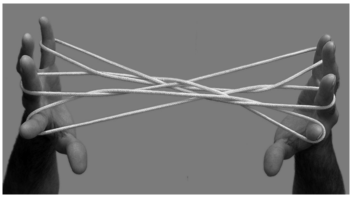
Step 7: Release 1 (pictures 88b and 88c).
Step 8: Transfer 2 loops to 1. Release 3. Extend (pictures 88d and 88e).



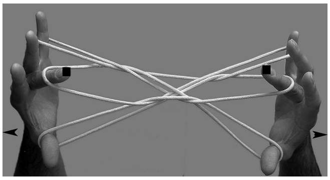
88a



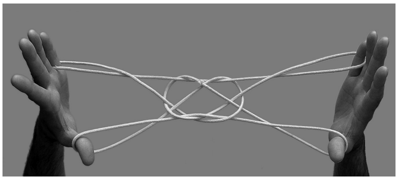
88b



88c

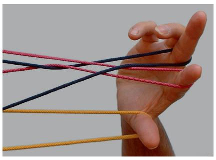


88d – Step 8: Transfer 2 loops to 1. Release 3. Extend

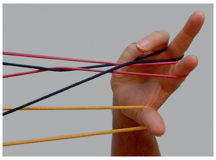


88e – Done

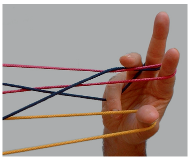
As illustrated in pictures 89a–89h, steps 6 and 7 entail that thumb loops 1∞ (yellow one) pass under all intermediate strings, then into the middle finger loops 3∞ (black one). This will be encoded as: $\underrightarrow{1\infty} \uparrow (3\infty) : \overrightarrow{1\infty} \longrightarrow 5$.



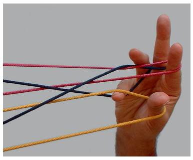
89a



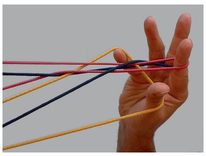
89b



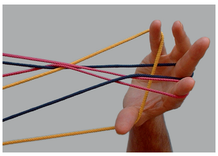
89c



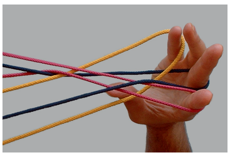
89d



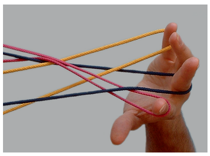
89e



89f



89g



89h

From this stage, the final figure is obtained through the release of the middle finger loops (3∞) after having transferred the index loop 2∞ to the thumbs (pictures 88d and 88e):

Storer's notation: $\overleftarrow{2\infty} \longrightarrow 1 : \square\, 3 \,|$.

The heart-sequence of the complete procedure is then:

$$\underline{O}.A : \overrightarrow{2\infty} \longrightarrow 3 : \left\{ \begin{array}{l} \overleftarrow{5\infty} \downarrow (3\infty) : \underset{\leftrightarrows}{5\infty} \longrightarrow 2 \\ \underrightarrow{1\infty} \uparrow (3\infty) : 1\infty \longrightarrow 5 \end{array} \right\} : \overleftarrow{2\infty} \longrightarrow 1 : \square\, 3 \,|$$

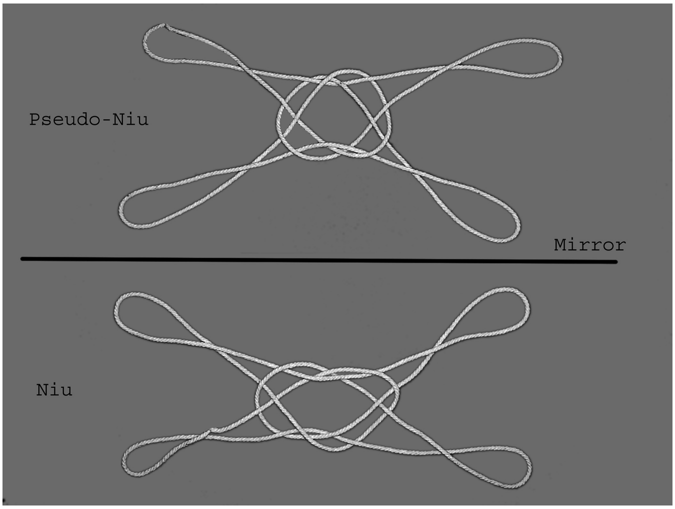
The transfer $\overrightarrow{2\infty} \longrightarrow 3$ is performed to free the indices. However, it is clear that the latter heart-sequence may be written without it. Furthermore, the transfer $\underleftarrow{5\infty} \longrightarrow 2$ followed by $\overleftarrow{2\infty} \longrightarrow 1$ may be written simply as $\underleftarrow{5\infty} \longrightarrow 1$. Therefore, the heart-sequence formula above is equivalent to:

$$\underline{O}.A : \left\{ \begin{array}{l} \overleftarrow{5\infty} \downarrow (3\infty) : \underset{\leftrightarrows}{5\infty} \longrightarrow 1 \\ \underrightarrow{1\infty} \uparrow (3\infty) : 1\infty \longrightarrow 5 \end{array} \right\} : \square\, 2 \,|$$

which is the heart-sequence expected.

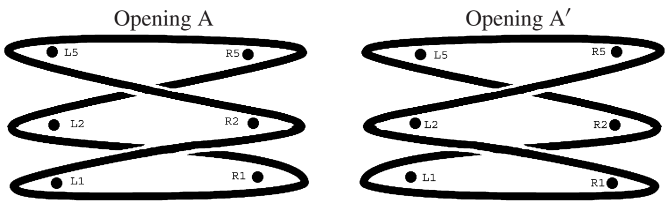
5.3.2.3.1 Mirror Image of the Final Figure

As we might expect, if we lay out the final figures of *Niu* and *Pseudo-Niu* down into a plane (projection), keeping the practitioner's viewpoint, the final figure of *Pseudo-Niu* is the "mirror-image" of the final figure of *Niu*. This result can be readily observed in the figure below.



90 – *Pseudo-Niu*: "mirror-image" of *Niu*

To summarize this result I will note $S(Niu) = Pseudo - Niu$, considering implicitly that *Niu* and *Pseudo-Niu* indicate the "final figures" of the procedures i.e. the exact "figures", crossings included. Curiously, Storer does not state this relation in his article. Nevertheless, he notices that the figures are not identical and cannot be obtained from one another by "rigid motion". It is also asserted that within procedure *Pseudo-Niu* the replacement of Opening A by a close one, already encountered as Opening B in Chap. 4 and noted $\underline{O}.A'$ by Storer,[10] leads to a figure "related to [*Niu*'s final] figure by a rigid motion" (rotation of the figure in its plane) (Storer 1988, p. 37). This property arises naturally from the "mirror relationship" between the procedures *Niu* and *Pseudo-Niu*, adding that $\underline{O}.A'$ leads to a spatial configuration which is, for an observer standing in front of the practitioner, identical to the one obtained with $\underline{O}.A$ as seen from the practitioner's point of view. In other words, the string diagram obtained starting with $\underline{O}.A'$ is the mirror image of the string diagram obtained under $\underline{O}.A$[11] (pictures 91a and 91b).



91a 91b

Therefore, if one lays out the final figure of *Pseudo-Niu* formed by starting with $\underline{O}.A'$, keeping the observer's point of view, the figure obtained would be identical to the final figure of *Niu*, laid out in keeping the practitioner's point of view. When both figures are laid out, keeping the same point of view—e.g. the practitioner's one—the figures can be obtained one another under a rotational symmetry with respect to the center of the figure.

5.3.2.3.2 Mirror-Relationship

Storer introduced the concept of "Pseudo-procedure" in the context of the analysis of *Brokhos* in order to show the efficiency of this symbolism. However, he did not use this conceptual tool systematically in his article. We will see in the following that the concept of Heart-sequence is efficient to study formally and

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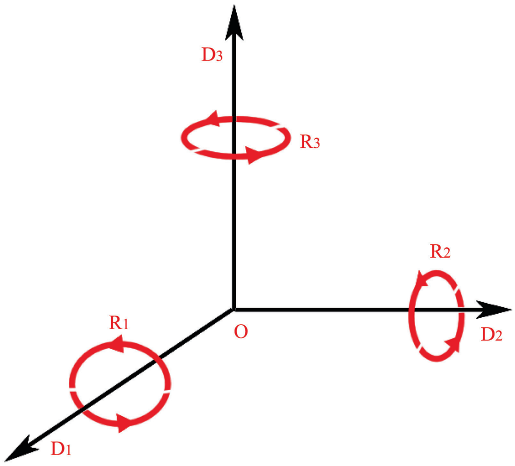
[10]From Position I, the right index starts moving first instead of the left one, then picks up the opposite palmar string.

[11]For that reason, I will refer to this opening as "Opening A_m" in Part IV of this book.

systematically "mirror-relationship" between "looking alike" string-figures. If two different string figure algorithms lead to two symmetrical (mirror-symmetry) final figures, the comparison of their heart-sequences will formally show whether or not the movements of loops caused by the algorithms are linked by "mirror-relationships".

For further geometrical comparisons of final figures, I introduce the commutative group of transformations into the three dimensional space composed with the three rotations R_1, R_2, R_3 of 180° with respect to the three perpendicular directions D_1, D_2, D_3 of the space (diagram below), the three reflections S_1, S_2, S_3 with respect to the planes perpendicular to D_1, D_2, D_3 passing through the origin O, and finally, the symmetry S_O (with respect to O) and the identity Id (picture 92).



92

The final figures obtained in the following will be considered as laid out into the horizontal plane (O, D_1, D_2).

Using a loop of string, a mirror, and the relation $S_o = S_1 \circ R_1$ (for instance), one can easily verify that the final figure of *Niu* is invariant under S_o. This implies that the final figures obtained under the transformations S_1 and R_1 are the same one:

$$S_1 \circ R_1(Niu) = Niu \Longrightarrow S_1 \circ S_1 \circ R_1(Niu) = S_1(Niu) \Longrightarrow R_1(Niu) = S_1(Niu)$$

This property is also easy to experiment.

For the same reason ($S_o = S_2 \circ R_2 = S_3 \circ R_3$), we get $R_2(Niu) = S_2(Niu)$ and $R_3(Niu) = S_3(Niu)$. Then, the action of the group G on the final figure *Niu*, leads to 4 "looking alike" final figures: Niu, $R_1(Niu)$, $R_2(Niu)$, and $R_3(Niu)$.

We have demonstrated above that :$Pseudo - Niu = S_1(Niu)$ so $Pseudo - Niu = R_1(Niu)$. We will encounter the two other final figures in the following.

5.4 Before Going Further

Heart-sequences allow a "topological" view (as I suggest calling it) on string figure procedures, permitting to better understand the impact of the elementary operations, or of the creation of particular patterns (such as the "double sided lozenge"), on the string. From an observer's viewpoint, one can speculate on how the actors in different societies have explored these string figure procedures. As far as I can see, Storer's Heart-sequence concept is relevant in every corpus of string figures that I have studied so far, and provides a homogeneous tool to analyse and classify string figure procedures as "Observers".

Many procedures starting with Opening A and forming a figure looking alike *Niu*'s final figure can be found in ethnographical literature. I collected some others myself. I call this set of procedures the "double sided lozenge" family. In the next Part, we will first focus on this set of string figure algorithms, and demonstrate how the concept of Heart-sequence allows them to be classified. Then, I will show how heart-sequences allow to analyse the transformations of one figure into another, as previously mentioned in Chap. 3.

References

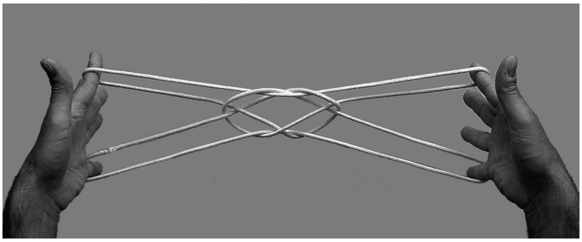
Ball WWR (1971) Fun with string figures. Dover, New York
Cunnington WA (1906) String figures and tricks from Central Africa. J R Anthropol Inst G B Irel 36:121–131
D'Antoni, J. (1997) Pinthios brokhos: the earliest account of a string figure construction. Bull Int String Fig Assoc 4:90–94
Mary-Rousseliere G (1969) Les jeux de ficelles des Arviligjuarmiut. Bulletin, Musées nationaux du Canada, vol 233. Imprimeur de la Reine, Ottawa
Miller LG (1945) The earliest(?) description of a string figure. Am Anthropol 47:461–462
Sherman M (2007) Someone who loved the string: a tribute to Tom Storer. Bull String Fig Assoc 14:1–37
Storer T (1988) String figures, volume 1. Bull String Fig Assoc 16 (Special Issue):1–212
Victor P-E (1940) Jeux d'enfants et jeux d'adultes chez les Eskimo d'Angmassalik: Les jeux de ficelle. Meddelelser om Gronland 125(7):1–212. Copenhagen

Part III
Analysing String Figure Algorithms

Chapter 6
Heart-Sequences and "Look-Alike" String Figures

6.1 *Pu kava* from the Marquesas Islands

During the Summer of 2005, I carried out fieldwork in Ua Pou Island in the Marquesas, French Polynesia. I have learnt on that occasion an interesting procedure called *Pu kava* (big shell) whose final figure is a "double-sided lozenge" (picture 93).[1]



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6.1.1 The Procedure Pu kava and Its Heart-Sequence

Let us consider the first operations of *Pu kava*. As with *Niu* both hands operate symmetrically and the following pictures 94a–94x illustrate the moves of the right hand only. Opening A is directly followed by a succession of operations carried out by the indices.

[1]In 1925, anthropologist Willowdean C. Handy published a paper about string figures from the Marquesas and Society Islands (Handy 1925) which doesn't contain the procedure *Pu kava*. This procedure, known as *Na tifai* (method 2), is described by Honor Maude and Kenneth P. Emery in their book about the string figures of the nearby Tuamotus Islands, French Polynesia. See Maude and Emory (1979, p. 2).

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_6

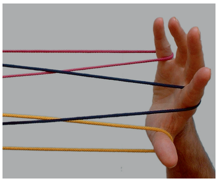
Step 1: Opening A (picture 94a).

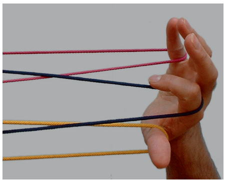
Step 2: Pass 2 proximal to 5 loops, then pick up both $5n$ and $5f$ and return (pictures 94b–94f).

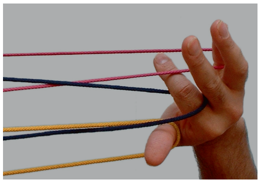
Step 3: Proximally, insert 2 into 1 loops. Pick up $1f$ and return (pictures 94g–94k).

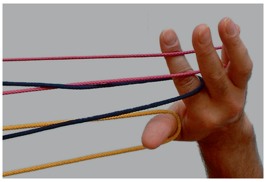
Step 4: Release 1 (pictures 94l–94n).

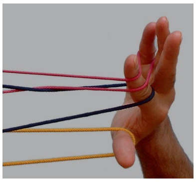
The aim of these operations is to allow thumb loops 1∞ (yellow) to pass over both index (black) and little finger (red) loops (2∞ and 5∞) (pictures 94a–94n). This will be encoded $\underline{O}.A : \overrightarrow{1\infty}\,(5\infty)$.

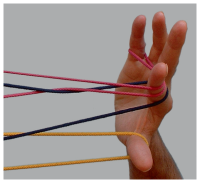

94a – Opening A

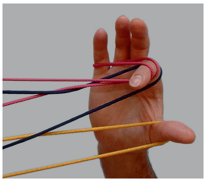

94b

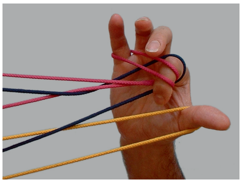

94c

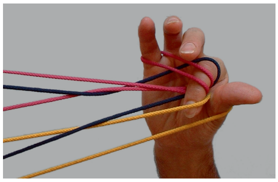

94d

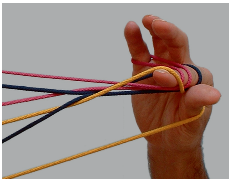

94e

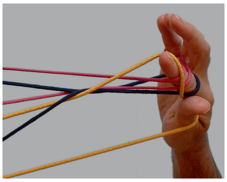

94f – End Step 2

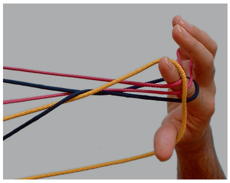

94g

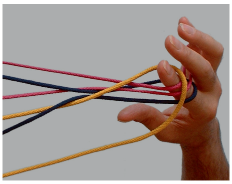

94h

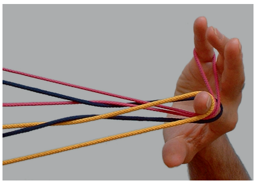

94i


94j


94k – End Step 3


94l


94m

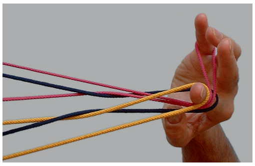

94n – End Step 4

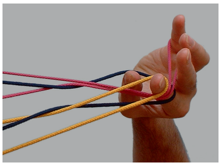
At the end of this sequence, original thumb loops 1∞ (yellow) are placed temporarily on the tip of indices (picture 94n). From this point, indices and thumbs grasp upper (distal) far index strings and rotate:

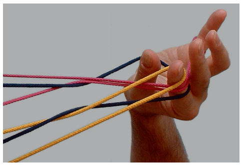
Step 5: Proximally, insert 1 into proximal 2 loops and seize distal $2f$ between 1 and 2 (pictures 94o–94r).

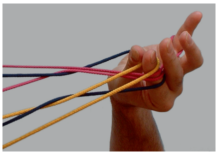
Step 6: Rotate seized 1 and 2 away from you, then return to position while rotating both hands, palms towards you. Release 1 while continuing to rotate 2 (pictures 94s–94x).[2]

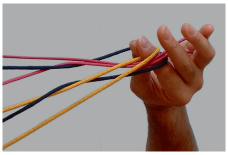
This rotation entails that the four radial index strings slip off during the process. Then, original thumb loops 1∞ (yellow) are transferred naturally to indices at the end of the rotation. The figure is extended, both hands facing each other (picture 94x).

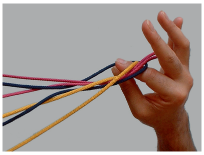

94o

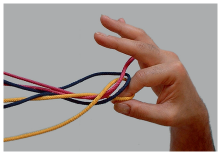

94p

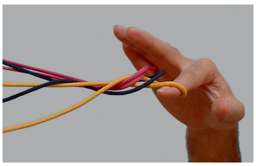

94q

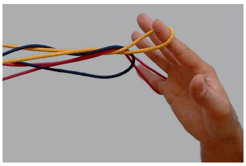

94r – End Step 5

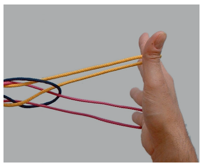

94s


94t


94u


94v


94w


94x – End Step 6

The operations illustrated in pictures 94s–94u above causes the original thumb to loop 1∞ (yellow) rotate 180° on themselves.

When a loop carried by a Functor F is rotated 180° anticlockwise *for an observer located on the left side of the practitioner*, Storer notes: $> F\infty$ ($< F\infty$, if the rotation is made clockwise).

In the rotation above, original thumb loops 1∞ (yellow) are rotated anticlockwise 180°. Hence, we will note: $> 1\infty$.

[2]See also procedure *Pu kava* in the accompanying website (Double-Sided Lozenge Family).

During the same sequence of operations (pictures 94s–94v above), original thumb loops 1∞ (yellow) pass towards the practitioner under little finger loops 5∞ (red). This will be coded: $\underleftarrow{1\infty}\,(5\infty)$.
Simultaneously, original thumb loops 1∞ (yellow) pass into lower (proximal) index loops 2∞ (black) from above. The latter 2∞ (black) are released during the movement. This can be symbolized by: $\overleftarrow{1\infty} \downarrow (2\infty) : \square 2$.
So, the three previous formulae put together, we get: $> 1\infty : \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty) : \square 2$. I will contract $> 1\infty : \underleftarrow{1\infty}\,(5\infty)$ simply as $> \underleftarrow{1\infty}\,(5\infty)$.
So, the formula becomes: $> \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty) : \square 2$.
Pictures 94v–94x show that original thumb loops 1∞(yellow) are rotated 180° anticlockwise and transferred to indices. This will be written: $> \overleftarrow{1\infty} \longrightarrow 2\,|$.
Finally, the heart-sequence of *Pu kava* is given by:

$$\underline{O}.A : \overrightarrow{1\infty}\,(5\infty) \;:> \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty) : \square 2 :> \overleftarrow{1\infty} \longrightarrow 2\,|$$

6.1.2 *Comparison with Niu*

6.1.2.1 Heart-Sequence Comparison

The movement of loops involved in the making of string figure *Pu kava* is different from the one in *Niu*. The heart-sequence above reveals that the string figure algorithm *Pu kava* entails the movement of the single pair of thumb loops 1∞, passing around little finger loops 5∞, and inserting into index loops 2∞. By contrast, the heart-sequence of *Niu* is based on the movement of two pairs of loops, thumb loops 1∞ and little finger loops 5∞, both inserting into index loops 2∞, one from above and the other from below.

Heart-sequence of *Pu kava*:

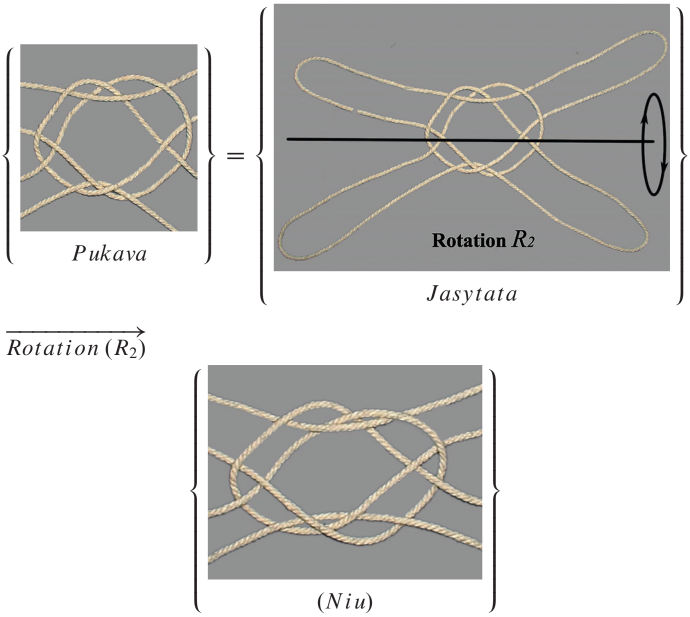
$$\underline{O}.A : \overrightarrow{1\infty}\,(5\infty) \;:> \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty) : \square 2 :> \overleftarrow{1\infty} \longrightarrow 2\,|$$

Heart-sequence of *Niu*:

$$\underline{O}.A : \left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) \;:\; \underrightarrow{1\infty} \rightarrow \;3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow \;1 \end{array} \right\} : \square\, 2\,|$$

6.1.2.1.1 Final Figures Comparison

Let us focus on the final figures of these two different procedures. Remember that to allow final figures to be compared, we have to lay out the figures each time in the same way. I have chosen the practitioner's viewpoint. In a remarkable way, we observe that *Niu*'s final figure is the image of *Pu kava*'s one under the rotation R_2. Formally we have: $Niu = R_2(Pukava)$, this phenomenon is illustrated in the diagrams below:



The heart-sequence of *Pu kava* is clearly different from the one of procedure *Niu*. We have thus identified two string figure algorithms the respective heart-sequences of which are definitely different, although they lead to the same final figure (modulo R_2) i.e. the same "knots" (crossings included).

6.1.2.2 Classification

In a noteworthy way, every "double-sided lozenge" string figure procedures, that I have learnt either in the field or in anthropological literature, can be classified into two groups defined as Group I or Group II. I call Group I the subset of the "double-sided lozenge family" regrouping those whose heart-sequences begin with $\underline{O}.A$ and describe the movement of one pair of loops (generally 1∞ or 5∞), passing around a second (generally and respectively 5∞ or 1∞) and through a third pair of loops (generally 2∞). In such a way the procedures *Kapiwa* and *Jasytata* described above belongs to Group I. Group II will be defined as the subset of the double-sided lozenge procedures, starting also with $\underline{O}.A$, but whose heart-sequences describe the movement of two pairs of loops (generally 1∞ and 5∞), both passing through a third pair of loops (generally 2∞), one from above and the other from below. In such a way, *Niu* is a member of Group II.

Let us now determine the heart-sequences of some other procedures which lead to a "double-sided lozenge". By doing so, we will begin a classification of the "double-sided lozenge" string figure algorithms, on the basis of the Heart-sequence concept. The first two following "double-sided lozenge" procedures are known among the Guarani-Ñandeva who live in the Chaco, Paraguay.[3]

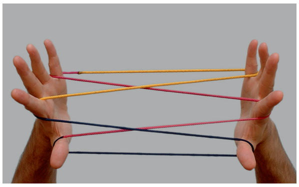
6.2 Estrellas from the Chaco, Paraguay

6.2.1 Jasytata from the Chaco, Paraguay

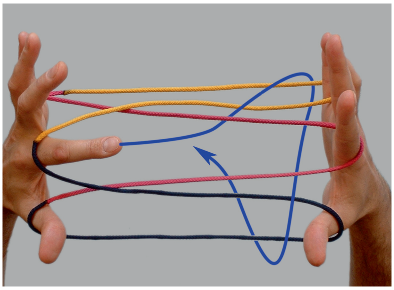
6.2.1.1 The Procedure *Jasytata* and Its Heart-Sequence

In October 2005, I have learnt the following procedure, called *Jasytata* (stars), among the Guarani-Ñandeva. The procedure starts with Opening A (Step 1—picture 95a). Then, the hands operate one after the other, and pictures 95b–95j show the left hand manipulating the loops on the right hand. The second step can be described as follows:

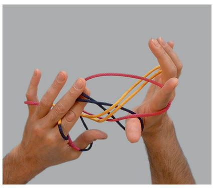
Step 2: Distally, insert $L2$ into $R2$ loop. Pass $L2$ away from you distal to $R5$ loop, then towards you proximal to both $R5$ loop and $R2$ loop. Pass $L2$ towards you distal to $R1$ loop, then pick up both $R1f$ and $R1n$. $L2$ return to position (picture 95b). Seize both $R1n$ and $R1f$ between $L2$ and $L3$. Release $R1$ (pictures 95c–95e). Distally, insert $R1$ into the loop seized between $L2$ and $L3$. Transfer this loop to $R1$. Extend (pictures 95f–95j).



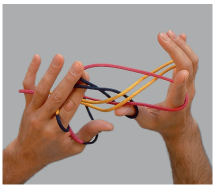
95a – Opening A



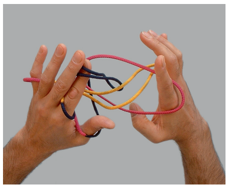
95b



95c

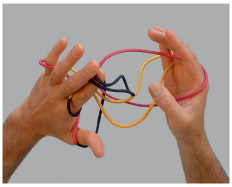


95d

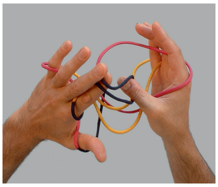


95e

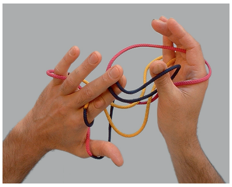
[3]See Sects. 8.1 and 8.5.



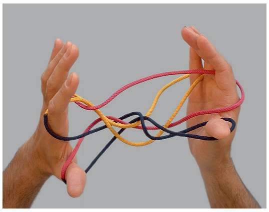
95f



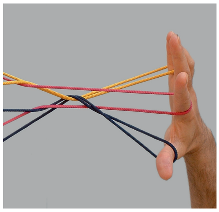
95g



95h



95i



95j – End Step 2

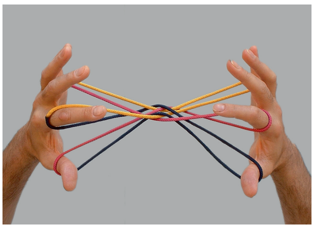
The aim of these operations (pictures 95a–95j) is actually to make $R1\infty$ (black) turn around $R5\infty$ (yellow), passing under (away from you) and then above (towards you) $R5\infty$ (red). Finally, $R1\infty$ (black) is inserted from below into $R2\infty$ (red). During this movement $R1\infty$ is rotated 360° clockwise: 180° while $L2$ picks up $R1\infty$ (pictures 95a–95f), and 180° while original loop $R1\infty$—grasped by $L2$ and $L3$—is transferred to $R1$ (pictures 95g–95j above). This can be formalized:

$$\underline{O}.A : \underrightarrow{R1\infty}\,(R5\infty) : \overleftarrow{R1\infty}\,(R5\infty) : \ll \underleftarrow{R1\infty} \uparrow (R2\infty)\,.$$

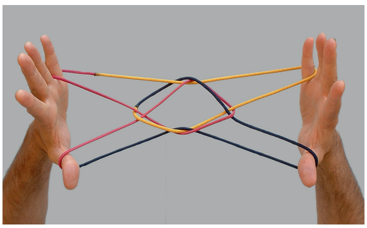
The same operations are then applied on the left hand. Although it is impossible to achieve in practice, we can consider that the movement of $R1\infty$ and $L1\infty$ may theoretically happen simultaneously. So, the heart-sequence will be simply written as follows:

$$\underline{O}.A : \underrightarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty}\,(5\infty) : \ll \underleftarrow{1\infty} \uparrow (2\infty)\,.$$

At this stage, the indices are released and the string is extended, formally written $\square 2\ |$. This leads to a "double-sided lozenge" final figure (pictures 95k and 95l).[4]



95k



95l

[4] See also the procedure *Jasytata* in the accompanying website (Double-Sided Lozenge Family).

The heart-sequence of *Jasytata* is then given by the following formula:

$$\underline{O}.A : \underrightarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty}\,(5\infty) : \ll \underleftarrow{1\infty} \uparrow (2\infty) : \Box 2 \mid$$

As for *Kapiwa*, it is the movement of a single pair of loops (1∞, in this case), passing around another ones (5∞), finally inserted from below into index loops 2∞.

The “fingering” of *Jasytata* is not so different from what I have termed “basic fingering”: loops 1∞ are grasped and directly manipulated by the index and middle finger of the opposite hands (pictures 95a–95h). This seems to indicate that the procedure *Jasytata* has been created in relation to an operative practice based on the movement of loops.

6.2.1.2 *Jasytata* and *Pu kava* Heart-Sequence Comparison

Like *Pu kava*, *Jasytata* belongs to Group I: once again, the final design is obtained thanks to the motion of a single pair of loops (1∞), passing around another ones (5∞), finally inserted from below into index loops 2∞. The heart-sequences of *Pu kava* and *Jasytata* show a great similarity in the movement of loops involved in the making of these two string figures.

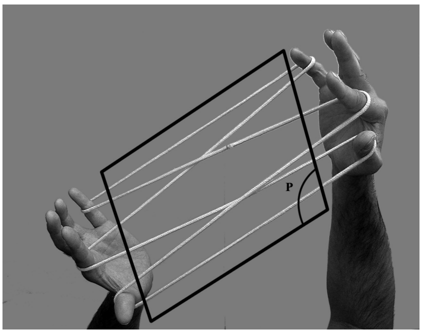
Pu kava $\longrightarrow$ $\underline{O}.A : \overrightarrow{1\infty}\,(5\infty) : > \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty) : \Box 2 : > \overleftarrow{1\infty} \longrightarrow 2 \mid$

Jasytata $\longrightarrow$ $\underline{O}.A : \underrightarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty}\,(5\infty) : \ll \underleftarrow{1\infty} \uparrow (2\infty) : \Box 2 \mid$

Apart from the transfer $\overleftarrow{1\infty} \longrightarrow 2$ at the end of *Pu kava*, the heart-sequences above are quite similar. The rotation of 360° (clockwise or anticlockwise) of thumb loops 1∞, which occurs within both heart-sequences, can theoretically be performed at the end of the process. So, omitting for the moment these rotations, let us compare the two following sequences:

$\overrightarrow{1\infty}\,(5\infty) : \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty)$ (occurring within *Pu kava*)

$\underrightarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty}\,(5\infty) : \underleftarrow{1\infty} \uparrow (2\infty)$ (occurring within *Jasytata*)



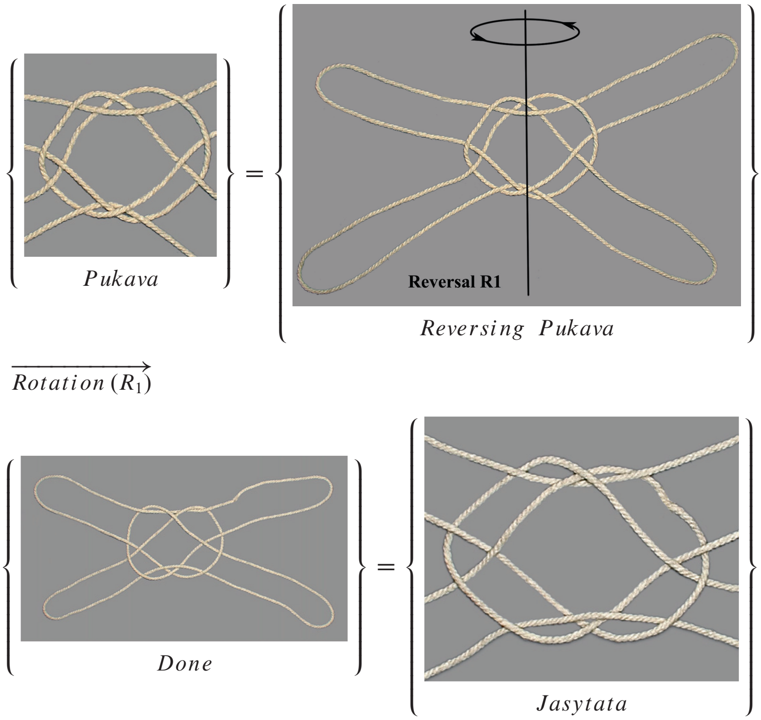
96

By considering that after $\underline{O}.A$ loops 1∞, 2∞ and 5∞ are placed in a coplanar way in the same plane P (picture 96), the two sequences above clearly symbolize two movements of 1∞ which are the reflection (i.e. symmetrical) of one another with respect to the plane P.

Furthermore, the rotations of 360°, $\gg 1\infty$ (*Pu kava*) and $\ll 1\infty$ (*Jasytata*) previously put aside, can also be seen as the reflection of one another with respect to P. This comparative analysis demonstrates that the movements of loops occurring in these two string figure algorithms can be seen as the plane-reflections of one another.

6.2.1.3 *Jasytata* and *Pu kava* Final Figure Comparison

A consequence of the previous outcome is that the two procedures *Jasytata* and *Pu kava* lead exactly to the same configuration of string. This can be seen by manipulating the final figures: *Jasytata*'s final figure can be obtained by reversing (reversal R_1) *Pu kava*'s final figure. This is shown in the diagrams below.



I will summarize this geometrical property as follows: $R_1(Pu\,kava) = Jasytata$.

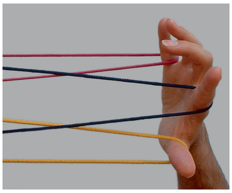
6.2.2 *Estrella, from the Chaco*

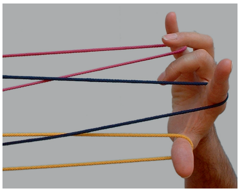
In the Chaco, I have recorded another string figure algorithm, that my informant named *Estrella* (in Spanish), whose final figure is also a double-sided lozenge. This procedure is somewhat identical to the already discussed string figure *Niu*.

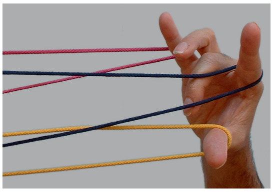
6.2.2.1 The Procedure Estrella and Its Heart-Sequence

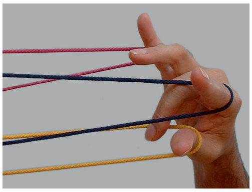
Let us consider the first operations of Estrella. The procedure starts with Opening A (Step 1). Then, the hands operate symmetrically and pictures 97a–97r below show the movements of the right hand.

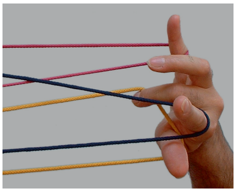
Step 2: Pass 3 proximal to 2 loops. Distally, insert 3 into 1 loops, then pick up $1f$. 3 return to position (pictures 97a–97g).
Step 3: Release 1 (pictures 97h–97i).

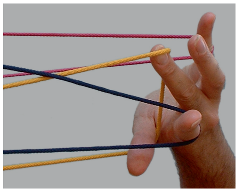

97a

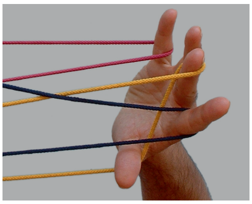

97b

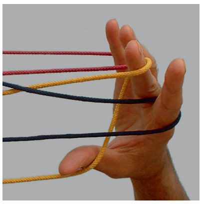

97c

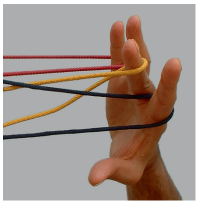

97d


97e


97f


97g – End Step 2

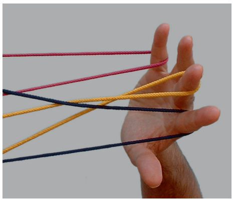

97h

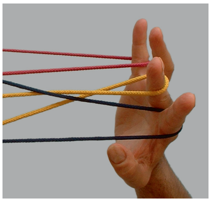

97i – End Step 3

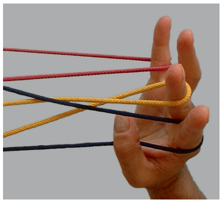
The goal of this succession of operations is to pass thumb loops 1∞ (yellow) under index loops 2∞ (black) and to transfer them to the middle fingers while rotating them 180° clockwise (pictures 97a–97i above). So, this sequence can be encoded: $< \underrightarrow{1\infty} \to 3$.

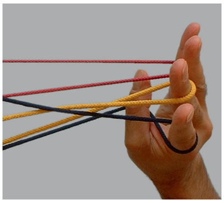
Then, the procedure goes as with *Niu* (pictures 97j–97r).

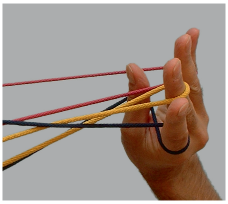
Step 4: Distally, insert 1 into 2 loops, pick up $5f$ and return to position (pictures 97j–97p).
Step 5: Release 5 (pictures 97q–97r).
Step 6: Release 2. Extend.[5]

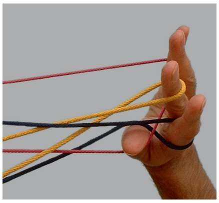

97j

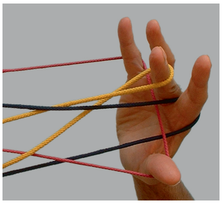

97k

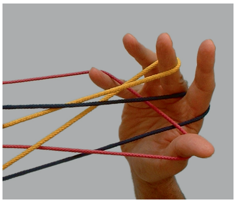

97l

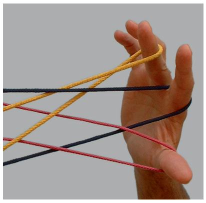

97m


97n


97o


97p – End Step 4


97q


97r – End Step 5

As in *Niu*, little finger loops 5∞ (red) are inserted from below into index loops 2∞ (black), and transferred to the thumbs (pictures 97j–97r): formally, $\underleftarrow{5\infty} \uparrow (2\infty) : \overrightarrow{5\infty} \longrightarrow 1$.

To get the final "double-sided lozenge", the index loops are released and the figure is extended (step 6): $\square 2 \mid$. The heart-sequence of *Estrella* can thus be written as follows:

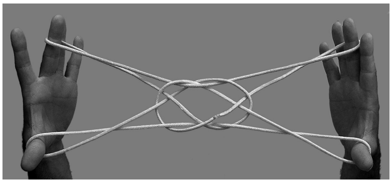
$$\underline{O}.A : \left\{ \begin{array}{c} < \underrightarrow{1\infty} \rightarrow 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\} : \square 2 \mid$$

This shows that, as with procedure *Niu*, the final figure of Estrella is the result of the motion of two pairs of loops (1∞, 5∞). However, the heart-sequences of these two procedures differ in a way that is interesting to analyse.

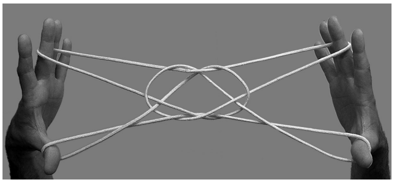
[5]See also the procedure Estrella in the accompanying website (Double-Sided Lozenge Family).

6.2.2.2 Comparison of *Niu* and Estrella Heart-Sequences

First, let us observe that *Niu* and Estrella final figures are almost identical (pictures 98a and 98b). There is however a slight difference in the way middle finger loops 3∞ are twisted.



98a – Niu



98b – Estrella

Let me remind the heart-sequence of *Niu*:

$$\underline{O}.A : \left\{ \begin{array}{c} \overrightarrow{1\infty} \downarrow (2\infty) \, : \, \underset{\longrightarrow}{1\infty} \to 3 \\ \underset{\longleftarrow}{5\infty} \uparrow (2\infty) : \overset{\longleftarrow}{5\infty} \longrightarrow 1 \end{array} \right\} : \Box\, 2 \mid$$

and the one of Estrella:

$$\underline{O}.A : \left\{ \begin{array}{c} < \underset{\longrightarrow}{1\infty} \to 3 \\ \underset{\longleftarrow}{5\infty} \uparrow (2\infty) : \overset{\longleftarrow}{5\infty} \longrightarrow 1 \end{array} \right\} : \Box\, 2 \mid$$

The similarity of *Niu* and Estrella final figures, adding to the comparison of their heart-sequences, led me to take a closer look at the configuration obtained from Opening A, after performing either the sequence $< \underset{\longrightarrow}{1\infty} \longrightarrow 3$ (within Estrella) or $\overrightarrow{1\infty} \downarrow (2\infty) \, : \, \underset{\longrightarrow}{1\infty} \to 3$ (within *Niu*), or rather, $\overrightarrow{1\infty} \downarrow (2\infty) \, :< \underset{\longrightarrow}{1\infty} \to 3$, in order to rotate thumb loops 1∞ in the same manner. It came up immediately that the final configurations, say X, are absolutely identical. This property can be stated symbolically as follows:

$$\underline{O}.A : < \underset{\longrightarrow}{1\infty} \longrightarrow 3 \Leftrightarrow \underline{O}.A : \overrightarrow{1\infty} \downarrow (2\infty) \, :< \underset{\longrightarrow}{1\infty} \to 3$$

It is a noteworthy "topological" property in the context of Opening A. It shows two transformations allowing to pass from the configuration reached under Opening A, that I will note $Conf(\underline{O}.A)$ in the following, to the configuration X previously introduced. According to the equivalence above and to the fact that Estrella shows the movement of two pairs of loops $(1\infty, 5\infty)$, I shall consider that Estrella (like *Niu*) belongs to Group II, even though 1∞ do not pass into 2∞ but under it only.

Thus we see how much the concept of Heart-sequence is useful, at least in the context of Opening A, to reveal "topological" phenomena such as the previous one. That is of course an observer's viewpoint. However, the latter analysis demonstrates that studying string figure algorithms in this manner allows a deeper understanding of the procedures which would certainly help to formulate some relevant questions worth asking the practitioners.

6.3 *Kapiwa* from the Trobriand Islands

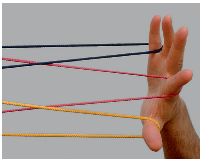
In the summer of 2006, in the Trobriand Islands (Papua New Guinea), I collected a string figure procedure, named *Kapiwa* (bee), leading once again to a "double-sided lozenge". An analysis through heart-sequences will explain the "mirror-image" relationship which exists between the final figures of *Jasytata* and *Kapiwa*.

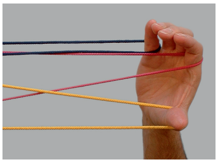
6.3.1 The Procedure Kapiwa and Its Heart-Sequence

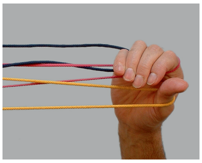
Consider the first operations of *Kapiwa*. The hands operate symmetrically and the pictures below show the moves of the right hand. *Kapiwa* starts with Opening A (Step 1). Then, two steps taken together allow to transfer the thumb loops to the wrists (pictures 99a–99k).

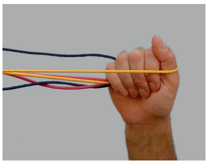
Step 2: Distally, insert 2345 into 1 loops. 2345 grasp $1f$, 2 loops and 5 loops. Pass $1f$ to the dorsal side of the hands while releasing 1, place then hands facing each other (pictures 99a–99h).

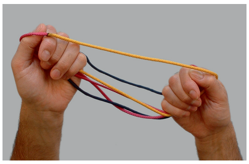
Step 3: 1 pick up lower $2n$ in order to transfer former 1 loops to the wrist (pictures 99h–99k).

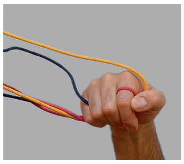

99a – Opening A

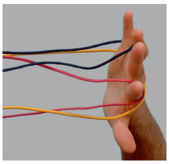

99b

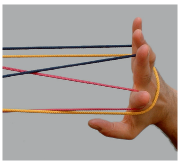

99c

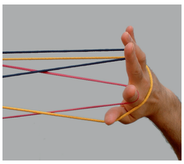

99d

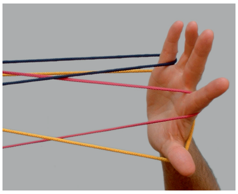

99e


99f

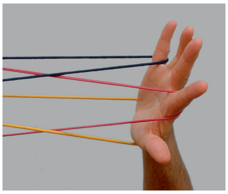

99g


99h – End Step 2


99i



99j



99k – End Step 3

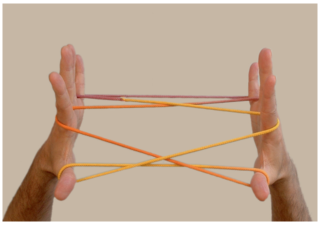
This is how, in several steps, thumb loops 1∞ (yellow) are rotated 180° anticlockwise (to an observer located on the left side of the practitioner), and are transferred to the wrists.

When a loop carried by a Functor F is rotated 180° anticlockwise "for an observer located on the left side of the practitioner", Storer notes: $> F\infty$ ($< F\infty$, if the rotation is performed clockwise.)

The movements of 1∞ mentioned above can then be summarized by the sequence:

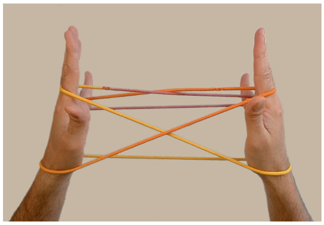
$\underline{O}.A :< 1\infty : \overrightarrow{1\infty} \longrightarrow w$, that I will note simply as $\underline{O}.A :< \overrightarrow{1\infty} \longrightarrow w$

By disregarding the hands, the following diagram demonstrates that the operations described above lead to a configuration equivalent to the one obtained by rotating thumb loops 1∞ anticlockwise of 180° (for an observer located on the left side of the practitioner) and by placing them again on their original fingers.



$\underline{O}.A :< 1\infty$

$\Leftrightarrow$

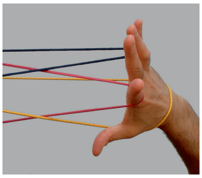


$< \overrightarrow{1\infty} \longrightarrow w$

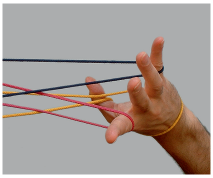
The point is actually to rotate the thumb loops and transfer them to the wrist in order to allow the thumbs to operate freely. The procedure continues through the following step:

Step 4: Pass 1 proximal to all intermediate strings. Proximally, insert 1 into 5 loops. Pick up $5f$ and return to position. Release 5 (pictures 100a–100h).

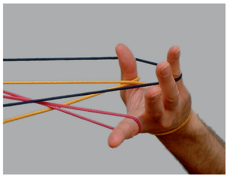
The effect of this succession of operations is to pass little finger loops 5∞ (black) under wrist loops $w\infty$ (yellow). Also, during this movement, 5∞ are rotated 360° clockwise. Then, the latter loops are transferred temporarily to the thumbs before continuing their movement. This is symbolized: $\gg \underleftarrow{\underline{5\infty}}\,(w\infty)$.



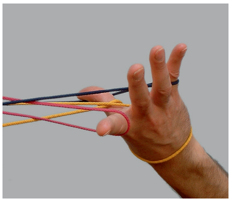
100a



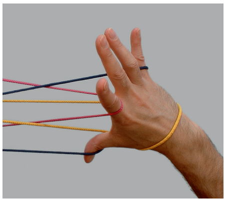
100b



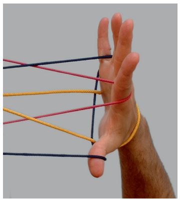
100c



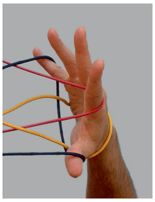
100d



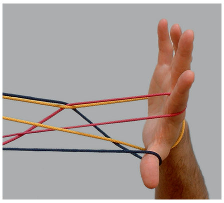
100e



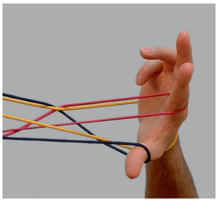
100f



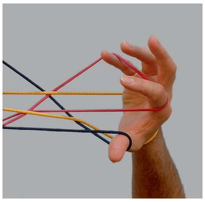
100g



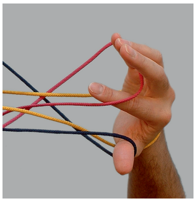
100h – End Step 4



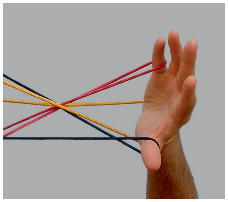
100i



100j



100k

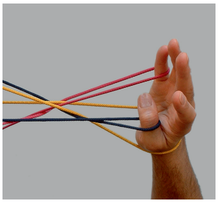


100l – End Step 5

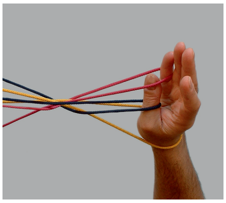
From this stage, step 5 consists in transferring index loops 2∞ to the little fingers (pictures 100i–100l). The procedure continues through the following two steps:

Step 6: Proximally, insert 1 into 5 loops. 1 pick up $5n$ and return to position (pictures 100m–100o).

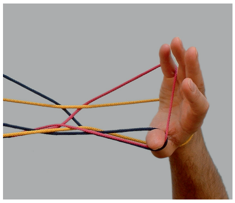
Step 7: 2 pick up proximal $1f$, then 1 press against the side of 2 to trap the string that runs from 1 to 2 and the string that runs from 1 to 5. Finally, the wrists begin to rotate (pictures 100p–100r).



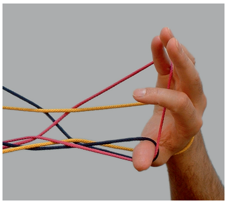
100m

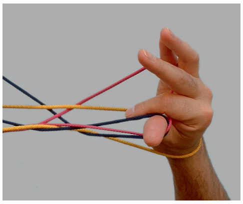


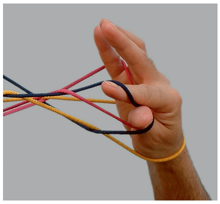
100n



100o – End Step 6


100p

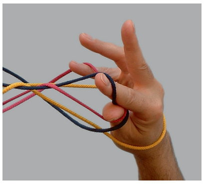

100q

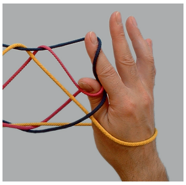

100r – End Step 7

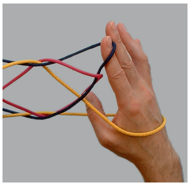
One can see, in pictures 100m–100r, that original little finger loops 5∞ (black), now carried by the thumbs, pass over wrist loops $w\infty$ (yellow), then, from below, through original index loops 2∞ (red), now carried by little fingers. This will be encoded: $\overrightarrow{5\infty}\ (w\infty) : \underrightarrow{5\infty} \uparrow (2\infty)$.

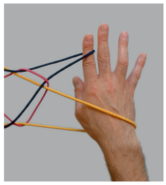
The procedure ends like this:

Step 8: Release 5, then release 1 while rotating the hands, turning the palms away (pictures 100s–100v).[6]


100s


100t


100u


100v – End Step 8

So, at the end of the process, original index loops 2∞ (red) are released and original little finger loops 5∞ (black) are transferred to the indices. This can be written: $\Box 2 : \overrightarrow{5\infty} \longrightarrow 2$.

Finally, the heart-sequence of *Kapiwa* is given by

$$\underline{O}.A : < \overrightarrow{1\infty} \longrightarrow w : >> \underleftarrow{5\infty}\,(w\infty) : \overrightarrow{5\infty}\ (w\infty) : \underrightarrow{5\infty} \uparrow (2\infty) : \Box 2 :$$
$$\overrightarrow{5\infty} \longrightarrow 2 \mid$$

This formula symbolizes the movement of 5∞, passing successively around wrist loops $w\infty$ and through index loops 2∞. Therefore, the procedure *Kapiwa* belongs to Group I.

6.3.2 Comparison of Kapiwa and Jasytata

Remember the heart-sequence of *Jasytata*:

[6] See also the procedure *Kapiwa* in the accompanying website (Double-Sided Lozenge Family).

$$\underline{O}.A :\ \underrightarrow{1\infty}\,(5\infty) :\ \overleftarrow{1\infty}\,(5\infty) : \ll\ \underleftarrow{1\infty} \uparrow (2\infty) :\ \square 2\ |$$

According to the previous section, *Kapiwa* and *Jasytata* belong to the same Group I.

Now consider the following two sub-sequences X and Y of the heart-sequences of *Kapiwa* and *Jasytata* respectively.

$$\underline{O}.A :\ <\ \overrightarrow{1\infty} \longrightarrow w :\ \underbrace{\underleftarrow{5\infty}\,(w\infty) : \overrightarrow{5\infty}\ (w\infty) :>>\ \underrightarrow{5\infty} \uparrow (2\infty)}_{X}\ :\ \square 2 :$$

$$\overrightarrow{5\infty} \longrightarrow 2\,|\ \ (Kapiwa)$$

$$\underline{O}.A :\ \underbrace{\underrightarrow{1\infty}\,(5\infty) :\ \overleftarrow{1\infty}\,(5\infty) : \ll\ \underleftarrow{1\infty} \uparrow (2\infty)}_{Y}\ :\ \square 2\,|\ \ (Jasytata)$$

Let us now focus on the sub-sequence X within *Kapiwa*'s heart-sequence:

$$X = \underleftarrow{5\infty}\,(w\infty) : \overrightarrow{5\infty}\ (w\infty) : \gg\ \underrightarrow{5\infty} \uparrow (2\infty)\,.$$

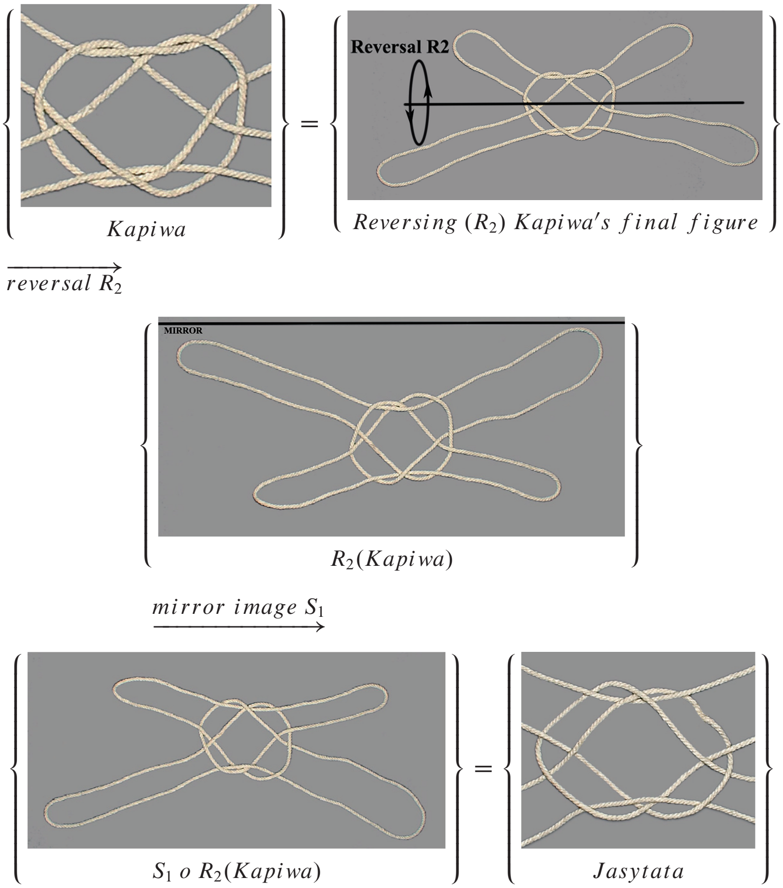
Wrist loops $w\infty$ were originally carried by the thumbs. Remember that the point was to transfer the thumb loops to the wrist in order to let the thumbs operate freely. Therefore, we can substitute 1∞ to $w\infty$ without changing the "spirit" of the sub-sequence X.

Thus, sub-sequence $X \iff \underleftarrow{5\infty}\,(1\infty) : \overrightarrow{5\infty}\ (1\infty) : \gg\ \underrightarrow{5\infty} \uparrow (2\infty)$. It is now easy to compare the sub-sequences X and Y.

Sub-sequence Y: $\underrightarrow{1\infty}\,(5\infty) :\ \overleftarrow{1\infty}\,(5\infty) : \ll\ \underleftarrow{1\infty} \uparrow (2\infty)$

Sub-sequence $X \iff \underleftarrow{5\infty}\,(1\infty) : \overrightarrow{5\infty}\ (1\infty) : \gg\ \underrightarrow{5\infty} \uparrow (2\infty)$

The comparison of these sub-sequences clearly reveals that the moves of the loops involved in sub-sequence X are the mirror moves of the loops in Y. This implies that *Jasytata*'s final figure should be the reflection of the final figure of *Kapiwa* with respect to a plane perpendicular to the figures' plane. Actually, it is not exactly the case. This is due to the way by which the final figures are presented. For *Kapiwa*, the loops of the wrist come from the loops of the thumbs. If the thumbs had kept these loops, they would have pointed down in order to present the final figure in a similar fashion. On the other hand, *Jasytata*'s final figure is presented with thumbs pointing up. Therefore, if we lay out the figures (as we have previously mentioned, i.e. projection in a plane keeping the practitioner's viewpoint) and reverse (Reversal R_2) *Kapiwa*'s final figure before looking at the final figure in a mirror (Reflection S_1), we can see that the latter image is identical to *Jasytata*'s final figure.



I will summarize this by writing down: $S_1 \circ R_2(Kapiwa) = Jasytata.$

By comparing the final figures of *Kapiwa* and *Jasytata*, one can see that all the crossings are reversed from one figure to the other. This implies that the final figure of *Jasytata* is the image of the final figure of *Kapiwa* under a reflection with respect to a plane parallel to the figure's plane. This remark is consistent with the fact that the composite transformation $S_1 \circ R_2$ is the reflection S_3. Furthermore $Kapiwa = R_2 \circ S_1\ (Jasytata)$, given that $Jasytata = R_3(Niu)$ we have $Kapiwa = R_2 \circ S_1 \circ R_3(Niu) = R_2 \circ R_3 \circ S_1\ (Niu) = R_2 \circ R_3 \circ R_1\ (Niu) = Niu$

6.3.2.1 Summary

Niu and *Estrella* belong to Group II, whereas *Pu kava*, *Jasytata* and *Kapiwa* all belong to Group I. The final figures of *Niu*, *Pu kava*, *Jasytata*, *Estrella* and *Kapiwa* can be obtained one from another by considering the transformations R_2 and R_3 (reversals) according to the following formulae.

$$\textit{Niu} = \textit{Estrella} = \textit{Kapiwa} \;\; \textit{Jasytata} = R_3(\textit{Niu}) \;\; \textit{Pu kava} = R_2(\textit{Niu})$$

Moreover, as shown above in Sect. 5.3.2, the procedure *Pseudo-Niu* is such that *Pseudo-Niu*$= R_1(Niu)$; however I have not, so far, found *Pseudo-Niu* neither in the field nor in the ethnographical papers on the subject. The set of final figures *Niu*, *Pu kava*, *Jasytata*, *Pseudo-Niu* is the Orbit of *Niu* under the action of the group of transformation G previously defined.

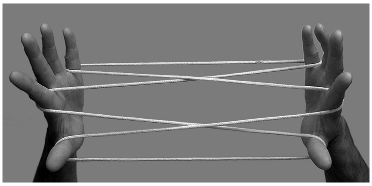
The above analysis shows that all the final figures of *Niu*, *Pu kava*, *Jasytata*, *Estrella*, *Kapiwa* and Pseudo-*Niu* are the same (crossing included) modulo a reversal R_1, R_2 or R_3. Then, a major question comes to mind: is this phenomenon occurring for any final figure of a "double-sided lozenge" string figure algorithm starting with Opening A? An example extracted from anthropological literature will give evidence of the contrary.

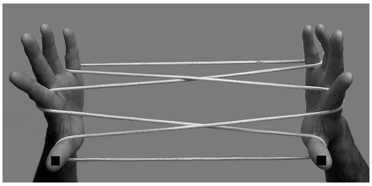
6.4 *Na tifai* from the Tuamotus

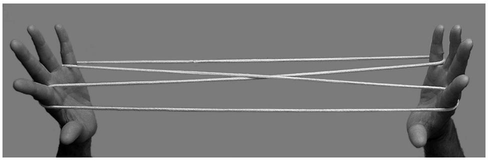
Na tifai (turtles) is a string figure stemming from Tuamotus, French Polynesia. It was collected by anthropologist Kenneth P. Emory about 80 years ago and published in 1979 by Honor Maude (Maude and Emory 1979, pp. 1–6). Actually, it is the making of three different string figures that are described under the name *Na tifai*. The first and the second one are exactly the procedures detailed above as *Niu* and *Pu kava* respectively. The third one is particularly interesting for our purpose. The final figure displayed in this case cannot be obtained as the image of the previously discussed double-sided lozenge figures, under the transformations S_i, R_i of the group G. In the following, I will refer to this third case as *Na tifai*. The discussion below will allow to understand the phenomenon. Furthermore, the analysis of the heart-sequence of *Na tifai* will show that it can be seen as a string figure algorithm belonging to Group II.

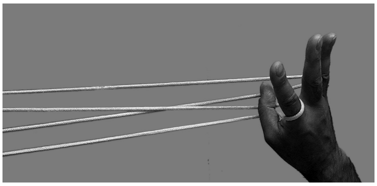
6.4.1 The Beginning of Na tifai

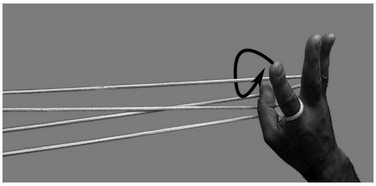
Na tifai begins with Opening A. Then, a sub-procedure put the string in a configuration that I note *Conf*(B), which is the second "normal position" of the procedure *Na tifai*. Pictures 101a–101g detail the "Passage" from Opening A to *Conf*(B).

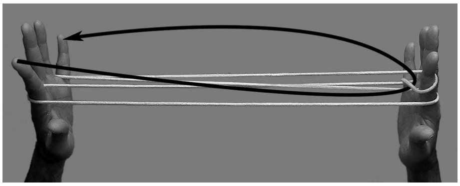

101a

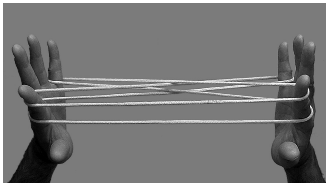

101b


101c

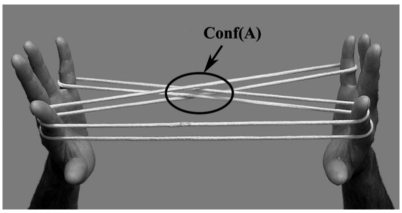

101d


101e

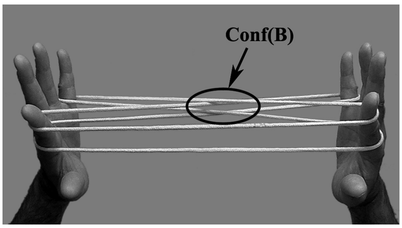

101f


101g

Conf (B) is actually very close to the second normal position, that I call *Conf* (A), of the procedure "Ten Men" described in Part I.[7] The difference between *Conf* (A) and *Conf* (B) lies in the way by which the far strings of upper index loops $u2\infty$ cross each other. The crossings made by the upper right and left far index strings ($uR2f$ and $uL2f$) are different (pictures 102a and 102b). These two configurations will be of fundamental importance for the following discussion on *Na tifai*.



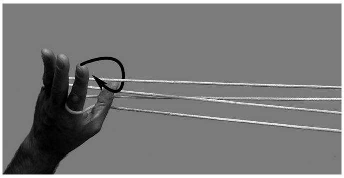
102a – Conf(A): $uL2f$ passing above $uR2f$



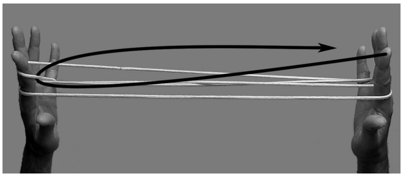
102b – Conf(B): $uL2f$ passing under $uR2f$

[7] See Sect. 3.2.2.1, picture 14f.

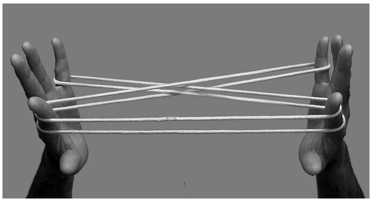
Procedure “Ten Men” has been observed throughout Oceania with some variations. These variations mainly concern the passage from the first normal position (reached through Opening A) to the second one, which is either $Conf(A)$ or $Conf(B)$. In summer of 2005, I recorded such a variation called *Au kape* (taro leaf) on Ua Pou Island, Marquesas.[8] *Au kape* begins as *Na tifai* until getting the configuration $Conf(B)$ (pictures 101a–101g). Although procedures *Au kape* and “Ten Men” are the same from $Conf(B)$ (resp. $Conf(A)$) to the final figure, the passages from Opening A to $Conf(B)$ (resp. $Conf(A)$) are very different from one another. Notice that the configuration $Conf(A)$ is likewise obtained from Opening A, by releasing the thumbs as for $Conf(B)$ (pictures 101a–101c), then implementing similar operations but to the left hand instead of the right one (pictures 103a–103c). This movement has been described in the ethnography, for instance in Compton (1919, p. 218).



103a



103b



103c

In a similar way, when permuting the use of the left and right index in steps 3 and 4 of procedure “Ten Men”,[9] it is $Conf(B)$ which is reached instead of $Conf(A)$. For instance, this permutation can be found in procedure *Salibu* (mirror), that I have personally collected in the Trobriand Islands.[10]

To be able to write down the heart-sequence of *Na tifai*, we first need to determine the heart-sequence of the sub-procedure above, which allows to pass from $Conf(\underline{O}.A)$ to $Conf(B)$. As we will see below, it is actually a difficult point to work out. The difficulty comes from the operations described in pictures 101d–101g above: after releasing thumb loops 1∞ of $Conf(\underline{O}.A)$, the goal of theses operations is to reconstitute a pair of loops which will be carried by the indices in distal

[8]This procedure can also be found as *Koukape* in Handy (1925, p. 29).

[9]See Sect. 3.2.2.1.

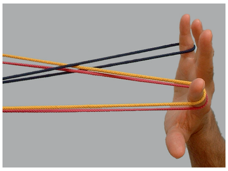
[10]See this procedure in the accompanying website (*Kaninikula* corpus/54.*Salibu*).

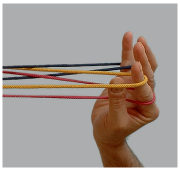
position ($u2\infty$). At first sight, it doesn't seem easy to formalize the consequence of these operations in terms of movement of loops passing around or through another. While trying to get a "passage" between $Conf(\underline{O}.A)$ and $Conf(B)$ or $Conf(A)$ based on manipulations of loops—without deleting or creating any loop—I have first discovered such a "passage" between $Conf(A)$ and $Conf(\underline{O}.A)$.

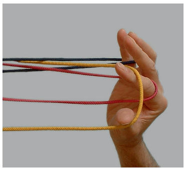
The following subsections are technically difficult and not absolutely essential to continue the reading of this book. It is then possible to jump directly to Sect. 6.4.5.2.

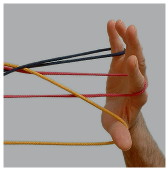
6.4.2 *From Conf*(A) *to Conf*(O̲.A)

One can get $Conf(\underline{O}.A)$ from $Conf(A)$ without either creating or deleting new loops. Pictures 104a–104k show a method to do so. The operations illustrated below are performed on the right hand and need also to be done on the other hand. First, upper index loops $u2\infty$ (yellow) are transferred to the thumb (pictures 104a–104d): formally, $\overleftarrow{u2\infty} \to 1$.


104a – Conf(A)


104b


104c

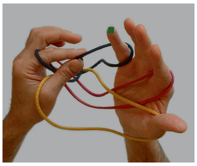

104d

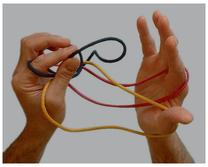
Then, both little finger loops 5∞ (black) and index loops 2∞ (red) are released and exchanged. More precisely, little finger loop 5∞ (black) passes over index loop 2∞ (red); the latter is rotated 180° clockwise and transferred to the little finger. Formally, $< \underrightarrow{2\infty} \to 5$ (pictures 104e–104h). As for the little finger loops 5∞ (black), it is rotated clockwise and transferred to the index. Formally, $< \overleftarrow{5\infty} \to 2$ (pictures 104i–104k).

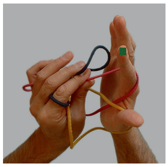
The two previous transfers can be theoretically done simultaneously. Therefore, we will write down $\left\{\begin{array}{c} < \underrightarrow{2\infty} \to 5 \\ < \overleftarrow{5\infty} \to 2 \end{array}\right\}$.

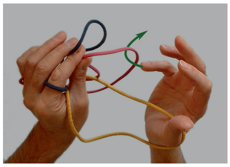
The heart-sequence of the passage from $Conf(A)$ to $Conf(\underline{O}.A)$ can be written as follows:

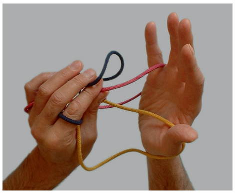
$$\underline{O}.A \Leftrightarrow Conf(A) : \overleftarrow{u2\infty} \to 1 : \left\{\begin{array}{c} < \underrightarrow{2\infty} \to 5 \\ < \overleftarrow{5\infty} \to 2 \end{array}\right\} \;|$$

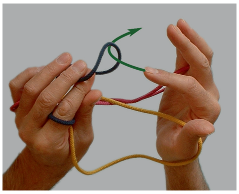

104e

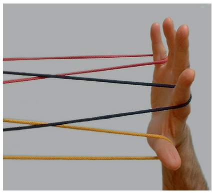

104f


104g


104h


104i


104j


104k – $Conf(\underline{O}.A)$

6.4.3 *From Conf*(O.A) *to Conf*(A)

Conversely, it is obviously possible to return to $Conf(A)$ simply by performing the opposite transfers. Formally, according to the formula

$$\underline{O}.A \Leftrightarrow Conf(A) : \overleftarrow{u2\infty} \to 1 : \left\{ \begin{matrix} < 2\infty \to 5 \\ \rightleftarrows \\ < 5\infty \to 2 \end{matrix} \right\} \mid$$

we need to cancel the following sequence

$$\overleftarrow{u2\infty} \to 1 : \left\{ \begin{matrix} < 2\infty \to 5 \\ \rightleftarrows \\ < 5\infty \to 2 \end{matrix} \right\} \mid$$

to return to $Conf(A)$ from $Conf(\underline{O}.A)$. This can be done through the sequence:

$$\underline{O}.A : \left\{ \begin{matrix} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{matrix} \right\} : \overrightarrow{1\infty} \to 2 \mid \Leftrightarrow Conf(A).$$

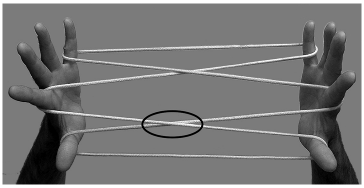
6.4.4 *Starting from Conf*(B)

While trying to work out a passage between $Conf(B)$ and $Conf(\underline{O}.A)$, using basic operations on loops, it seems that we inevitably put the string in a spatial configuration that is somewhat similar to $Conf(\underline{O}.A)$, which differs from it on a single crossing only. I note this configuration $Conf(\underline{O}.A)^*$ (pictures 105a and 105b). More precisely, starting with $Conf(B)$ instead of $Conf(A)$, the sequence

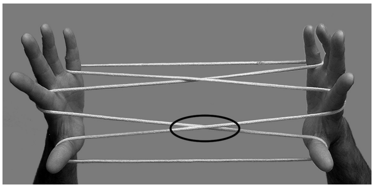
$$\overleftarrow{u2\infty} \to 1 : \left\{ \begin{array}{c} < 2\infty \to 5 \\ \rightleftarrows \\ < 5\infty \to 2 \end{array} \right\} \mid$$

previously described (passage from $Conf(A)$ to $Conf(\underline{O}.A)$) leads to a spatial configuration which differs from $Conf(\underline{O}.A)$ on the crossing between $R1f$ and $L1f$ strings only.

Formally, we have $Conf(\underline{O}.A)^* = Conf(B) : \overleftarrow{u2\infty} \to 1 : \left\{ \begin{array}{c} < 2\infty \to 5 \\ \rightleftarrows \\ < 5\infty \to 2 \end{array} \right\} \mid$



105a – $Conf(\underline{O}.A)^*$



105b – $Conf(\underline{O}.A)$

It is obviously possible to get back to $Conf(B)$ from $Conf(\underline{O}.A)^*$: We proved above that

$$Conf(A) = \underline{O}.A : \left\{ \begin{array}{c} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2 \mid$$

So, for the same reason, we have

$$Conf(B) = Conf(\underline{O}.A)^* : \left\{ \begin{array}{c} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2 \mid .$$

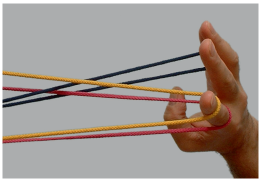
Although starting with Opening A, the procedure *Na tifai* is connected to $Conf(\underline{O}.A)^*$. As we will see below, the part of the *Na tifai* heart-sequence which follows $Conf(\underline{O}.A)^*$ is very close to Estrella’s previously analysed heart-sequence. So, it is its connection to $Conf(\underline{O}.A)^*$ which causes that *Na tifai*’s final figure cannot be obtained as the transformation of *Niu*’s final figure under neither R_1, R_2, nor R_3.

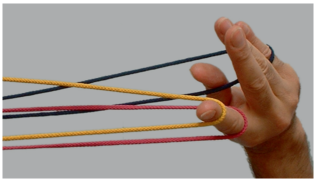
6.4.5 Heart-Sequence of Na tifai

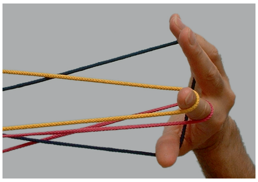
After passing through $Conf(B)$ a few operations allow to display the expected “double-sided lozenge”. The steps are illustrated by the following pictures, focusing on what happens to the right hand, given that both hands operate symmetrically.[11]

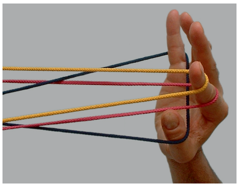
[11] See also the procedure *Na tifai* in the accompanying website (Double-sided Lozenge Family).

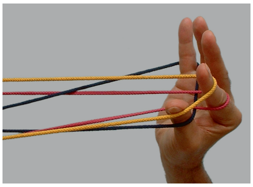
Step 1: Opening A
Steps 2–5: Take up the string into $Conf(B)$ (picture 106a).
Step 6: Proximally, 1 pick up $5n$ and return (pictures 106a–106c).
Step 7: 1 pick up upper $2n$ and return (pictures 106d and 106e).
Step 8: Navaho 1 (pictures 106f and 106g).
Step 9: Release upper 2 and 5 loops. Extend (pictures 106h–106l).

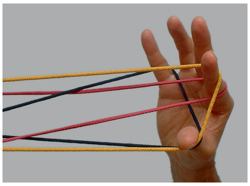

106a – Conf(B)

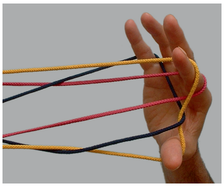

106b

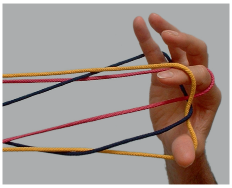

106c – End Step 6

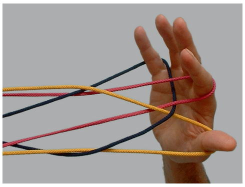

106d

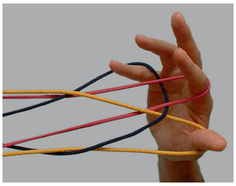

106e – End Step 7

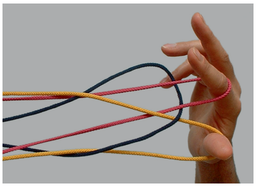

106f

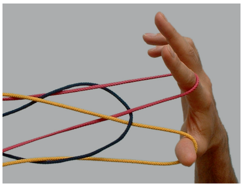

106g – End Step 8


106h


106i


106j


106k

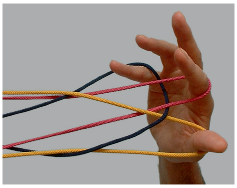

106l

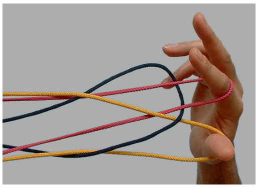
The goal of the previous enlargement (step 6, pictures 106a–106c) is to make easier the insertion of upper index loops $u2\infty$ (yellow) through little finger loops 5∞ (black) (pictures 106d–106i). This insertion occurs through the sub-procedure Navaho (step 8, pictures 106f and 106g).

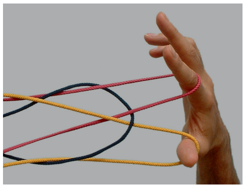
Upper index loops $u2\infty$ is then released in order to complete the insertion of these loops from above into little finger loops 5∞ (black), finally transferred to the thumbs (pictures 106h and 106i). The full sequence can be summarized as:

$$Conf(B) : \underrightarrow{u2\infty}\,(l2\infty) : \overrightarrow{u2\infty} \downarrow (5\infty) : \underrightarrow{u2\infty} \to 1$$

Then, the release of the little fingers makes the "double-sided-lozenge" appear.
This is encoded: $\square 5 \mid$.


106j


106k


106l

Starting from *Conf*(B) the heart-sequence of *Na tifai* is given by:

$$Conf(B) : \underrightarrow{u2\infty}\,(l2\infty) : \overrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \to\ 1 :\ \square 5 \mid$$

According to the previously obtained formula

$$Conf(B) =\ Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{array} \right\} :\ \overrightarrow{1\infty} \to 2 \mid$$

and putting the two formulae together, we get:

$$\underbrace{Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2\ \mid}_{Conf(B)}$$

$$\underbrace{\underrightarrow{u2\infty}\,(l2\infty) : \overrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \to\ 1 :\ \square 5 \mid}_{Second\ part\ of\ Na\ Tifai} \tag{6.1}$$

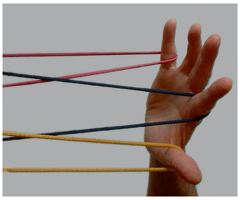
Let us now rewrite the latter formula in a simpler form. In the second part of this formula, according to the transfer $\overrightarrow{1\infty} \to 2$ indicated in the first one, we see that $u\,2\infty$ comes from the original 1∞. In a same way, in the second part, 5∞ comes from the rotated original 2∞ according to the rotation and the transfer $> \overrightarrow{2\infty} \to 5$ occurring in the first part of the formula. Therefore, in this context, omitting the transfers $\overrightarrow{1\infty} \to 2$ and $\overrightarrow{2\infty} \to 5$ of the first part, $\overrightarrow{u2\infty} \downarrow (5\infty)$ becomes $\overrightarrow{1\infty} \downarrow (2\infty)$. And the release $\square 5$ at the end of the formula (6.1) becomes $\square 2$. So the following part

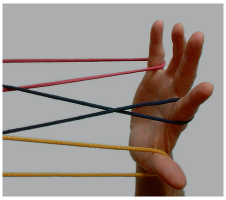
$$Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2 : [\ldots] : \overrightarrow{u2\infty} \downarrow (5\infty) : [\ldots] : \square 5 \mid$$

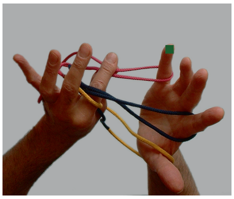
of the formula (6.1) becomes

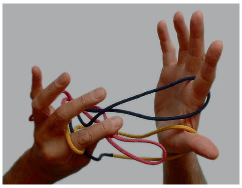
$$Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > \underleftarrow{5\infty} \to 2 \\ > 2\infty \end{array} \right\} : [\ldots] : \overrightarrow{1\infty} \downarrow (2\infty) : [\ldots] : \Box 2 \mid$$

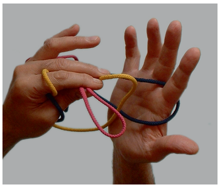
According to the transfer $> \underleftarrow{5\infty} \to 2$ in the first part of the formula (6.1), we see that $l2\infty$ comes from 5∞. We have already seen that $u2\infty$ comes from the original 1∞. So, $\underrightarrow{u2\infty}\ (l2\infty)$ in the second part means that original thumb loops 1∞ need to pass under original little finger loops 5∞ before being inserted into 2∞. Formally, we need $\underrightarrow{1\infty}\ (5\infty)$. The pictures 107a–107f illustrate how to do so. After rotating index loops 2∞ (black—pictures 107a and 107b), one can pass little finger loops 5∞ (red) under index loops 2∞, and over thumb loops 1∞ (yellow) (pictures 107c and 107d). Thumb loops 1∞ (yellow) are then inserted from above into index loops 2∞ (pictures 107e and 107f).

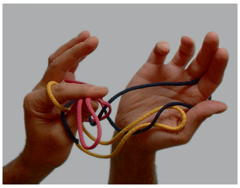

107a – Opening A


107b


107c


107d


107e


107f

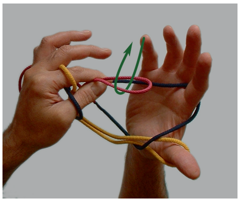
So formally, the part

$$> \underleftarrow{5\infty} \to 2 : [\ldots] : \underrightarrow{u2\infty}\ (l2\infty) : \overrightarrow{u2\infty} \downarrow (5\infty)$$

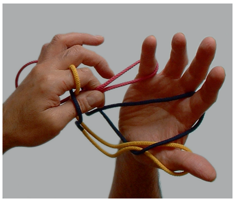
of the formula (6.1) becomes

$$> \underleftarrow{5\infty}(2\infty) : \underrightarrow{1\infty}\ (5\infty) : \overrightarrow{1\infty} \downarrow (2\infty)$$

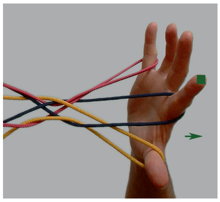
The original 5∞ (red) and 1∞ (yellow) can now return to their original fingers (pictures 107g and 107h).



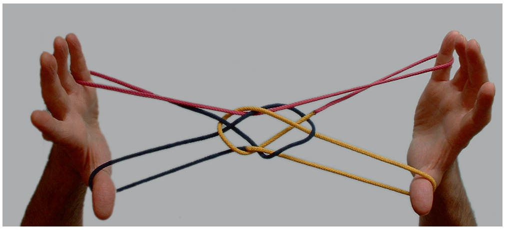
107g



107h



107i



107j – *Na tifai*'s final figure

To get the final figure of *Na tifai* the latter sequence needs to be performed on the other side, the index loops released and the string extended (pictures 107i and 107j). So, the formula (6.1) above is equivalent to the following sequence:

$$\begin{aligned}&\mathit{Conf}\ (\underline{O}.A)^{*} : > 2\infty : > \underleftarrow{5\infty}(2\infty) : \underrightarrow{1\infty}\,(5\infty) : \overrightarrow{1\infty}\downarrow(2\infty) : \overrightarrow{5\infty}\to 5\\ &\qquad : \underleftarrow{1\infty}\to 1 : \square 2\ |\end{aligned}$$

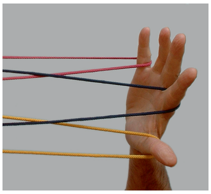
One can observe that, omitting the rotation $> 2\infty$, the insertion $\overrightarrow{1\infty}\downarrow(2\infty)$ can be replaced by $\underrightarrow{1\infty}\uparrow(2\infty)$. So, we get

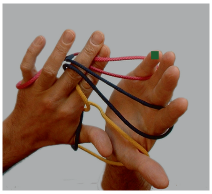
$$\mathit{Conf}\ (\underline{O}.A)^{*} : > \underleftarrow{5\infty}(2\infty) : \underrightarrow{1\infty}\,(5\infty) : \underrightarrow{1\infty}\uparrow(2\infty) : \overrightarrow{5\infty}\to 5 : \underleftarrow{1\infty}\to 1 : \square 2\ | \tag{6.2}$$

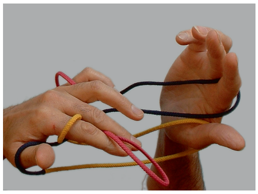
At first sight, the part of this sequence after *Conf* $(\underline{O}.A)^{*}$ seems quite different from the heart-sequences of the previously discussed "double-sided lozenge" string figure algorithms. Actually, the formula (6.2) above can be rewritten in an equivalent one which is comparable to the heart-sequence of Estrella. To do so, one can decide that 5∞ and 1∞ do not return to their original fingers, choosing for instance to transfer them to 1 and 5 respectively. Pictures 108a–108g illustrate this.

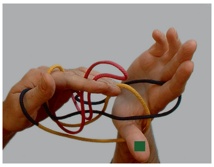
Original little finger loops 5∞ (red) pass under index loops 2∞ (black—pictures 108a–108c) and will be rotated and transferred to the thumb at the end: formally, we have $> \underleftarrow{5\infty} \longrightarrow 1$. So, the latter instruction replaces $> \underleftarrow{5\infty}(2\infty) : [\ldots] : \overrightarrow{5\infty}\to 5$ in the formula (6.2) above.

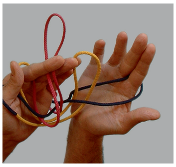
Moreover, the insertion $\underrightarrow{1\infty} \uparrow (2\infty)$ entails predictably the passages $\underrightarrow{1\infty}\,(5\infty)$, since $\underrightarrow{1\infty} \uparrow$ means that 1∞ must pass under all intermediate strings before passing through 2∞. Finally, original thumb loops 1∞ (yellow) are transferred to the little fingers (pictures 108d–108g).

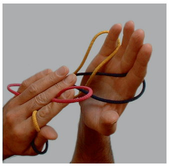

108a

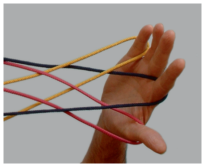

108b


108c


108d


108e


108f


108g

Therefore, the heart-sequence becomes:

$$Conf(\underline{O}.A)^* : \left\{ \begin{array}{c} > \underleftarrow{5\infty} \longrightarrow 1 \\ \underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \longrightarrow 5 \end{array} \right\} : \square\, 2 \,|$$

Remark. The modification of the final transfers ($\underleftarrow{5\infty} \longrightarrow 1$ and $\overrightarrow{1\infty} \longrightarrow 5$) implies that the heart-sequence above actually leads to the reversal $R2$ of *Na tifai*'s final figure.

6.4.5.1 A Variation on *Na Tifai*: Comparison to Estrella

Let us call *Na Tifai*^{A} the variation on *Na tifai* which consists in passing through $Conf(A)$ instead of $Conf(B)$. Note that I did not find this procedure neither in the field nor in ethnographical literature. According to the discussion above the heart-sequence of *Na tifai*^{A} is given by

$$\underline{O}.A : \left\{ \begin{array}{c} > \underleftarrow{5\infty} \longrightarrow 1 \\ \underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \longrightarrow 5 \end{array} \right\} : \square\, 2 \,|$$

It also leads to a "double-sided lozenge". Remember the heart-sequence of Estrella (Chaco, Paraguay):

$$\underline{O}.A : \left\{ \begin{array}{c} < \underrightarrow{1\infty} \rightarrow 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\} : \Box 2 \mid$$

In this sequence the transfer of 1∞ can be done theoretically to 5 instead of 3. Then, we get the sequence

$$\underline{O}.A : \left\{ \begin{array}{c} < \underrightarrow{1\infty} \rightarrow 5 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\} : \Box 2 \mid$$

It appears that the heart-sequence of *Na tifai*^{A} is the mirror process of the heart-sequence of Estrella. Therefore, the final figure of *Na tifai*^{A} is the mirror image of the final figure of Estrella.

6.4.5.2 *Na tifai* in Group I or II?

The previous section demonstrates that the use of $Conf(B)$ within *Na tifai* is the reason for the non-similarity of its final figure with the double-sided lozenges first discussed. Nevertheless, I have demonstrated that the heart-sequence of *Na tifai* is based on the mirror symmetry of the movement of loops occurring in Estrella, but relating to a configuration noted $Conf\ (\underline{O}.A)^*$, which differs from $Conf\ (\underline{O}.A)$ in one simple crossing. Therefore, I shall consider it belonging to Group II.

6.4.6 *Classification in Group I and II*

As mentioned earlier, every double-sided lozenge string figure procedure that I have learnt so far can be classified into either Group I or Group II. Table I in Annex I presents those from Oceania. As seen with the example of *Jasytata*, double-sided lozenge string figures can also be found in collections from South America (Chaco), and also from Central Africa (Zande, West shore of Tanganika), and India (Gujarat). Table II in Annex I gives them according to Group I and II criteria. This brings to light that although the figure "double-sided lozenge" is made all over the world with various methods, only two underlying principles of transformation (Group I or Group II) come up.

As far as I can see, the heart-sequence of a string figure algorithm belonging to Group I is one of the four heart-sequences, "modulo" some transfers of loops, obtained from *Jasytata*'s heart-sequence under the action of a Klein group. This group is composed of the two reflections S_1 and S_2 with respect to the perpendicular planes P_1 and P_2 (picture 109), the symmetry with respect to the line $d = P_1 \bigcap P_2$ and the Identity Id of the three dimensional space.

In the context of Opening A, the "core" of these four heart-sequences are given by

$$Y \equiv \underrightarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty}\,(5\infty) : \underleftarrow{1\infty} \uparrow (2\infty)\ (\textit{Jasytata})$$

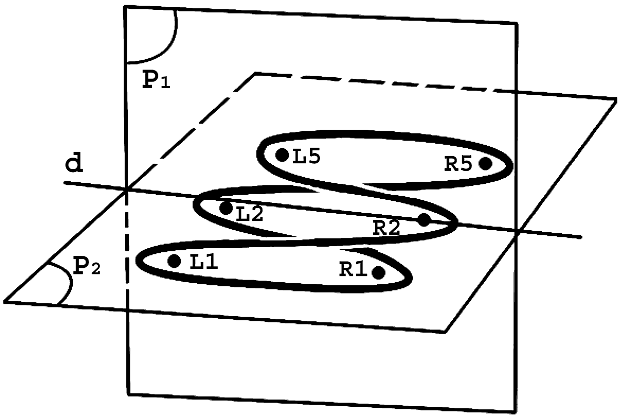
$$S_1(Y) \equiv \underleftarrow{5\infty}\,(1\infty) : \overrightarrow{5\infty}\,(1\infty) : \underrightarrow{5\infty} \uparrow (2\infty)\ (\textit{Kapiwa})$$

$$S_2(Y) \equiv \overrightarrow{1\infty}\,(5\infty) : \underleftarrow{1\infty}\,(5\infty) : \overleftarrow{1\infty} \downarrow (2\infty)\ (\textit{Pu kava})$$

$$S_d(Y) \equiv \overleftarrow{5\infty}\,(1\infty) : \underrightarrow{5\infty}\,(1\infty) : \overrightarrow{5\infty} \downarrow (2\infty)$$

In a similar way, the heart-sequence of a Group I string figure procedure can also be obtained ("modulo" some transfers of loops) through the action of the Klein group on *Niu*'s heart-sequence. Remember that the core of the heart-sequence of *Niu* is

$$\left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \rightarrow 3 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\}$$



109 – Plane projection of the Opening A configuration Perpendicular planes P_1 and P_2 and their intersection

Let us substitute the transfer $\underrightarrow{1\infty} \rightarrow 3$ by $\underrightarrow{1\infty} \rightarrow 5$.

$$N : \left\{ \begin{array}{l} \overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \rightarrow 5 \\ \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \end{array} \right\}$$

It is then easy to determine the heart-sequences obtained through the action of the Klein group. We have:

$$S_2(N) : \left\{ \begin{array}{l} \underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \rightarrow 5 \\ \overleftarrow{5\infty} \downarrow (2\infty) : \underleftarrow{5\infty} \longrightarrow 1 \end{array} \right\} \qquad S_1(N) : \left\{ \begin{array}{l} \overleftarrow{5\infty} \downarrow (2\infty) : \underleftarrow{5\infty} \longrightarrow 1 \\ \underrightarrow{1\infty} \uparrow (2\infty) : \overrightarrow{1\infty} \rightarrow 5 \end{array} \right\}$$

and,

$$S_d(N): \left\{ \begin{array}{l} \underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1 \\ \overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \rightarrow 5 \end{array} \right\}$$

Remember that $S_1(N)$ is the core of the heart-sequence of procedure Pseudo-*Niu* (introduced in Chap. 5), that I have not found so far neither in the field nor in ethnographical literature. According to the fact that the two sub-sequences $\overrightarrow{1\infty} \downarrow (2\infty) : \underrightarrow{1\infty} \rightarrow 5$ and $\underleftarrow{5\infty} \uparrow (2\infty) : \overleftarrow{5\infty} \longrightarrow 1$ within N can be interchanged or performed simultaneously (in theory), we have: $S_2(N) \equiv S_1(N)$ and $S_d(N) \equiv N$.

I define the procedures belonging to Group I (resp. Group II) as "dynamically equivalent" in the sense that their heart-sequences consist in movements of loops which are related to one another under a plane or mirror symmetry. As shown above, when comparing double-sided lozenge final figures, these symmetries (in the movements of loops) throw light on the transformations connecting different final figures. It is likely that these "dynamically" equivalent procedures emerged independently in many different communities. In geographically and culturally distant areas, the mathematical activity which would have consisted in working out algorithms led to similar procedures that were similar in substance but different in form.

Tables I and II in Annex I show that some corpora of string figures contain one representative of each Groups I and II. Such a phenomenon occurs in the Chaco (*Jasytata* and Estrella), on Nauru Island (*Ekwan* III, *Eongatubabo*), on the Tuamotus (*Na tifai* I, *Na tifai* II) and on the Solomon Islands (*Niu*, *Nepe*). The latter example is particularly interesting. Both string figures *Niu* and *Nepe* (close to *Kapiwa*) were recorded by Raymond Firth in the same small area (Reef Islands, Solomon)[12] in 1928/1929 (Maude 1978, p. 1). Moreover, the final figures of both these procedures are absolutely identical (crossings included). This seems to indicate that some practitioners or creators of string figures worked out two different procedures, based on different heart-sequences, to obtain a "double-sided lozenge". This brings to light the interest that some practitioners had in the procedures (heart-sequence + fingering): if they were only interested in the final figures, they probably would not have tried to find out different procedures to display identical string figures.

6.4.7 *Before Going Further*

We have seen that writing down a heart-sequence consists in rewriting a string figure procedure as a new algorithm, which formalizes the movement of loops,

[12]The Reef Islands are a group of 16 small coral Islands, 80 km away from Santa Cruz Island, eastern Solomon.

ignoring the way fingers operate on them during this procedure. This is guided by the identification of either the sequences of operations on loops which can be theoretically done simultaneously (and thus in any order) or the ones which cannot be switched round.

Different string figure procedures can share exactly the same heart-sequence. When it is not the case, their heart-sequences can be sometimes defined as "equivalent". We have seen that a few transfers of loops from one finger to another do not generally alter the "spirit" of a given heart-sequence. Two heart-sequences can thus sometimes be seen as equivalent, "modulo" some tranfers of loops. I have also suggested to consider as "dynamically equivalent" string figure procedures, the heart-sequences of which can be obtained from one another through symmetries, thus explaining certain symmetry relationship between final figures. These equivalences between heart-sequences enable us to view as similar string figure procedures that are very different at first sight, thus providing a methodology to classify them. The previous study shows furthermore that "dynamically" equivalent procedures can be found in areas that are culturally and geographically distant from one another.

The classification of the double-sided lozenge string figures has been carried out in the context of "Opening A". Many different openings can be found in various corpora of string figures. However, the goal of these sub-procedures is always to obtain the first "stable" configuration, which consists in a taut state of the string with a certain number of loops created on fingers. It is from these configurations that the movements of the loops can be analysed, the heart-sequences written, and a comparative analysis carried out in the context of a particular opening. However, the heart-sequence concept can also be an efficient tool in comparing the various first configurations obtained through different openings, and thus in comparing string figure algorithms which do not start with the same opening. We will come back to that point later, in Part IV.

As we will see in Chap. 9, the elementary operations involved for the making of string figures are generally roughly the same from one cultural area to another, unlike the sub-procedures: the use of certain characteristic sub-procedures makes differences very clear from one corpus to another. A comparative and systematic analysis of the sub-procedures through their heart-sequences would certainly enable them to be classified. The classification of the "double-sided lozenge" string figures suggests that sub-procedures could frequently share the same heart-sequence from one corpus to another. Therefore, the sub-procedures could be classified with a limited number of "groups" (such as Groups I and II). If such were the case, the sub-procedures would be more differentiated, from one corpus to another, by the various fingerings created for the implementation of similar movements of loops. Let us now turn to the transformations occurring in string figure-making and their analysis through heart-sequences.

References

Compton RH (1919) String Figures from New Caledonia and Loyalty Islands. J R Anthropol Inst G B Irel 49:204–236

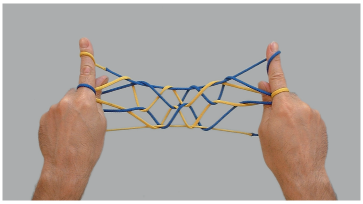
Handy WC (1925) String Figures from the Marquesas and Society Islands. Bishop Museum, Bulletin 18, Honolulu

Maude H (1978) Solomon Island String Figures. Homa Press, Canberra

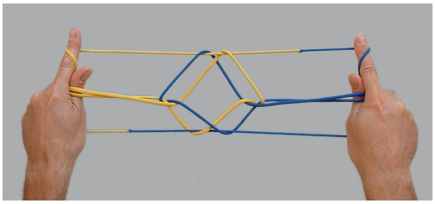
Maude H, Emory K (1979) String Figures of the Tuamotus. Homa Press, Canberra

Chapter 7
Understanding Transformations

In Chap. 3, we have seen that the concept of transformation appears on two different levels throughout the various string figure corpora. First of all, a string figure algorithm is in itself a continuous transformation of a loop of string. Secondly, a final figure is sometimes transformed into another one. The Papuan procedure "Stars and Moon" (Sect. 3.4.2) is an example of such a transformation.



110a – Stars ⟶



110b – Moon

The concept of heart-sequence provides an efficient tool for the understanding of such transformation. In the case of "Stars and Moon", it will be demonstrated that the transformation in question is based on a "deconstruction" of a part of the figure "Stars".

7.1 Deconstruction

7.1.1 From "Stars" to "Moon" Versus "Egg"

The figure "Stars" is the final figure of a procedure often recorded in the Western Pacific.[1] Also, I have personally collected it in the Trobriand Islands under the

[1]In New Caledonia, for instance, Compton found it under the same name "Stars" (Compton 1919, p. 217).

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_7

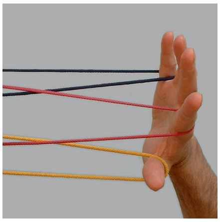
name *Misima* (which is the name of an island in Milne Bay Province, Papua New Guinea).[2] Remember that, in the corpus collected by Shishido and Noguchi in the Highlands of Papua New Guinea (Shishido and Noguchi 1987), the figure “Moon” is also the final figure of a string figure algorithm called “Egg”. Moreover, as we will see below, both procedures “Egg” and “Stars and Moon” start in the same way. The point is then to get a better understanding of the process which allows to display the figure “Moon” (or “Egg”) from the figure “Stars”.

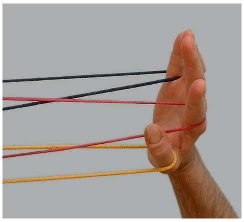
7.1.1.1 Heart-Sequence of “Stars” and “Egg”

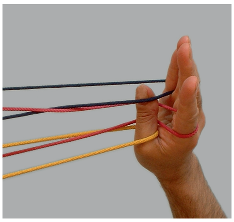
Procedure “Stars and Moon” is performed by the two hands operating simultaneously and symmetrically. The pictures below show the process on the right hand only. After Opening A (Step 1), the goal of the first operations of the procedure is to enlarge little finger loops 5∞ (black one—pictures 111a–111e).

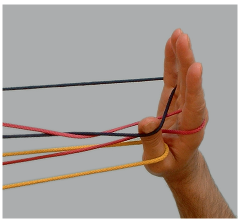
Step 2: Pass 1 distal to 2 loops. Proximally, insert 1 into 5 loops, pick up $5n$ and return (pictures 111a–111e). Proximally, insert 2 into proximal 1 loops, pick up proximal $1f$ and return. Release 1. Extend (pictures 111f–111k).

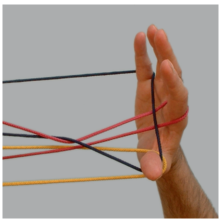
This step allows thumb loops 1∞ (yellow) to be passed through little finger loops 5∞ (black) from below (pictures 111f–111k): formally, $\overrightarrow{1\infty} \uparrow (5\infty)$. The thumbs are then released in order to let their loops complete their insertion through 5∞ (black), and the original 1∞ (yellow) to be transferred to indices (pictures 111i–111k): formally, $\overleftarrow{1\infty} \to 2$. This sequence can then be written $\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \to 2$.

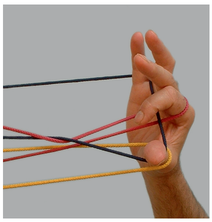

111a


111b

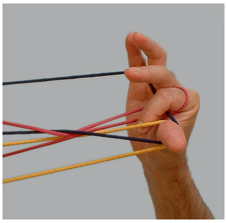

111c

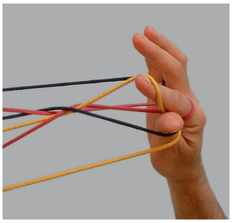

111d

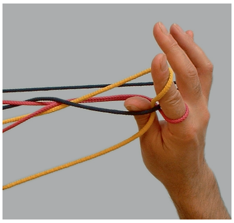

111e

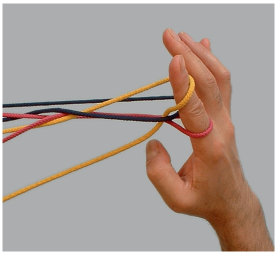

111f

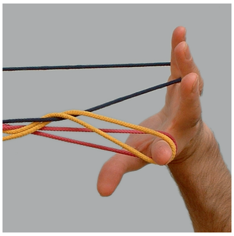
[2]See the procedure 44. Misima in the accompanying website (*Kaninikula* Corpus).


111g


111h


111i

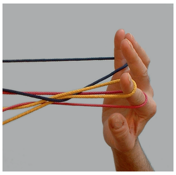

111j

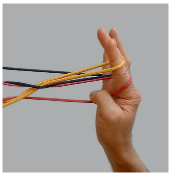

111k – End Step 2

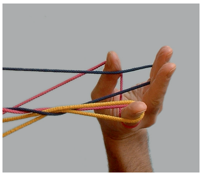
Procedure "Stars" continues through the following step:

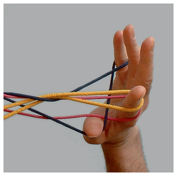
Step 3: Distally, insert 1 into proximal (lower) 2 loops. Pick up $5f$ and return (pictures 111l–111o). Release 5. Extend.

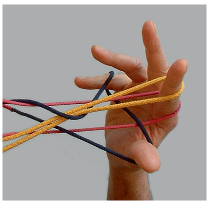
Little finger loops 5∞ (black) are thus inserted from below into lower index loops $l2\infty$ (red) while being rotated 180° anticlockwise, as shown in pictures 111l–111r.

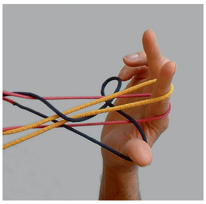

111l

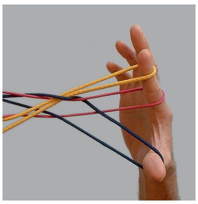

111m


111n


111o


111p


111q

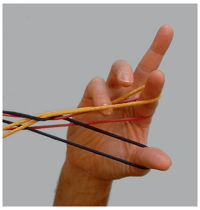

111r – End Step 3

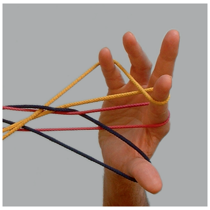
We can see that little finger loops 5∞ (black) are transferred to the thumbs. The heart-sequence of the sequence above is then $\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \rightarrow 1$.

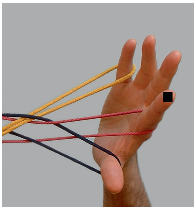
It is from this stage that procedures "Egg" and "Stars and Moon" diverge one another. To get "Egg" from the configuration shown in picture 111r, one needs to transfer upper index loops $u2\infty$ (yellow) to little finger while rotating them 180° anticlockwise ($< u2\infty \rightarrow 5$), and release index loops ($\square 2$).

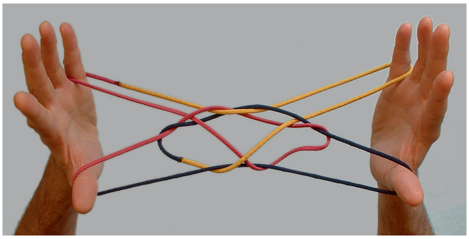
Continuation of "Egg":

Step 4: Distally, insert 5 into upper 2 loops, pick up $2n$. Release upper 2 loops (pictures 112a–112c).
Step 5: Release 2 (picture 112d).

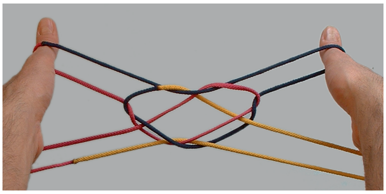

112a

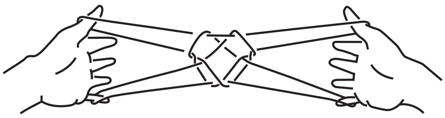

112b

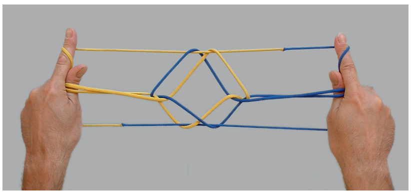

112c – End Step 4

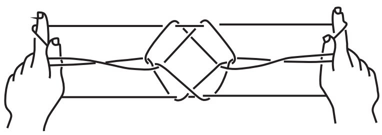

112d – End Step 5

The figure is displayed in pointing the fingers away from you. Working in this way, it is exactly the same figure as "Moon" which is shown to the audience (pictures 112e–112h).


112e – Egg's final figure


112f – Egg (Shishido and Noguchi 1987, p. 51)


112g – Moon


112h – Moon (Shishido and Noguchi 1987, p. 55)

The heart-sequence of "Egg" can be written down

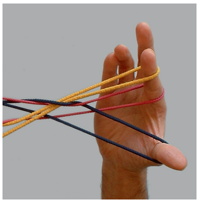
$$\underbrace{\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \to 2}_{Pictures\ 111a-k} \ : \underbrace{\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \to 1 :}_{Pictures\ 111l-r}$$

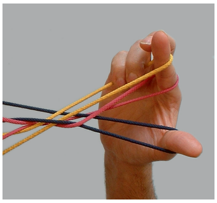
$$\underbrace{< u2\infty \to 5 : \square 2}_{Continuation\ to\ \text{“}Egg\text{”} : Pictures\ 112a-e} \qquad |$$

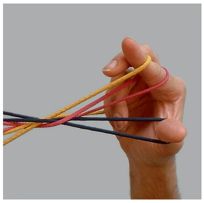
Let us come back to the description of the making of "Stars", from the stage shown in picture 111r (end step 3):

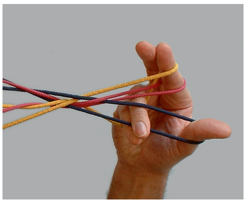
Step 4 (of "Stars"): 5 and 4 hook down distal $2f$. Five and four seize $1n$ and return. Release 1 (pictures 113a–113h).

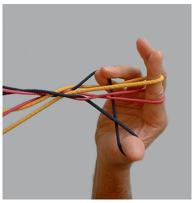
It is plain to see that the goal of these operations is to pass thumb loops 1∞ (black) under lower index loops $l2\infty$ (red), and to insert them from below into upper index loops $u2\infty$ (yellow), and finally transfer them to the little fingers.


113a


113b


113c


113d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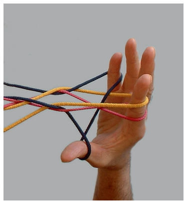
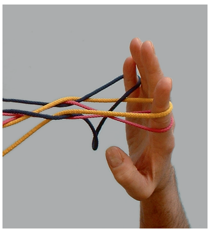
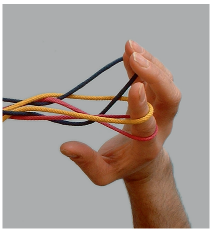

113f


113g


113h – End Step 4

Thumb loops 1∞ (black) are rotated 180° clockwise during the process. The sequence above (pictures 113a to 113h) can be formalized by the following formula:

$$\underrightarrow{1\infty}(l2\infty) : \underrightarrow{1\infty} \uparrow (u2\infty) : > \overrightarrow{1\infty} \rightarrow 5.$$

The two latter sequences $\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \rightarrow 1$ and $\underrightarrow{1\infty}(l2\infty) : \underrightarrow{1\infty} \uparrow (u2\infty) : > \overrightarrow{1\infty} \rightarrow 5$ put together show the movement of little finger loops 5∞ (black) which return to their initial position. So, theoretically, at the end of the first sequence that we have encoded $\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \rightarrow 1$, the transfer $\overleftarrow{5\infty} \rightarrow 1$ can be omitted. Therefore, the formula

$$\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \rightarrow 1 : \underrightarrow{1\infty}(l2\infty) : \underrightarrow{1\infty} \uparrow (u2\infty) : > \overrightarrow{1\infty} \rightarrow 5$$

becomes

$$< \underleftarrow{5\infty} \uparrow (l2\infty) : > \underrightarrow{5\infty}(l2\infty) : \underrightarrow{5\infty} \uparrow (u2\infty).$$

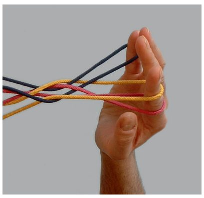
The last transfer is implicit since 5∞ return to little fingers, and not indicated in the sequence. Furthermore, the two consecutive rotations $<$ and $>$ obviously cancel out. So, finally we get

$$\underleftarrow{5\infty} \uparrow (l2\infty) : \underrightarrow{5\infty}(l2\infty) : \underrightarrow{5\infty} \uparrow (u2\infty).$$

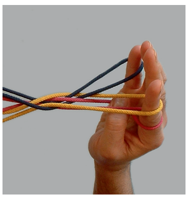
Procedure "Stars" continues through the following step:

Step 5: Distally, insert 1 into proximal index loops, pick up both distal and proximal 2 strings. Navaho 1. Release distal 2 loops. Extend (pictures 113i–113p).

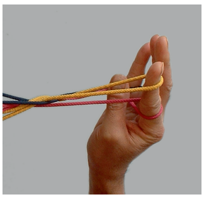
This succession of operations, and especially the sub-procedure Navaho (pictures 113m–113n), imply the insertion, from below, of upper index loops $u2\infty$ (yellow) into the lower ones $l2\infty$ (red).



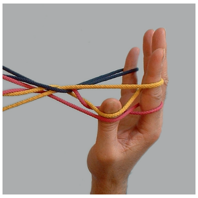
113i

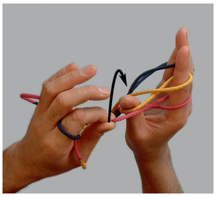


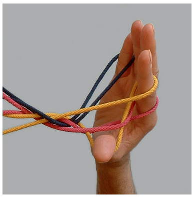
113j

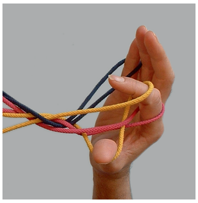


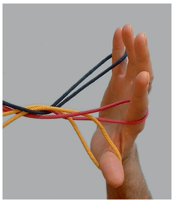
113k


113l


113m – Navaho


113n – Navaho done


113o


113p – End Step 5

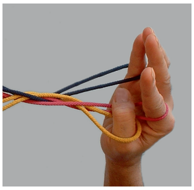
Upper index loops $u2\infty$ (yellow) are rotated anticlockwise during the process and transferred to the thumbs: formally, it comes

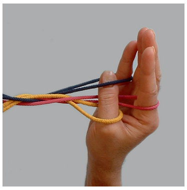
$$\underleftarrow{u2\infty} \uparrow (l2\infty) :> \overleftarrow{u2\infty} \to 1$$

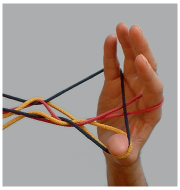
A Caroline Extension is then performed.

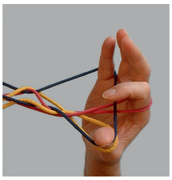
Step 6: Pass 1 distal to 2 loops. Proximally, insert 1 into 5 loops. Pick up $5n$ and return to position. Caroline Extension. Release 1. Extend (pictures 113q–113w).

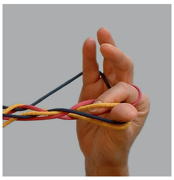
The consequence is the insertion of thumb loops 1∞ (yellow) from below into little finger loops 5∞ (black).

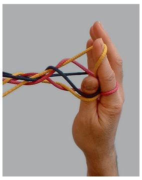

113q

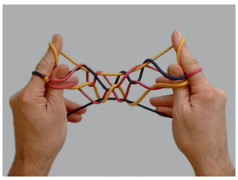

113r


113s


113t – Caroline Extension


113u


113v


113w

We see in the pictures 113q–113w that thumb loops 1∞ (yellow) are actually inserted from below into little finger loops 5∞ (black) while passing above index loops 2∞ (red). Finally, thumb loops 1∞ are transferred to the indices. So, this sequence will be encoded: $\overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2$.

Please note once again that the two latter sequences $\underleftarrow{u2\infty} \uparrow (l2\infty) : > \overleftarrow{u2\infty} \rightarrow 1$ and $\overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2$ can be rewritten, omitting the transfer $\overleftarrow{u2\infty} \rightarrow 1$, as the movement of upper index loops $u2\infty$ (yellow). Formally, the sequence

$$\underleftarrow{u2\infty} \uparrow (l2\infty) : > \overleftarrow{u2\infty} \rightarrow 1 \ : \ \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2$$

can be rewritten as

$$\underleftarrow{u2\infty} \uparrow (l2\infty) : > \overrightarrow{u2\infty} \uparrow (5\infty) : (\overleftarrow{u2\infty} \rightarrow 2)$$

The last transfer $\overleftarrow{u2\infty} \rightarrow 2$ can be omitted in the formula, since loops $u2\infty$ return to the indices. Finally, the heart-sequence of the procedure leading to “Stars” can be written down

$$\underbrace{\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2}_{Pictures\ 111a-k\ (above)} \ : \ \underbrace{\underleftarrow{5\infty} \uparrow (l2\infty) : \underrightarrow{5\infty}(l2\infty) : \underrightarrow{5\infty} \uparrow (u2\infty)}_{Pictures\ 111l-r\ +\ 113a-h\ (above)} \ :$$
$$\underbrace{\underleftarrow{u2\infty} \uparrow (l2\infty) : > \overrightarrow{u2\infty} \uparrow (5\infty)}_{Pictures\ 113i-w\ (above)} \ |$$

and the heart-sequence of “Egg”

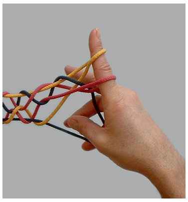
$$\underbrace{\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2}_{Pictures\ 111a-k\ (above)} \ : \ \underbrace{\underleftarrow{5\infty} \uparrow (l2\infty) : < \overleftarrow{5\infty} \rightarrow 1}_{Pictures\ 111l-r\ (above)} :$$
$$\underbrace{< u2\infty \rightarrow 5 : \square 2}_{Continuation\ to\ \text{“}Egg\text{”}\ :\ 112a-e} \qquad |$$

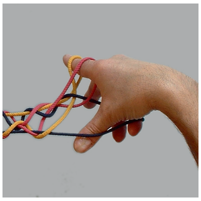
7.1.1.2 Transformation from “Stars” to “Moon”

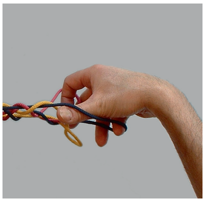
I can now describe and analyse the transformation from “Stars” to “Moon”. We will see that, in this case, the passage from one figure to another happens through the “deconstruction” of the figure “Stars”. Formally, the latter deconstruction implies the deletion of the part of the heart sequence of “Stars” occurring after the sub-sequence $\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2 : \underleftarrow{5\infty} \uparrow (l2\infty)$ leading to the figure "Egg". The transformation goes like this:

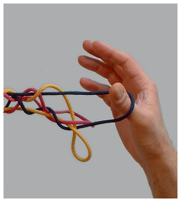
Step 7: Release 1. Proximally, insert 1 into 5 loops, pick up $5n$ and return. Release both 2 and 5 loops.

Little finger loops 5∞ (black) are then transferred to the thumbs under an anticlockwise rotation of the thumbs. At the same time, the indices release their two loops during the movement (pictures 114a–114d).


114a


114b


114c

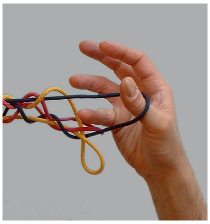

114d – End Step 7

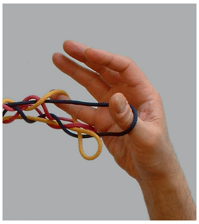
Transformation continued:

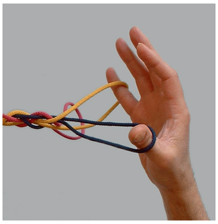
Step 8: Proximally, insert 5 into the former lower 2 loops as indicated in pictures 114e–114g.

Through these operations, the little fingers untangle the result of the sub-sequence $\underleftarrow{u2\infty} \uparrow (l2\infty) :> \overrightarrow{u2\infty} \uparrow (5\infty)$ of "Stars".

Remember that this sub-sequence has allowed, at the end of the procedure "Stars", the insertion of $u2\infty$ (yellow) into $l2\infty$ (red) and 5∞ (black). These insertions are clearly undone through the operation shown in pictures 114e and 114f.


114e

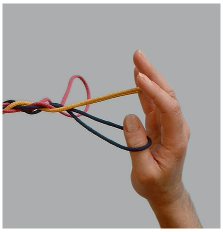

114f

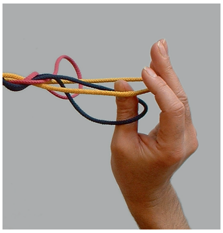

114g

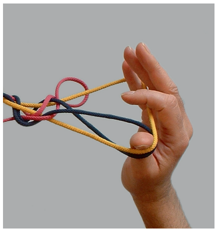
Lower index loops $l2\infty$ (red) are also released during the process, as it is the case for the making of "Egg" described above.

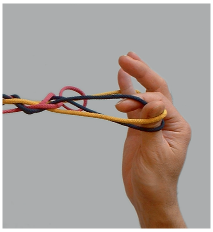
At this stage, the configuration resulting from the sub-sequence $\underrightarrow{5\infty}(l2\infty)$: $\underrightarrow{5\infty} \uparrow (u2\infty)$ of "Stars" will be undone. Remember that the goal of this sub-sequence was to insert 5∞ (black) from below into $u2\infty$ (yellow). This insertion is clearly undone under the Caroline extension shown in pictures 114h–114l.

Step 9: Proximally, insert 1 into 5 loops, pick up $5n$ and return. Caroline Extension (pictures 114h–114l).

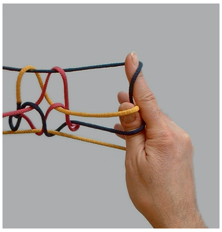

114h


114i


114j


114k

$\longrightarrow$


114l

At this final stage, the two sub-sequences $\underrightarrow{5\infty}(l2\infty) : \underrightarrow{5\infty} \uparrow (u2\infty)$ and $\underleftarrow{u2\infty} \uparrow (l2\infty) :> \overrightarrow{u2\infty} \uparrow (5\infty)$ of "Stars" have been deleted from the heart-sequence of "Stars". Formally, from the heart-sequence of "Stars",

$$\underline{O}.A \;:\; \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \to 2 : \underleftarrow{5\infty} \uparrow (l2\infty) :$$

$$\underbrace{\underrightarrow{5\infty}(l2\infty) : \underrightarrow{5\infty} \uparrow (u2\infty)} : \underbrace{\underleftarrow{u2\infty} \uparrow (l2\infty) :> \overrightarrow{u2\infty} \uparrow (5\infty)} \mid$$

we get: $\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \to 2 : \underleftarrow{5\infty} \uparrow (l2\infty) :$

Remember that at this stage of the original procedure "Stars", the little finger loops were rotated 180° anticlockwise and transferred to the thumbs (formally, $< 5\infty \to 1$) (then, we had omitted this operation in order to simplify the formula—see pictures 111l–111r above).

I have noticed above that lower index loops $l2\infty$ (red) are released during the transformation from "Stars" to "Moon". So, we get the following formula:

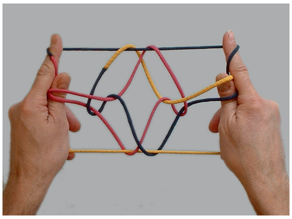
$$\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \to 2 : \underleftarrow{5\infty} \uparrow (l2\infty) : < 5\infty \to 1 : \Box l2\infty$$

If one rotates 180° anticlockwise loops $u2\infty$ (yellow—picture above) and transfers them to the little fingers, before releasing loops $l2\infty$ (which becomes 2∞) and extending the string, we get

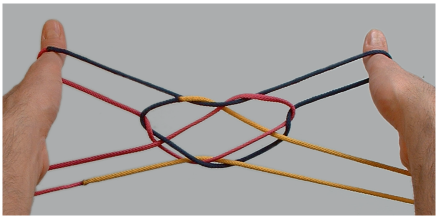
$$\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2 : \underleftarrow{5\infty} \uparrow (l2\infty) : < 5\infty \rightarrow 1 : < u2\infty \rightarrow 5 : \square 2 \mid$$

which is the formula previously given as the heart-sequence of "Egg".

This demonstration has proved that the figure "Moon" results from a deconstruction of the procedure "Stars", allowing to return to the stage from which the figure "Egg" can be displayed. This also explains final figures "Egg" and "Moon" are absolutely identical. The only difference between these two figures lies in the way a pair of loops are held: thumb loops 1∞ within "Egg" (picture 114n—black on the right side) are held by the indices to display "Moon" under a Caroline extension (picture 114m).



114m – Moon



114n – Egg

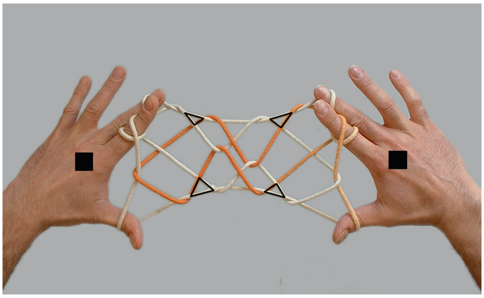
7.1.2 *Another Example*

7.1.2.1 From *Au kape* to a Double-Sided Lozenge

The Marquesan procedure called *Au kape* (taro leaf) differs from the string figure algorithm "Ten Men"[3] on the way it reaches the configuration that I have noted $Conf(B)$.[4] Moreover, *Au kape* begins with the same operations than in *Na Tifai* from the Tuamotus, previously analysed. Therefore, procedure *Na tifai* is almost fully included in procedure *Au kape*, as, in a similar way, "Egg" is included into "Stars and Moon". It is then technically possible, starting from the final figure of "Egg" is included into "Stars and Moon". It is then technically possible, starting from the final figure of *Au kape*, to deconstruct a part of the procedure in order to display the final figure of *Na Tifai* (double-sided lozenge). To do so, one can release both hands and lay out the figure on a plane surface, trying to keep visible the little triangles indicated in picture 115a.

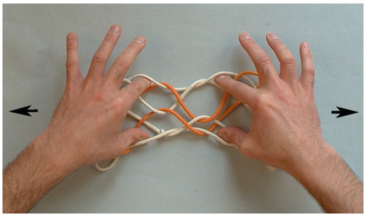
[3]See Sect. 3.2.2.1.

[4]See Sect. 6.4.1 (The beginning of *Na Tifai*).



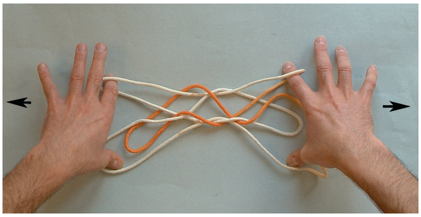
115a – From *Au kape* to a “double-sided lozenge”

The thumbs and indices are then inserted into the latter four triangles as indicated in picture 115b. Finally, a double-sided lozenge appears under the extension of the string (pictures 115c and 115d).

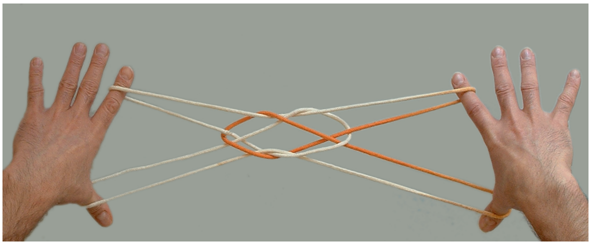


115b – lozenge’

⟶



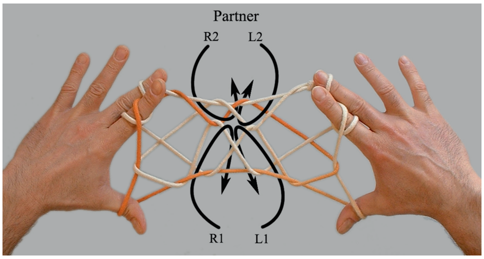
115c



115d – From *Au kape* to a “double-sided lozenge”

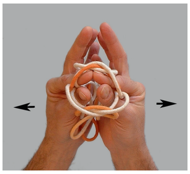
7.1.2.2 Transformation of *Au kape*

In *Ua Pou*, Marquesas Islands, I have recorded a transformation of *Au kape* which is based on the above deconstruction. The transformation is performed by a partner who grasps the final figure in a well-defined way. The vernacular term used to define this operation is “*tui*” which means “to sew”. The partner seizes the final figure of *Au kape* with his thumbs and indices, as shown in the following picture.

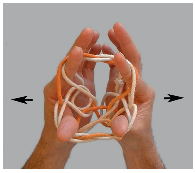


116a – Transformation of *Au kape*

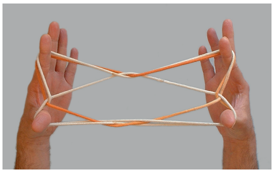
Thumbs and indices are first inserted into the same four little “triangles” as in the previous example (see above picture 115a—From *Au kape* to a “double-sided lozenge”). However, instead of extending the string, the four fingers are inserted into the “lozenge” at the centre of the figure. At this stage, the string is given to the partner who enlarges the latter “lozenge” and extend the string (pictures 116b–116d).



116b

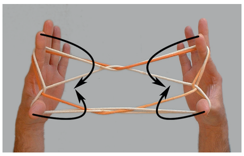


116c

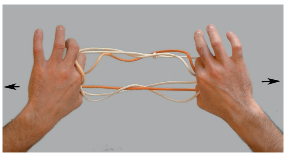


116d

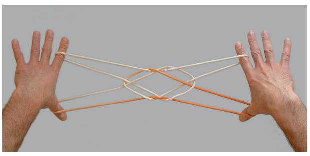
Thumbs and indices are inserted into the large “lozenge” shown at the previous stage (picture 116e), and the string is extended (pictures 116e–116g). A double-sided lozenge is thus displayed.



116e



116f



116g

It can be seen that the insertion of thumbs and indices into the large “lozenge” (picture 116e) and the previous insertion into the small “lozenge” at the centre of the figure (picture 116a) cancel out. So, in this case, it has been chosen not to get the double-sided lozenge straightaway but in passing through an intermediate figure which is deconstructed immediately afterwards.

In the two previous examples (“Stars and Moon” and “From *Au kape* to a double-sided lozenge), the transformation from one figure (a) to anotherfigure (b) occurs under a “deconstruction”. Formally, we have seen that the heart-sequence of the procedure B leading to the figure (b) is a sub-sequence of the heart-sequence of the procedure A leading to the figure (a). This phenomenon occurs frequently in the string figure corpora. This observation seems to indicate at least two possible methods probably used by the actors to explore the string figure algorithms. On one hand, it is possible that some practitioners tried to deconstruct a given procedure A to see whether or not it would yield to an interesting figure (b). In this case, they could get it either directly or as a deconstruction.

On the other hand, they could have invented a new procedure A—leading to (a)—trying to work out a continuation of a given algorithm B—leading to (b). Knowing that procedure B is included into procedure A, it would have thus become possible to deconstruct figure (a) to make figure (b) appear as a magical trick.

In some other cases, the transformation from one figure to another can be based on a deconstruction which is immediately followed by another construction, as if the practitioner was taking a few steps behind in the algorithm, followed by some operations in another direction. Such is the case in a procedure called *Mwaya tomdawaya* which I collected in Vakuta Island (Trobriand archipelago, Papua New Guinea). This procedure allows to show a long series of figures.[5] The first figure is the final figure of the procedure called *Salibu* in the Trobriands (already encountered above as “Ten Men” or “*Au kape*”). This figure is then transformed into four lozenges in a row. Let us now study this series.

7.2 From *Salibu* to 4-Lozenges

7.2.1 Heart-Sequence of Salibu

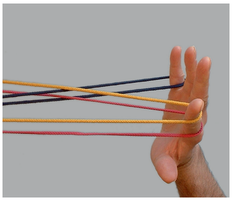
Let us first write down procedure *Salibu*’s heart-sequence. As already seen, this procedure begins with Opening A (Step 1). The second normal position is the configuration $Conf(B)$.[6] In the discussion about string figure *Na tifai*, I have discussed the connection between $Conf(\underline{O}.A)$ and $Conf(B)$.[7] Let us now focus on the movement of loops during the process, from $Conf(B)$ onwards. The same operations are done simultaneously on the two hands. The pictures below only show the right side.[8] The thumbs enlarge little finger loops 5∞ (black) (pictures 117a–117f).

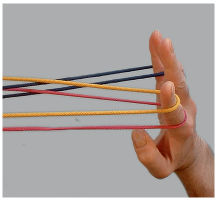
[5] See the procedure 59. *Mwaya tomdawaya* in the accompanying website.

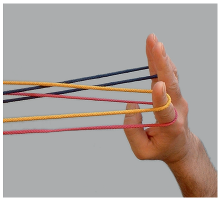
[6] See Sect. 6.4.1.

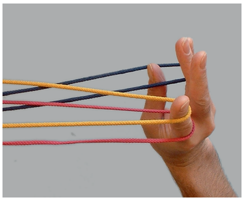
[7] See Sect. 6.4.4.

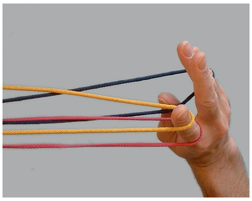
[8] See also the procedure 54. *Salibu* in the accompanying website (Kaninikula Corpus).

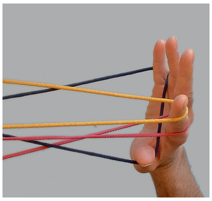

117a


117b

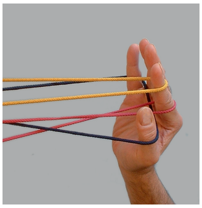

117c

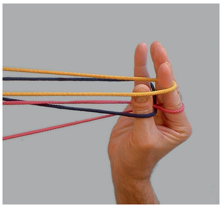

117d

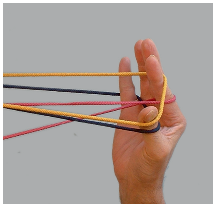

117e

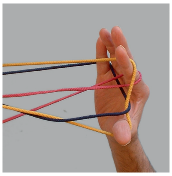

117f

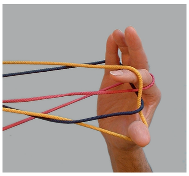
Insertion 1—The thumbs are inserted, from below (proximally) into distal index loops $u2\infty$ (yellow—pictures 117g and 117h), the sub-procedure *Navaho* is performed (pictures 117i and 117j), and finally, distal index loops are released (pictures 117k and 117m).

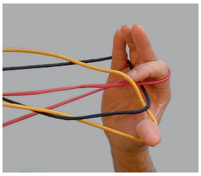

117g

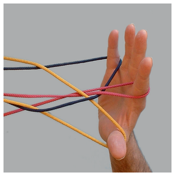

117h


117i – Navaho


117j – Navaho done


117k


117l

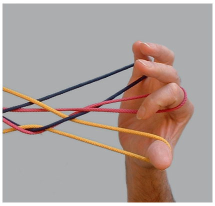

117m

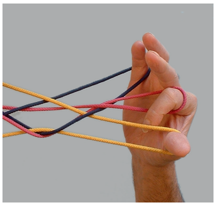
One can see that the goal of this sequence (*Navaho* in particular) is to insert from above upper index loops $u2\infty$ (yellow) into little finger loops 5∞ (black). If we had not enlarged little finger loops 5∞ (black) with the thumbs, to perform this insertion it would have been necessary to pass upper index loops $u2\infty$ (yellow) under the lower index ones $l2\infty$ (red). The enlargement of 5∞ can thus be seen as a possible "fingering" to do so. Formally, the latter sequence is then equivalent to $\underrightarrow{u2\infty} \downarrow (5\infty)$.

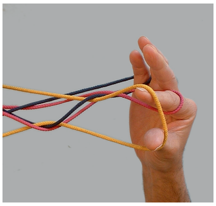
Furthermore, upper index loops $u2\infty$ (yellow) are transferred to the thumbs during the process: $\underrightarrow{u2\infty} \rightarrow 1$. At this stage, from the beginning, the heart-sequence is given by

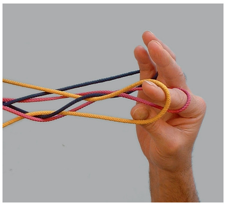
$$Conf(B) : \underrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \rightarrow 1.$$

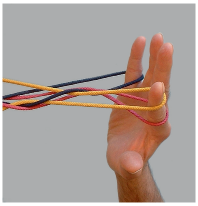
Thumb loops 1∞ (yellow) are then transferred to the indices (pictures 118a–118e).


118a


118b

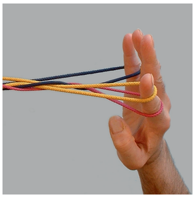

118c

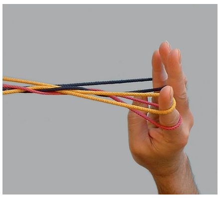

118d

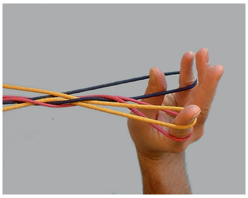

118e

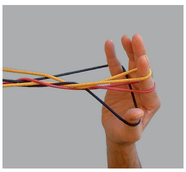
From the beginning, the sequence can be simply encoded $Conf(B) : \underrightarrow{u2\infty} \downarrow (5\infty)$, considering implicitly that upper index loops $u2\infty$ (yellow) return to their original fingers.

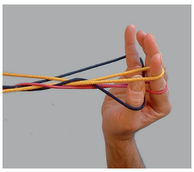
Insertion 2—The previous sub-sequence is performed twice as illustrated in pictures 118f–118l. However, in this case, the indices will not release their upper loops (yellow) at the end (picture 118l).

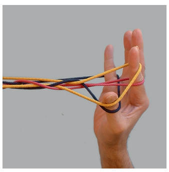

118f

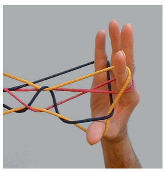

118g


118h


118i

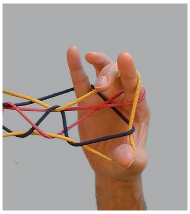

118j

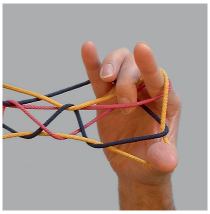

118k

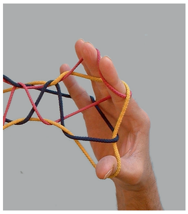

118l

Since upper index loops are not released, the insertions $\underrightarrow{u2\infty} \downarrow (5\infty)$ are not fully completed. It is in fact only the upper near index strings $u2n$ (yellow) which are inserted into little finger loops 5∞ (black) and transferred to the thumbs. Therefore, I will encode this second insertion $\underrightarrow{u2n} \downarrow (5\infty) : \underleftarrow{u2n} \rightarrow 1$.

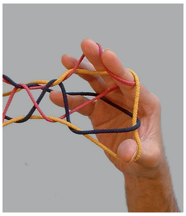
Insertion 3—Similarly, the lower index strings $l2n$ (red) are inserted from below into upper index loops $u2\infty$ (yellow) and transferred to the middle fingers (pictures 118m–118o). Formally, we have $\underrightarrow{l2n} \uparrow (u2\infty) : \overrightarrow{l2n} \rightarrow 3$.

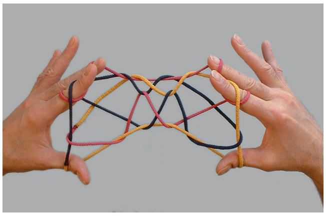

118m


118n


118o

Finally, the little fingers release their loops (□5) and the palms turn away (pictures 118p and 118q).


118p


118q – Salibu

Starting from $Conf(B)$, the heart-sequence of *Salibu* is given by:

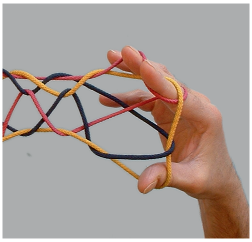
$$Conf(B) : \underrightarrow{u2\infty} \downarrow (5\infty) : \underrightarrow{u2n} \downarrow (5\infty) : \underleftarrow{u2n} \rightarrow 1 :$$

$$\underrightarrow{l2n} \uparrow (u2\infty) : \overrightarrow{l2n} \rightarrow 3 : \square 5 \mid .$$

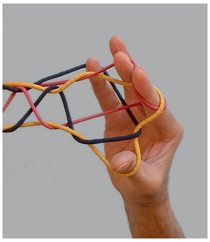
7.2.2 *Transformation*

Let me now describe the passage from figure *Salibu* (picture 118q) to the second figure of the series *Mwaya Tomdawaya*. I will call this figure "4-Lozenges" since it has no name, as far as I know, in the vernacular language of the Trobriand Islands.

First, the little fingers pick up the strings resulting from the loops that they have just released (pictures 119a and 119b).

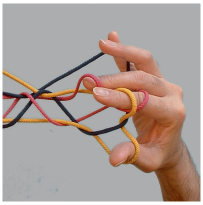


119a

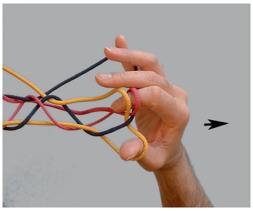


119b

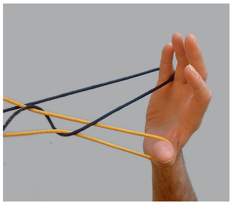
At this stage, a "deconstruction" is entailed by the release of the middle finger and index loops (pictures 119c–119e): formally, $\square 2 : \square 3$.



119c



119d



119e

The result of "Insertion 3" above is clearly undone by operation $\square 3$. Operation $\square 2$ has two effects. The release of upper index loops $u2\infty$ (yellow) allows these loops to complete their insertion ("Insertion 2" above) into little finger loops 5∞ (black). Loops $u2\infty$ (yellow) are finally transferred to the thumbs only: formally, we have $\underrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \rightarrow 1$.
The second effect is simply the release of lower index loops $l2\infty$ (red): formally, $\square l2\infty$ or simply $\square 2$ according to the previous transfer of loops $u2\infty$ (yellow) to the thumbs.

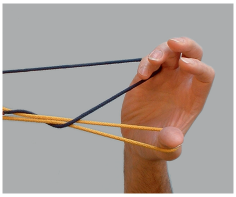
At this stage of the procedure *Mwaya tomdawaya*, according to this deconstruction, and starting from $Conf(B)$, the heart-sequence can be reduced as the following formula:

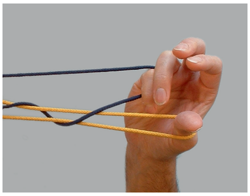
$$\underbrace{Conf(B) : \underrightarrow{u2\infty} \downarrow (5\infty)}_{Insertion\ 1} : \underbrace{\underrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \rightarrow 1 : \square 2}_{Insertion\ 2\ +\ Insertion\ 3\ +\ \text{“}deconstruction''}$$

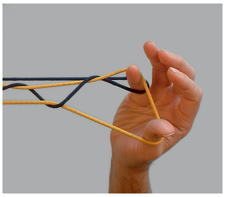
The procedure continues as shown in pictures 119f–119m. The goal is to insert from below little finger loops 5∞ (black) into thumb loops 1∞ (yellow). This last stage will make the four lozenges appear (picture 119m). We see that little finger loops 5∞ are rotated 180° anticlockwise and transferred to indices. Formally, we get: $< \underrightarrow{5\infty} \uparrow (1\infty) : \overrightarrow{5\infty} \rightarrow 2$.
From the beginning, and starting from $Conf(B)$, the heart-sequence of the series *Mwaya tomdawaya* until reaching the "4-lozenges" can be reduced as follows:

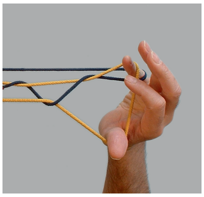
$$\underbrace{Conf(B) : \underrightarrow{u2\infty} \downarrow (5\infty)}_{Insertion\ 1} : \quad \underbrace{\underrightarrow{u2\infty} \downarrow (5\infty) : \underleftarrow{u2\infty} \rightarrow 1 : \Box 2}_{Insertion\ 2\, +\, Insertion\ 3\, +\, ``deconstruction''} \quad :$$

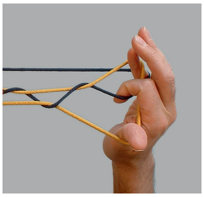
$$\underrightarrow{5\infty} \uparrow (1\infty) : (> \overrightarrow{5\infty} \rightarrow 2 + Extension)$$

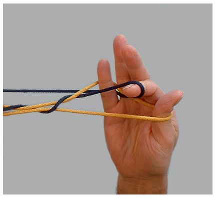

119f

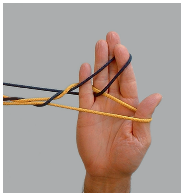

119g

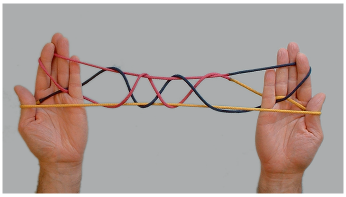

119h


119i


119j


119k


119l


119m – Extension

By noting $[\underrightarrow{u2\infty} \downarrow (5\infty)] * 2$ the duplication of the insertion $\underrightarrow{u2\infty} \downarrow (5\infty)$, it comes

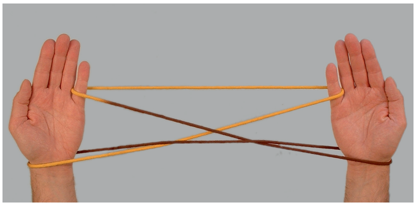
$$Conf(B) \; : [\underrightarrow{u2\infty} \downarrow (5\infty)] * 2 : \underleftarrow{u2\infty} \rightarrow 1 : \Box 2 : \; \underrightarrow{5\infty} \uparrow (1\infty) :$$

$$(> \overrightarrow{5\infty} \rightarrow 2 + Extension)$$

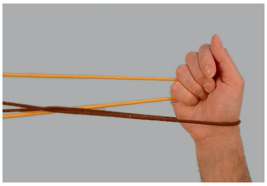
Procedure *Mwaya tomdawaya* can be formally connected to another Trobrianders' procedure called *Kala tugebi navalulu* (Linen for young mother), which also leads to four "lozenges" in a row. This formal connection will allow us to hypothesize on the way Trobriander practitioners could have in certain cases explored string figure algorithms.

7.2.3 Heart-Sequence of *Kala tugebi navalulu*

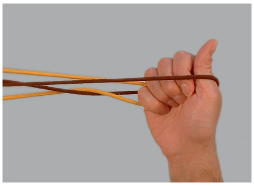
The first step of *Kalatu gebi navalulu* will be described later under the name Opening M_4.[9] It leads to the configuration, say X, shown in picture 120a. Little finger loops 5∞ (yellow on the right hand) are then inserted from above into wrist loops $w\infty$ (brown on the right hand). These insertions are due to the transfer of the wrist loops to the thumbs as demonstrated in pictures 120b–120f (the operations are made symmetrically on both sides—the pictures below show the right hand only). So, formally we have $Conf(X) : \overleftarrow{5\infty} \downarrow (w\infty) : \overleftarrow{w\infty} \to 1$.



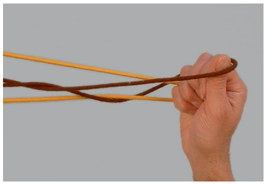
120a



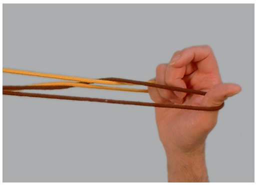
120b



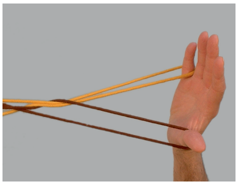
120c



120d



120e

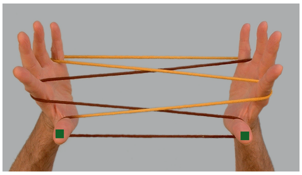


120f

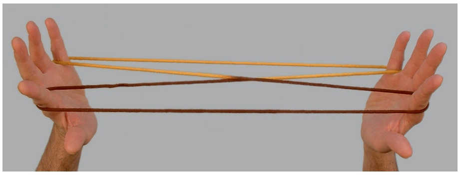
Since procedure *Mwaya tomdawaya* starts with Opening A, we need, for the purpose of comparison, to connect formally $Conf(X)$ to Opening A. Actually, it is possible to pass from $Conf(\underline{O}.A)$ to a configuration, say Y, similar to $Conf(X)$, by releasing the thumbs ($\square 1$—pictures 121a and 121b), then in transferring index loops 2∞ to the thumbs, while rotating these loops 180° clockwise (pictures 121c–121f). Formally, we have $Conf(Y) = \underline{O}.A : \square 1 : > \overleftarrow{2\infty} \to 1$.

[9]See the procedure 8. *Kala tugebi navalulu* in the accompanying website.

– Release of the thumbs (pictures 121a and 121b).

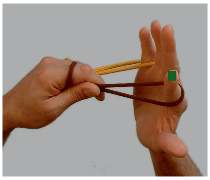


121a

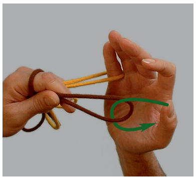


121b

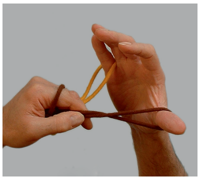
– The rotation and the transfer of the index loops (pictures 121c–121e).



121c

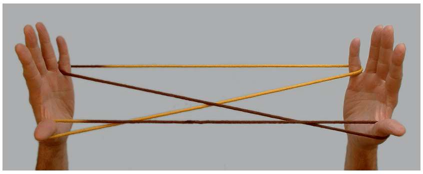


121d

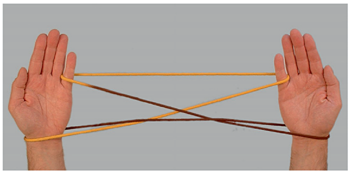


121e

When it is done on both hands, this sequence leads to the *Configuration Y* (picture 121f).



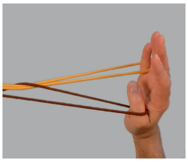
121f – Configuration Y

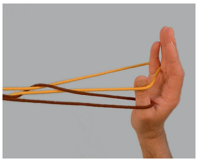


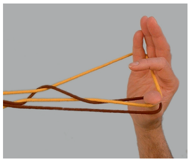
121g – Configuration X

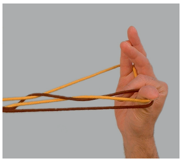
By comparing $Conf(X)$ and $Conf(Y)$ (pictures 121f and 121g), we readily see that the difference between these two configurations lies in the way a pair of loops are held either by the thumbs in $Conf(Y)$ or by the wrist in $Conf(X)$. The sequence $Conf(X) : \overleftarrow{5\infty} \downarrow (w\infty) : \overleftarrow{w\infty} \rightarrow 1$ previously written down is then equivalent to $Conf(Y) : \overleftarrow{5\infty} \downarrow (1\infty)$, and finally to $\underline{O}.A : \Box 1 :> \overleftarrow{2\infty} \rightarrow 1 : \overleftarrow{5\infty} \downarrow (1\infty)$, in the sense that these sequences lead to the same configuration.

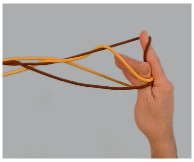
The next stage of the procedure *Kala tugebi navalulu* consists in inserting thumb loops 1∞ (brown) from below into little finger loops 5∞ while transferring them to the indices. The four lozenges are then displayed. This is done under a "Caroline extension" as shown in pictures 122a–122f. Formally, we have $\underrightarrow{1\infty} \uparrow (5\infty) : (\overleftarrow{1\infty} \rightarrow 2 + Extension)$.

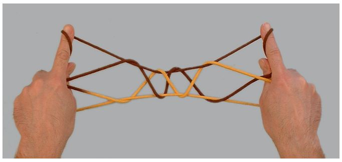

122a


122b


122c


122d


122e


122f – Kalatu gebi navalulu

Finally, the heart-sequence of procedure *Kala tugebi navalulu* can be written down

$$\underline{O}.A : \square 1 : > \overleftarrow{2\infty} \to 1 : \overleftarrow{5\infty} \downarrow (1\infty) : \underrightarrow{1\infty} \uparrow (5\infty) : (\overleftarrow{1\infty} \to 2 + extension)$$

In order to bring to light the connection between *Kala tugebi navalulu* and the transformation of *Salibu* into "4-lozenges", we are now going to focus on the heart-sequence of this transformation. Then, I will demonstrate that the latter heart-sequence can be rewritten into an equivalent sequence, that is easy to compare to the heart-sequence of *Kala tugebi navalulu*.

7.2.4 Understanding the Phenomenon

It has been proved, when discussing the Tuamotus' string figure *Na tifai*, that the configuration $Conf(B)$, which is the second normal position of the procedure *Salibu*, can also be obtained through the following sequence:

$$Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > \underline{5\infty} \to 2 \\ \overleftrightarrow{} \\ > 2\infty \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2\ |$$

where $Conf\ (\underline{O}.A)^*$ is a configuration which differs to $Conf\ (\underline{O}.A)$ in one crossings only.[10] So, formally, the heart-sequence of *Mwaya tomdawaya*, from the beginning to the "4-lozenges", that I have determined above

$$Conf(B) : [\underrightarrow{u2\infty} \downarrow (5\infty)] * 2 : \underleftarrow{u2\infty} \to 1 : \square 2 : \underrightarrow{5\infty} \uparrow (1\infty) :$$
$$(> \overrightarrow{5\infty} \to 2 + Extension)$$

[10] See Sect. 6.4.4.

becomes

$$Conf\ (\underline{O}.A)^* : \left\{ \begin{array}{c} > \underleftarrow{5\infty} \to 2 \\ > \overrightarrow{2\infty} \to 5 \end{array} \right\} : \overrightarrow{1\infty} \to 2 : [\underrightarrow{u2\infty} \downarrow (5\infty)] * 2 : \underleftarrow{u2\infty} \to 1 : \tag{7.1}$$

$$\square 2 : \ \underrightarrow{5\infty} \uparrow (1\infty) : \ (> \overrightarrow{5\infty} \to 2 \ + extension)$$

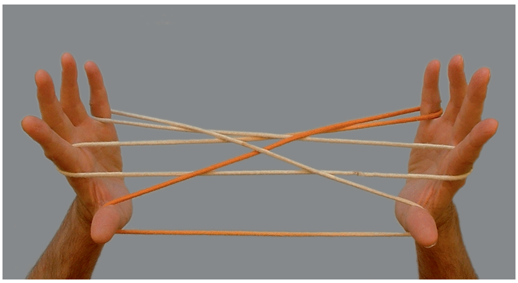
If we do not operate the transfer $\overrightarrow{1\infty} \to 2$ in the formula (7.1) above, the subsequence $\overrightarrow{1\infty} \to 2 : [\underrightarrow{u2\infty} \downarrow (5\infty)] * 2 : \underleftarrow{u2\infty} \to 1$ becomes $[\underrightarrow{1\infty} \downarrow (5\infty)] * 2$, considering that 1∞ return to their original fingers. Therefore, from the beginning, we get the following equivalent sequence

$$Conf\ (\underline{O}.A)^* \ : \left\{ \begin{array}{c} > \underleftarrow{5\infty} \to 2 \\ > \overrightarrow{2\infty} \to 5 \end{array} \right\} : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2 : \square 2 : \ \underrightarrow{5\infty} \uparrow (1\infty) :$$

$$(> \overrightarrow{5\infty} \to 2 + Extension) \tag{7.2}$$

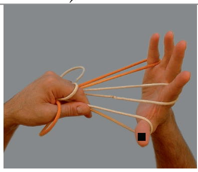
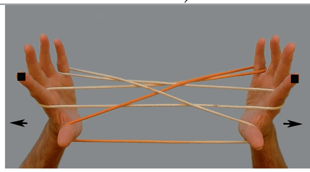
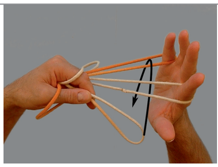
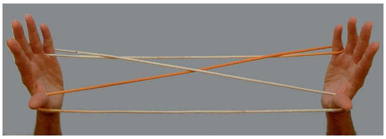
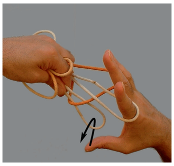
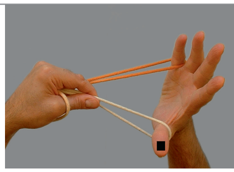
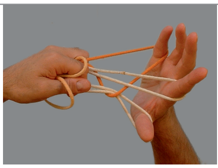
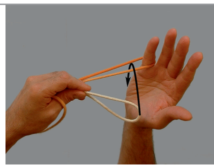
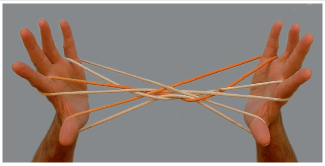
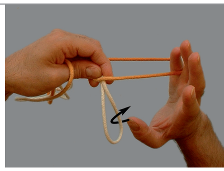
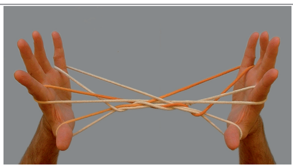
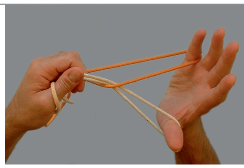
In the formula above, the release $\square 2$ can be performed before $[\underrightarrow{1\infty} \downarrow (5\infty)] * 2$ without any change. Since this commutation is essential for the following transformation of the formula (7.2), let me illustrate this property.

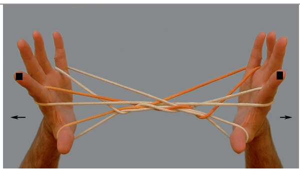
From the configuration $Conf\ (\underline{O}.A)^*$, the sequence $\left\{ \begin{array}{c} > \underleftarrow{5\infty} \to 2 \\ > \overrightarrow{2\infty} \to 5 \end{array} \right\}$ leads to the configuration shown in picture 123a, as already demonstrated while trying to get a passage from $\underline{O}.A$ to $Conf(A)$.[11] From this stage, the sequence $[\underrightarrow{1\infty} \downarrow (5\infty)] * 2 :$ $\square 2$ is illustrated in pictures 123b–123i. For the purpose of comparison, facing the previous illustrations, the sequence $\square 2 : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2$ is illustrated in the pictures 123b'–123i'.



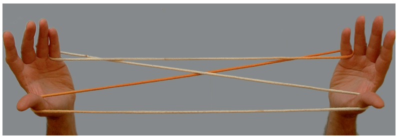
123a

[11] See Sect. 6.4.2 (From $Conf\ (\underline{O}.A)$ to $Conf(A)$).

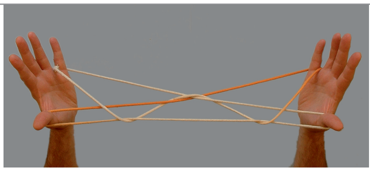
Sequence $[\underrightarrow{1\infty} \downarrow (5\infty)] * 2 : \square 2$	Sequence $\square 2 : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2$
 123b	 123b' – Release of the indices
 123c – First insertion (right side)	 123c'
 123d)	 123d'
 123e)	 123e' – First insertion (right side)
 123f – After the first insertion on both sides)	 123f'
 123g – After the second insertion (on both sides)	 123g'



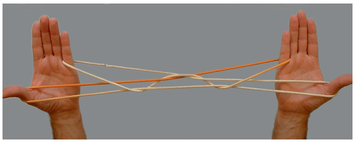
123h – Release of the indices



123h' – After the first insertion (both sides)



123i



123i' – After the second insertion (both sides)

Both sequences $[\underrightarrow{1\infty} \downarrow (5\infty)] * 2 : \square 2$ and $\square 2 : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2$ lead to the same configuration, as shown in pictures 123i and 123i'. Therefore, the beginning of the formula (7.2) is equivalent to:

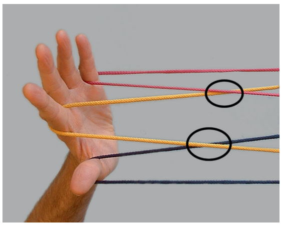
$$\underbrace{Conf\ (\underline{O}.A)^* : \begin{Bmatrix} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{Bmatrix} : \square 2}_{S} : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2 : \underrightarrow{5\infty} \uparrow (1\infty) :$$

$$(> \overrightarrow{5\infty} \to 2 + Extension) \tag{7.3}$$

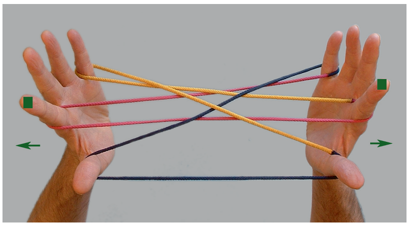
Let us now prove that the sequences $S = Conf\ (\underline{O}.A)^* : \begin{Bmatrix} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{Bmatrix} : \square 2$ and $S' = Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5$ lead to the same configuration. Once again, we shall establish this by describing both sequences.

7.2.4.1 Illustration of the Sequence *S*

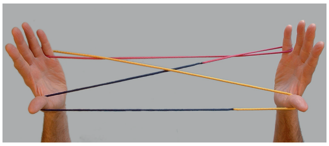
S starts from $Conf(\underline{O}.A)^*$ (picture 124a).



124a – $Conf\ (\underline{O}.A)^*$



124b

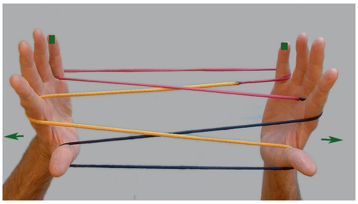


124c

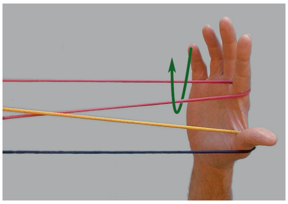
As seen above, the sequence $\left\{\begin{matrix} > 5\infty \to 2 \\ \leftrightarrows \\ > 2\infty \to 5 \end{matrix}\right\}$ then leads to the configuration shown in picture 124b. The sequence S is ended by the release of index loops ($\square$2—pictures 124b and 124c).

7.2.4.2 Illustration of the Sequence *S'*

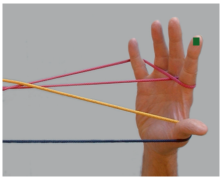
S' also starts from $Conf(\underline{O}.A)^*$. The little finger loops are then released ($\square$5) (pictures 125a and 125b). The index loops are rotated 180° anticlockwise and transferred to the little fingers (pictures 125b and 125c): formally, $> \overrightarrow{2\infty} \to 5$



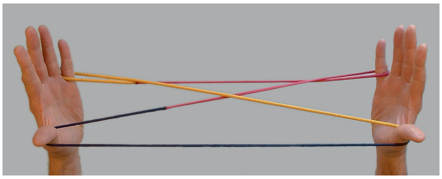
125a – $Conf\left(\underline{O}.A\right)^*$



125b



125c



125d

Finally, we see that the sequence $S' = Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5$ leads to the same configuration than the sequence S (picture 125d).

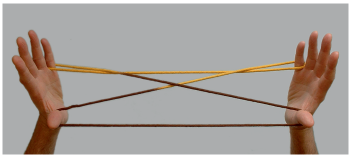
Therefore, the sequence S and S' are equivalent in the sense that both sequences lead to the same configuration. According to this equivalence, the formula (7.3) can be rewritten as follows:

$$\underbrace{Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5}_{S'} : [\underrightarrow{1\infty} \downarrow (5\infty)] * 2 : \underrightarrow{5\infty} \uparrow (1\infty) :$$

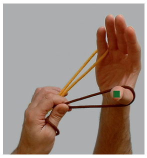
$$(> \overrightarrow{5\infty} \to 2 + Extension) \tag{7.4}$$

7.2.4.3 Final Rewriting

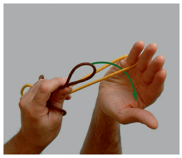
One can observe that the first insertion $\underrightarrow{1\infty} \downarrow (5\infty)$ in (7.4) is equivalent to a 360° clockwise rotation of little finger loops ($\ll 5\infty$). This equivalence is illustrated in pictures 126a–126e.



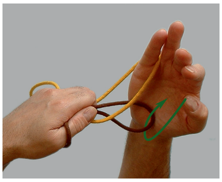
126a



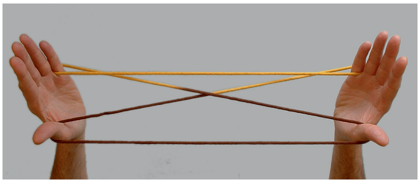
126b



126c



126d



126e

We see that the configuration in picture 126e can be obtained from the one in picture 126a simply by rotating little finger loops as mentioned above. So, formally,

$$\underbrace{Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5}_{S'} : \underrightarrow{1\infty} \downarrow (5\infty)$$

$$\Leftrightarrow \quad Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5 : \ll 5\infty$$

Moreover, $> \overrightarrow{2\infty} \to 5 : \ll 5\infty \;\; \Leftrightarrow \; > \ll \overrightarrow{2\infty} \to 5 \;\; \Leftrightarrow \; < \overrightarrow{2\infty} \to 5$. Hence, we get

$$\underbrace{Conf(\underline{O}.A)^* : \square 5 : > \overrightarrow{2\infty} \to 5}_{S'} : \underrightarrow{1\infty} \downarrow (5\infty)$$

$$\Leftrightarrow \quad Conf(\underline{O}.A)^* : \square 5 : < \overrightarrow{2\infty} \to 5.$$

So, the heart-sequence (7.1) of *Mwaya tomdawaya*, from $Conf(\underline{O}.A)^*$ to the "4-Lozenges", can finally be reduced as

$$\begin{aligned} &Conf(\underline{O}.A)^* : \square 5 : < \overrightarrow{2\infty} \to 5 : \overrightarrow{1\infty} \downarrow (5\infty) : \underleftarrow{5\infty} \uparrow (1\infty) \\ &: \; (> \overrightarrow{5\infty} \to 2 + extension). \end{aligned} \tag{7.5}$$

This formula can now be compared to the heart-sequence of *Kala tugebi navalulu*.

7.2.4.4 Formal Comparison

Let us compare the two sequences below:

Sequence A: *Kala tugebi navalulu*

$\underline{O}.A : \square 1 : > \overleftarrow{2\infty} \to 1 : \overleftarrow{5\infty} \downarrow (1\infty) : \underrightarrow{1\infty} \uparrow (5\infty) : (\overleftarrow{1\infty} \to 2 + \mathit{Extension})$

Sequence B: beginning of *Mwaya tomdawaya*

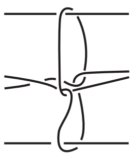
$Conf(\underline{O}.A)^* : \square 5 : < \overrightarrow{2\infty} \to 5 : \overrightarrow{1\infty} \downarrow (5\infty) : \underleftarrow{5\infty} \uparrow (1\infty) : (> \overrightarrow{5\infty} \to 2 + \mathit{Extension})$

Openings excepted, one can see that we get one sequence from the other by exchanging the role of thumb loops 1∞ and little finger loops 5∞. Therefore, the movement of the loops in Sequence A can be seen as the "mirror image" of thoses in Sequence B. Although it was difficult to grasp it at first sight, the above analysis reveals that procedures *Mwaya tomdawaya* and *Kala tugebi navalulu* are strongly connected. The construction of the figure "4-Lozenges" are definitely based on the same principle i.e. the same "topological" phenomenon. Moreover, this formal analysis brings some new lights on the transformation of *Salibu* into "4-Lozenges" in *Mwaya tomdawaya.* Indeed, one can see that the "deconstruction" of *Salibu* allows to go back a few steps in order to join up with the heart-sequence of another string figure algorithm. Such a connection suggests that Trobriand practitioners might have explored the string figure algorithms by trying to connect them one another. This would have consisted in identifying the potential junction points between algorithms, thus allowing to branch off from one procedure to another, using a "deconstruction".

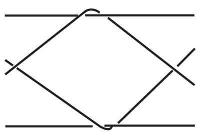
7.3 Motifs and Heart-Sequences

In the first part of this book, I have introduced the concept of "Motif", which covers geometrical "patterns" that are combined to make the "drawing" of a final figure, without taking into account the exact crossings of the string. According to this definition, the "double-sided lozenge" is such a "Motif".

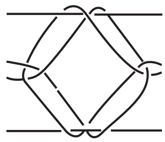
In some cases, a set of string figures can be seen as a combination of various motifs. As mentioned in Part I,[12] the Solomon string figures published in Maude (1978) show such combinations of the motifs "lozenge", "caterpillar" and "double-sided lozenge".



127a – Caterpillar



127b – Lozenge

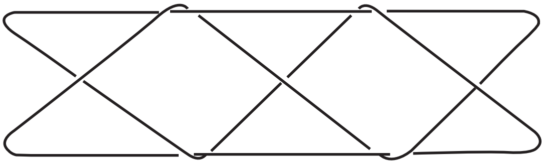


127c – Double-sided lozenge

[12] See Sect. 3.4.3.

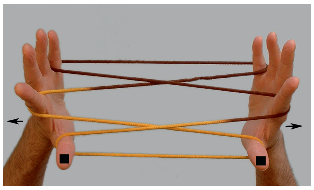
7.3.1 *Double Lozenges*

Some of these figures contain two motifs "lozenge" in a row that I will call "double lozenges".

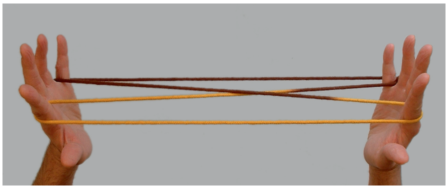


128

The motif "double lozenges" is sometimes obtained under the following sequence. The procedure starts with Opening A, then thumb loops 1∞ are released (pictures 129a and 129b). Formally, $\underline{O}.A : \square 1$.

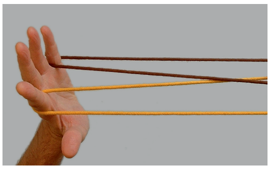


129a

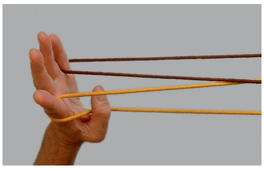


129b

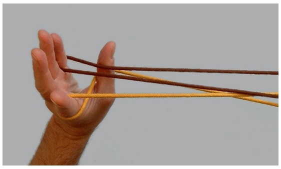
Little finger loops 5∞ (brown) are inserted from below into index loops 2∞ (yellow) while being rotated 180° anticlockwise, and transfer temporary to the thumbs (pictures 129c–129h). Once again, the hands operate symmetrically and the following pictures show the left side only. Formally, we have $\underleftarrow{5\infty} \uparrow (2\infty) :> \overleftarrow{5\infty} \to 1$.



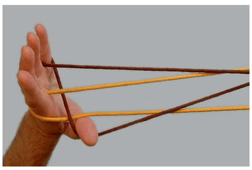
129c



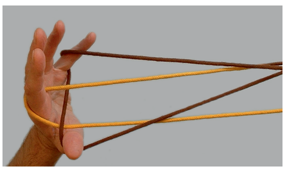
129d



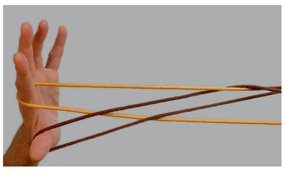
129e



129f

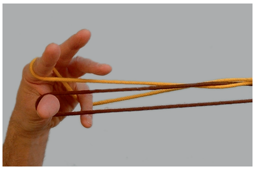


129g

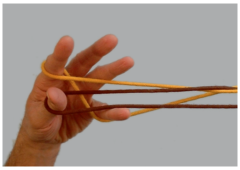


129h

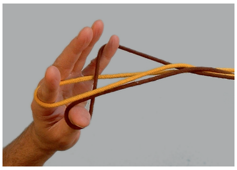
Thumb loops 1∞ (i.e. the original little finger loops) are then inserted into index loops 2∞ from below while being rotated 180° clockwise, and transferred to the little fingers (pictures 129i–129m). Formally, $\underrightarrow{1\infty} \uparrow (2\infty) : < \overrightarrow{1\infty} \to 5$. At this point, we get the "braid" shown in picture 129n.



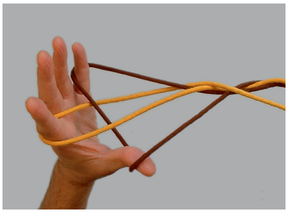
129i



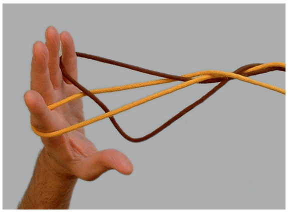
129j



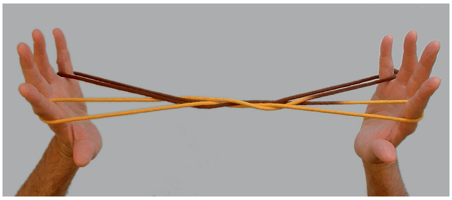
129k



129l

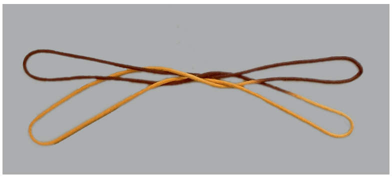


129m

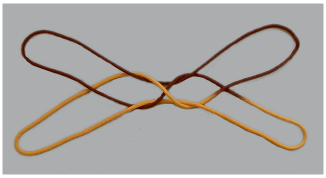


129n

When laying out the figure and enlarging the strings, one can see that the figure expected (double lozenges) appears (pictures 129o and 129p).

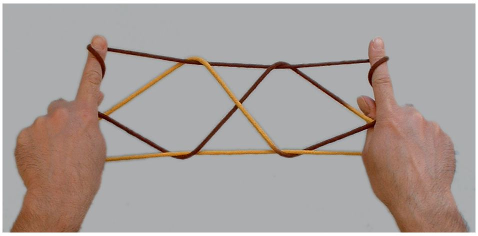


129o



129p

Several times in the paper Storer (1988), the author refers to such a "braid" as the "Prefix" of the figure which can be displayed from it. In this particular case, the "double lozenge" is displayed under a "Caroline extension" as shown in picture 129q.



129q

7.3.1.1 Reduction of the Heart-Sequence

Formally, the full sequence from Opening A to the “prefix” of the motif “double lozenges” is given by

$$\underline{O}.A : \square 1 : \underset{\longleftarrow}{5\infty} \uparrow (2\infty) : > \overleftarrow{5\infty} \rightarrow 1 : \underset{\longrightarrow}{1\infty} \uparrow (2\infty) : < \overrightarrow{1\infty} \rightarrow 5.$$

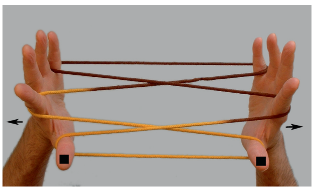
Theoretically, the transfer $\overleftarrow{5\infty} \rightarrow 1$ can be omitted. When doing so, $\underset{\longrightarrow}{1\infty} \uparrow (2\infty) : < \overrightarrow{1\infty} \rightarrow 5$ becomes $\underset{\longrightarrow}{5\infty} \uparrow (2\infty) : < \overrightarrow{5\infty} \rightarrow 5$ or simply $< \underset{\longrightarrow}{5\infty} \uparrow (2\infty)$, considering implicitly that 5∞ return to their original fingers. Then, from the beginning, we finally get

$$\underline{O}.A : \square 1 : > \underset{\longleftarrow}{5\infty} \uparrow (2\infty) : < \underset{\longrightarrow}{5\infty} \uparrow (2\infty).$$

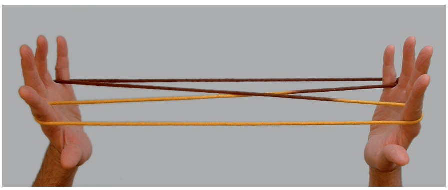
For the coming discussion, we will memorize this formula as $\underline{O}.A : \square 1 : S_1$, noting S_1 the part of the sequence after $\underline{O}.A : \square 1$.

7.3.2 Caterpillar

In the Solomon Islands, the pattern “double caterpillars” can be obtained under the following sequence. It begins similarly than the previous sequence (pictures 130a and 130b): $\underline{O}.A : \square 1$.



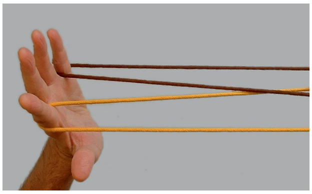
130a

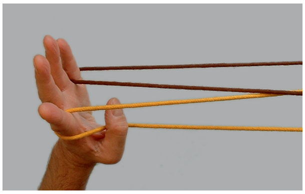


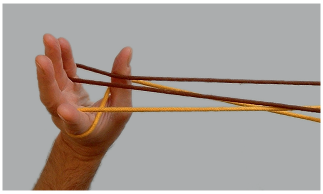
130b

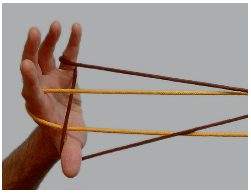
Little finger loops 5∞ (brown) are then inserted from below into index loops 2∞ (yellow) while being rotated 180° anticlockwise. Also, the little finger loops are transferred to the thumbs, however, in this case, without releasing the little fingers. I encode this: ($\overline{\Box 5}$).

Formally, we get $\underleftarrow{5\infty} \uparrow (2\infty) :> \overleftarrow{5\infty} \rightarrow 1\ (\overline{\Box 5})$. (pictures 130c–130f—The hands operate similarly one after the other, and the pictures below show the left side only).

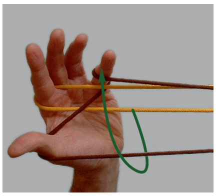

130c

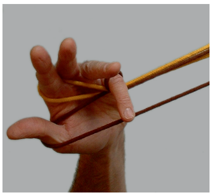

130d

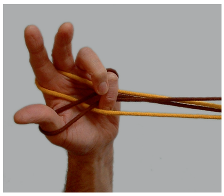

130e

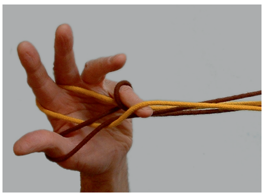

130f

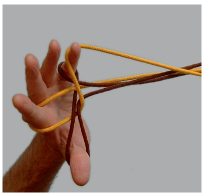
The operation shown in the pictures below entails the creation of a new loop on the little finger. This loop is made with the near index string $2n$. To do so, $2n$ is passed proximal to the near thumb string $1n$, then distal to all the intermediate strings (picture 130g), and placed around the little finger without releasing the index. The movement of the string $2n$ is operated by the little finger as shown in pictures 130g–130k. It thus create a new loop on the little finger in distal position. Formally, we have $\underleftarrow{2n}(1n) : \overrightarrow{2n}(2\infty) : \overrightarrow{2n} \rightarrow 5\ (\overline{\Box 2})$.

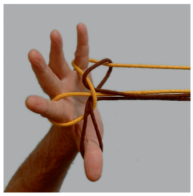

130g


130h

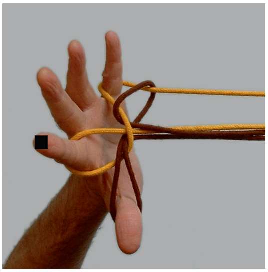

130i


130j

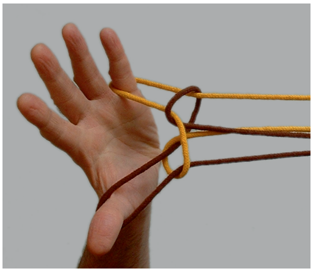

130k


130l – Just after "navaho 5"

Then, the sub-procedure *Navaho* is performed on the little finger. This causes the insertion from above of upper little finger loop $u5\infty$ (yellow) into lower little finger loops $l5\infty$, and the release of these loops (picture 130l). Formally, $u5\infty \downarrow (l5\infty) : \square l5\infty$, considering implicitly that $l5\infty$ return to their original fingers. Finally, the indices are released and the "prefix" of the motif "caterpillar" appears (pictures 130m and 130n).



130m



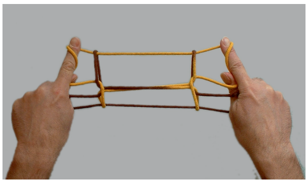
130n

When this procedure is done on both side one after the other, the pattern "double caterpillars" can be displayed under a "Caroline extension" (picture 130o). The full sequence leading to the prefix of the "double caterpillars" is given by

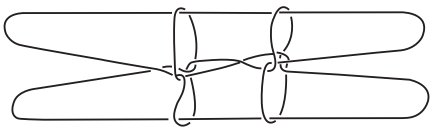
$$\underline{O}.A : \square 1 :$$

$$\underbrace{\underset{\leftarrow}{5\infty} \uparrow (2\infty) : > \overleftarrow{5\infty} \rightarrow 1\,(\overline{\square 5}) : \underset{\leftarrow}{2n}(1n) : \overrightarrow{2n}(2\infty) : \overrightarrow{2n} \rightarrow 5\,(\overline{\square 2}) : u5\infty \downarrow (l5\infty) : \square l5\infty}_{S_2}$$

We will memorize it as $\underline{O}.A : \square 1 : S_2$, noting S_2 the part of the sequence after $\underline{O}.A : \square 1$.



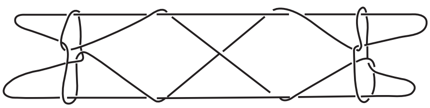
130o



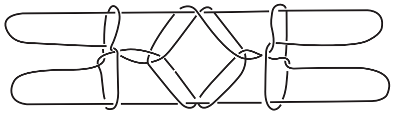
130p – Double caterpillar (Maude 1978, p. 68)

7.3.3 *Combination: Concatenation*

The Solomon Islands string figures in Maude (1978), with final figures showing the motifs "lozenge", "caterpillar", or "double-sided lozenge", can be seen as the result of combination and concatenation of sub-sequences such as S_1 or S_2. For instance, the string figure *Repi susuhe'u* (Maude 1978, pp. 65–66)—that we have encountered in Chap. 3—show two lozenges at the centre and two outer "caterpillars" (picture 131a).



131a – Double lozenges + double caterpillars (Maude 1978, p. 66)



131b – Double-sided lozenge + double caterpillars (Maude 1978, p. 70)

It can be demonstrated that the heart-sequence of *Repi susuhe'u* is given by

$$\underline{O}.A : \square 1 : S_1 : S_2.$$

Another example is the string figures *Namu* (Maude 1978, pp. 69–70) which shows a double-sided lozenge at the centre and two outer "caterpillars" (picture 131b). The double-sided lozenge at the centre is obtained under a sequence S which belongs to Group II—introduced in Chap. 5. Moreover, the procedure *Namu* can be seen as the concatenation of the two sequences S and S_2. Without going into the details, I assert that many a Solomon Islands procedure described in Maude (1978) can be analysed by concatenation and combination of a small number of "sub-sequences" (such as S_1, S_2 or S in the previous examples): each of them allowing to display a particular "motif".

The previous analysis of "Motifs" suggests that a methodology to create new string figure algorithms was probably used by the actors. In this case, we may reasonably believe that the creation of new string figures was motivated by working out possible combination of "motifs". The practitioners or creators of these procedures certainly designed "sub-procedures" to achieve some "motifs", and they tried to combine them by concatenation of these sub-procedures.

7.4 Before Going Further

We have analysed a string figure algorithm as a "heart-sequence" implemented by a precise "fingering". In this chapter, we focused on "heart-sequences", leaving the "fingerings" aside as far as possible. Working in this way, we have seen that the concept of Heart-sequence is an efficient tool to analyse, at a "topological" level, some phenomena which often occur within the string figure algorithms: procedures leading to "look-alike" figures, transformation of one figure into another, combinations of various motifs used for the making of several different figures.

I have introduced several conceptual tools to investigate string figure corpora in a formal and comparative manner. All of these tools (elementary operation, sub-procedure, opening, normal position, passage, heart-sequence, fingering) were essential for the analysis of my own fieldwork findings. In particular, the concept of sub-procedure will play a key-role in the following pages. Sometimes seen as a "Passage" from one "normal position" to another, the sub-procedures will be alternately analysed, depending on the situation, under the complementary prisms of their heart-sequence or fingering.

In a preliminary work Vandendriessche (2004), I demonstrated that interesting results could emerge from a comparative analysis of corpora of string figures collected in geographically and culturally distant areas of the planet. In particular, the comparison between string figures from Ammassalik, Greenland, collected by Paul-Emile Victor (1940), and string figures from the Trobriand Islands, Papua New Guinea[13] led me to conclude that the use of certain characteristic sub-procedures could make differences very clear from one cultural area to another. At this point in my research project, I felt it absolutely necessary to collect my own fieldwork data. I was convinced that the opportunity to meet practitioners would provide vital information about the methodology that is used to create string figures, the transmission and memorization of such procedures, and also their social role in a given community. Over the last few years, I have carried out fieldwork in Ua Pou Island, Marquesas, French Polynesia, in the Chaco, Paraguay, in the Trobriand Islands, Papua New Guinea and in Ambrym Island, Vanuatu.[14]

I have chosen to focus here on the corpora I have collected in the Trobriand Islands and in the Chaco, since these two collections are those which offer the most striking contrast and are therefore the most suitable for a comparative study. Nevertheless, I will refer to Vanuatu and the Marquesas, and also to secondhand sources such as the previously mentioned corpus from Ammassalik, to highlight certain phenomena by comparison. As for the comparative description of the corpora collected in the Trobriands and in the Chaco, I will not stick to the chronological order of my field works, I will rather follow the chronology by which I have analysed my data findings. Over the years 2006–2007, I concentrated on the Trobriands corpus, then I applied the same methodology to the Chaco corpus for comparative purposes.

References

Compton RH (1919) String figures from New Caledonia and Loyalty Islands. J R Anthropol Inst Great Br Irel 49:204–236

Maude H (1978) Solomon Island string figures. Homa Press, Canberra

Senft G, Senft B (1986) Ninikula fadenspiele auf den Trobriand inseln Papua New Guinea. Baessler-Archiv 34(1):93–235

[13] For this corpus I put together second hand sources from Papua New Guinea and nearby countries quoted in the article by Senft and Senft (1986). See Chap. 7.

[14] I carried out ethnographical fieldwork as part of the 4 year 2005–2009 ACI project (Aide Concertée Incitative) entitled "Anthropology of Mathematics", coordinated by Agathe Keller, historian of mathematics, and myself. Financially, we were supported by the French Research Ministry.

Shishido Y, Noguchi H (1987) Some string figures of Highland people in Papua New Guinea. Bull Int String Fig Assoc 14:38–69

Storer T (1988) String figures. Bull String Fig Assoc 16 (Special Issue):1–212

Vandendriessche E (2004) Les jeux de ficelle: Témoins d'une activité mathématique dans des sociétés traditionnelles de l'Arctique et de l'Océanie. Master thesis, Paris Diderot University

Victor P-E (1940) Jeux d'enfants et jeux d'adultes chez les Eskimo d'Angmassalik: Les jeux de ficelle. Meddelelser om Gronland 125(7):1–212. Copenhagen

Part IV
String Figures in the Field

Chapter 8
Cultural and Cognitive Aspects of String Figure-Making in Two Different Societies

8.1 The Right Place to Go

8.1.1 Trobriand Islands, Papua New Guinea

In 1983, ethnolinguist Gunter Senft, a specialist of the Kilivila language that is spoken by the Trobriand Islanders (Papua New Guinea) (Senft 1986), and his wife, Barbara Senft, an elementary school teacher, spent eleven months working in the village of Tauwema, located in the islet of Kaile'una, one of the Trobriand Islands. The latter are located off the east coast of Papua New Guinea's mainland.[1] Gunter Senft's project was to study "ritual communication"[2] whereas Barbara Senft wanted to focus on everyday child behaviour in the Trobriand Islands. Soon after their arrival in January 1983, the two researchers were struck by the importance of string figures (called *Ninikula* by the inhabitants of Kaile'una) in the Kaile'una Islanders' everyday life. Therefore, they decided to carry out a study of this phenomenon and drew up a complete list of *Ninikula*. This led them in 1986 to publish the article "Ninikula Fadenspiele auf den Trobriand Inseln Papua New Guinea" (Senft and Senft 1986). The Senfts studied the way string figures were embedded in local culture. For that purpose, they have recorded and analysed the songs or short stories, called *vinavina*, which often go along with the making of these figures in the Trobriand Islands. I will refer to this work on several occasions in the following, comparing its findings to my own fieldwork data.

Gunter and Barbara Senft did not try to record the procedures leading to the final string figures. They just took photographs and made drawings of the final patterns. However, for the making of some string figures, the authors cross-referred to three publications: Noble's paper (1979) and Jayne's book (1962), both already quoted,

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[1] See the map in Sect. 8.3.1 (Getting to the village Oluvilei).

[2] Senft (1987).

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_8

and a book by Jost Elffers and Michael Schuyt.[3] Gunter Senft told me that they found these cross-references by comparing the final figures without looking at the processes. As it was a reconstruction, I could not be absolutely sure that the methods given by Noble and Jayne were actually those known to the Trobrianders. So, a collection of the Trobrianders' string figures recording their exact processes was still lacking.

Furthermore, since Senfts' paper refers to 89 string figures, I was quite sure that, in 1983, some Trobrianders still knew how to make a large number of string figures, and that I could expect to meet some of these people. This article is one of the last scientific publications based on a collection of string figures from Oceania. The Trobriand archipelago was thus a place in the South Pacific where I could reasonably think that this practice was still alive, and, as demonstrated by the Senfts, strongly connected to other cultural aspects of the Trobrianders' lives. Moreover, there is a large amount of anthropological literature about Trobrianders which began with Malinowski's work. Hence, I could expect interesting outcomes from the connections between these anthropological monographs and my personal data on string figures. Malinowski, in all his writings on the anthropology of the Trobriand archipelago, refers only once to string figures, in his book *The Sexual Life of Savages in Northwestern Melanesia* (Malinowski 1929). We will return later to this short passage, in which he mentions four string figures (without giving the procedures) in connection to the study of Trobrianders' sexuality.

I carried out ethnographical research in the Trobriands during two missions, which took place in June–July 2006 and July–August 2007 respectively. At the beginning of the first mission, some encounters led me to the village of Oluvilei, Kiriwina Island, where I decided to stay.[4]

8.1.2 Chaco, Paraguay

I knew, from reading José Braunstein's articles[5] and my email discussion with the author, that string figures were (still) practiced in the Chaco, a vast region of South America that extends into Paraguay, Argentina, Bolivia and Brazil. In early 2005, while I was searching for places to carry out fieldwork, I met Jean-Pierre Estival and his wife Herminia. Jean-Pierre Estival is an ethnomusicologist who worked for several years in Paraguay. His wife Herminia is Paraguayan and belongs to

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[3]The original edition of this book was published in German in 1978: *Das Hexenspiel*, DuMont Buchverlag, Cologne, R.F.A. Then a French edition was published in 1979: "Les Jeux de ficelle", Editions Robert Laffont, Paris, p. 206. This book cannot be considered as a scientific work. It is clearly a book designed for entertainment. Many string figures from many lands are described (without using Haddon's nomenclature). And, unfortunately, the ethnographical sources are rarely quoted.

[4]See the maps in Sect. 8.3.1 (Getting to the village Oluvilei) and Sect. 8.3.5 (Kinship system, districts and cultural areas).

[5]Braunstein (1992a; 1992b; 1996).

the community of Guarani-Ñandeva dwelling in the Santa Teresita mission in the Paraguayan Chaco. Herminia was planning to visit her family and she kindly offered me the opportunity to accompany her. This ethnographic mission took place in October 2005.

8.2 General Methodology

I proceeded in the same way in all fields by applying the same general methodology to collect string figures through working sessions with experts.

8.2.1 Working Sessions

I stayed in the villages for a short period of time, from 15 days (in the Chaco) to six weeks (in the Trobriands). The making of string figures usually takes place during a few weeks or months of the year. For instance, in the Trobriand Islands, as we will see further on, it is during the rainy season that people practice the most. As I had, until then, never had the opportunity to be in the field during the "string figure season", I had to ask to meet the individuals that were highly skilled in the making of string figures. Generally, I began to work with a few elders (men or women) with whom, in several days, I learnt most of the figures known in the area. Then, the remaining string figures of the corpus were often taught to me by men or women who were close family members of these elders. Finally, children taught me the easiest procedures, some of which were unknown to the adults or perhaps forgotten by them—this is an important point, and we shall return to it later.

Each working session allowed me to learn by heart three or four procedures that I encoded afterwards, using the symbols I had created to write these procedures down (see below). The first working sessions gave me the opportunity to learn the specific terminology often used for the transmission of string figures. Sometimes, I could also make observations about cultural, social or cognitive aspects of string figure making. However, most of the time, the procedures were so difficult to learn that I had to concentrate on learning them. Fortunately, I was able to film each of these sessions, and the videos enabled me to make some subsequent interesting observations, as we will see further on.

Once the corpus had been roughly gathered, I could focus on the multiple aspects of this practice. I organized two different types of working sessions. The first type of meeting was with the elders and other people considered to be "experts" by the villagers. I learnt about how they were taught to make string figures, and from whom. I attempted to understand the context: When does this activity take place? On which occasions? I also tried to obtain information on the significance given to the string figures, and connections with other features of local culture (myths, stories, prohibitions, etc.). As explained in Part I of this book, string figures are sometimes accompanied by oral "texts", which are recited either at the end of the procedure or while making the figure; and apparently these narrations are strongly connected to the procedure. I had planned to study this connection, and therefore I collected a large number of these texts.

The second type of meeting was more informal. My presence in the village and my interest in string figures usually motivated many people to start playing, even though it was not traditionally the right time of the year. This gave me the opportunity to take advantage of meetings such as evening gatherings in the Trobriands, or resting time after lunch in the hot days of the Chaco, to suggest that we practice string figures all together. Most of the time, I started making string figures with one or two individuals, generally the ones I had worked with, on the pretext that I needed them to remind me of the figures they had taught me. Very often, some other members of the group—elders, adults or even children—took the string, either demonstrating a string figure they knew or asking to be reminded of the steps in a procedure they had forgotten. It was usually very pleasant for us all. Above all, these informal sessions provided me with some observations of fundamental importance about the transmission and cognitive aspects of the practice of string figures.

8.2.2 Recording String Figures

We have seen in Chap. 2 that, since the end of the nineteenth century, most anthropologists interested in the subject have used Haddon and Rivers' nomenclature for recording string figures. Basing myself on this nomenclature and on Honor Maude's variation on it, I have created (as Storer did) a set of symbols for coding string figures: with these symbols I can reduce a string figure to a simple formula. Furthermore, as I will demonstrate later on, each corpus can be seen as a set of formulae, which can be analysed by computer routines through the concepts of "elementary operation" and "sub-procedure".

There are some examples of the coding system:

R (resp. L) means "right" (respectively "left").

The fingers are numbered from 1 to 5 as in Storer's systemology. "*Loop*" is abbreviated "l", then the loops made on the right hand are written Ril, whereas the ones made on the left hand are noted $Lil,\ \ for\ i \in \{1, \ldots, 5\}$.

When L and R are omitted, it means that the loops on both sides have to be considered.

n and f, abbreviations of "near" and "far", are used instead of *radial* and *ulnar,* to denote the radial and the ulnar strings carried by a given finger, when the palms of the hands are facing each other and the fingers are pointing up. So $R2n$ means "right near (radial) index string", whereas $2n$ means "both near (radial) index strings".

The openings are encoded Op. So, Opening A becomes OpA.

The elementary operation "inserting" is coded $>$.

"From the proximal side" is encoded $pr\_$.

So, the instruction "Insert thumbs, from proximal side, into index finger loops" will be encoded: $(pr\_1 > 2l)$.

The elementary operations "picking up", "hooking up" and "hooking down" are noted respectively p^+, h^+ and h^-.

For instance, the instruction "The thumbs pick up the radial little finger strings" will be coded: $(1\ \ p^{+}\ 5n)$.
Finally, by lining up the above instructions we get the formula $(OpA)(pr\_1\ >\ 2l)(1\ \ p^{+}\ 5n)$ which means "Opening A. Insert thumbs, from proximal side, into index finger loops and pick up the radial little finger strings".

8.3 Insight into the Trobriand Islanders' Society

8.3.1 Getting to the Village Oluvilei

The Trobriand Islands form an archipelago of coral atolls, with a total land area of about 440 square kilometers, located off the east coast of the main land of Papua New Guinea (PNG). It consists of a main island called Kiriwina[6] (approximately 48 kilometer by 16 kilometer on its largest part), where most of the population of 20,000 indigenous inhabitants live, and three other smaller islands, Vakuta, Kaile'una (where Gunter Senft has carried out his research over the years) and Kitava, as well as a number of small islets which are either uninhabited or sparsely populated.

132 – Trobriand Islands

[6]Malinowski refers to the island of "Boyowa" instead of "Kiriwina". The name "Boyawa" is not often used nowadays. According to Malinowski, "Kiriwina" was at that time the name of one of the island's districts.

During the first days that followed my arrival in Kiriwina, I was sent to John Kasaipwalova, a respected intellectual and poet who is also involved in the political life of the region. I spent a few days in his residence, which is located in a pretty place called Bweka, about 15 kilometers from Losuia, the only small town of Kiriwina.[7] John was immediately interested in my project and he prompted me to collect the "oral texts" which often go with string figures. According to him, these texts can be regarded as genuine poems that are linked to local myths and stories (see Sect. 8.4). I began collecting string-figures from people working for John in his house and in his gardens. My informants were Taudoya, a 40-year old man, and a young woman called Bavely. They spent hours teaching me some complex string figures. Yet, even though my discussions with John and the working sessions with Taudoya and Bavely were enriching, I wanted to stay in a Trobriander village. Lydia, one of John's sisters, introduced me to Kenisa, a man who lives with his family in a village called Oluvilei[8] located about ten kilometers from Losuia, on the eastern coast of Kiriwina, and who agreed to let me stay with him.

8.3.2 First Steps in the Village

Kenisa speaks quite good English. This is not the case with all the Trobrianders. Some of them learn English if, like Kenisa, they had the opportunity to stay for a while on the mainland of Papua New Guinea (PNG). In this case, they can speak English but do not necessarily know how to write it. Otherwise, they have to learn it at school. But education is expensive and not available to everyone. However, many Trobrianders understand English quite well, even though most of them cannot speak English properly. As for Pidgin English, which is known by most Papuans in the mainland of PNG—as it is by many people throughout Melanesia—it is seldom spoken in the Trobiand Islands.

[7]Bweka had been the site chosen in the seventies by John and some other Trobriander artists to build the Kiriwina Art Center. This Center does not exist anymore even though John is trying to set up a new project to rehabilitate it. However, Bweka has become a kind of hotel, accommodating people who are passing through. For further detail about the Kiriwina Art Center Project (Kasaipwalova 1975).

[8]Malinowski refers to this village as "Olivilevi" (Malinowski 1922, p. 68). I have chosen to use the writing "Oluvilei" since it has been given to me by some literate villagers. Moreover, it is indeed phonetically closer than the way it is pronounced nowadays.

133a – Bowelogusa

133b – Kenisa (dinner time)

At the beginning of my stay in the village, my movements were limited to a few places in the neighbourhood. It took me more than a week to get a clearer idea of the map of Oluvilei and the neighbouring villages. Kenisa, his wife Bowelogusa and their family looked after me with careful attentions. I had to get used to many things there, in particular the smallest details of everyday life.

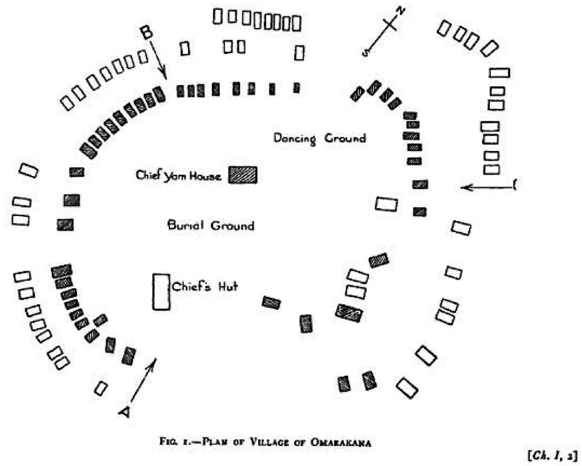
133c – Village of Oluvilei

133d – My "street"

133e – My house (2006)

133f – Chief's yam house (*liku*)

In the Trobriand Islands, all the villages are roughly arranged in the same manner: a circular central dancing place with small houses (*bwala*—consisting of a single room and a veranda) and the yam houses (*bwema*—in which yams are stored) built around it on stilts. I was struck by the fact that the layout of Trobriand villages is usually quite similar, as far as I could see, to the one depicted 80 years ago by Malinowski when he described the village of Omarakana (picture 134).



134 – Plan of Omarakana extracted from Malinowski (1929, p. 10)

The villages of Oluvilei and of Okaiboma are located next to each other. Taken together, they form a densely populated area of about 1,000 inhabitants. In the summer of 2007, I asked Mounaya, a young man from Oluvilei, who guided me several times throughout the archipelago, to conduct the census survey which is detailed in the table below.

	Oluvilei	Okaiboma
Women	102	140
Men	99	153
Young people (2–15 years)	137	206
Kids (under 2)	34	42
Total	372	541

8.3.3 Gardening and Marking Time

In this region, the climate is tropical and there are two main seasons: the rainy season from December to April, and the dry season from May to November. During the dry season, Trobrianders spend most of their time working in the gardens, which are absolutely essential for providing food and where they grow mostly yams, taros, manioc, sweet potatoes, and some green vegetables. This cultivation, together with pig farming and fishing, provides most of their livelihood. The harvest of yams takes place each year between June and August. The tubers are then placed into the "yam houses" (*bwema*) to be consumed throughout the year. Life in the Trobriand Islands is punctuated by garden work in such a way that the year is divided into two different periods, which correspond roughly to the two tropical seasons. Half of the year is devoted to planting, fencing, weeding, harvesting, cutting, and burning the gardens to get them ready for the next planting. The other semester, during which no garden work is done at all, is a time devoted to other activities, such as woodcarving or mat weaving. These two phases (busy period in the gardens/idle period in the gardens) were grouped by Marcia Ascher under the expression "garden cycle" (Ascher 2002, p. 41). In her book "Mathematics Elsewhere", Ascher referred to the articles "Lunar and seasonal calendar in the Trobriands" (Malinowski 1927), and "The seasonal gardening calendar of Kiriwina, Trobriand Islands" (Austern 1939). Both these texts testified that Trobrianders marked time using a traditional calendar, based on a superposition of two cycles: the "garden cycle" and the "lunar cycle" (Ascher 2002, pp. 41–46). More than once I asked people in Oluvilei about this calendar, and it seems that it is no longer in use, although further investigations would be necessary to confirm this. According to Austern, yams were harvested during the last lunar month of the year called *Kuluwasasa* (over July and August) (Austern 1939, p. 239). The following month or the first month of the year was called *Milamala*. During this period, the spirits of the Dead (*Baloma*), normally dwelling in *Tuma* Island, would visit the villages, before returning home with the full moon of the month *Milamala* (over August and September) (Malinowski 1916): then came the time of the great "festival" which was the starting point of a new "garden cycle", when the land was prepared for the next planting before the rainy season.

Nowadays the end of the yam harvest is still marked by festivities, which are grouped under the name of *Milamala* festival. Unfortunately, I did not have the opportunity to attend this festival: in summer of 2006, a rainy period over June and July caused a late harvest in August, which delayed the festival for over a month. In the summer of 2007, until mid-June, people were fully occupied by the national parliamentary election, so the festival was cancelled.

8.3.4 Going Around Oluvilei

At the beginning of my first stay in Oluvilei, I concentrated on collecting string figures in the village and in the neighbouring villages. In Bweka, I had already learnt 32 procedures from Bavely and Taudoya, who both come from the centre of

Kiriwina. All except four of these string figures were also known to my informants from Oluvilei. However, they named nine of these figures differently. This shows that differences may occur between corpora of string figures from one small area of the island to another (or from one village to another). I am convinced that it could be of fundamental importance to capture such variations in order to gain a better understanding of these practises' mode of circulation throughout the archipelago. With this idea in mind, I began to widen the scope of my investigations and decided to visit other places. In 2006, I walked to Omarakana (centre east), Kaibola (north) and Wabutuma (centre west),[9] three villages that are located about 5–15 kilometers from one another. This trip confirmed that the names given to string figures often vary throughout Kiriwina, as do the oral texts attached to string figures (*vinavina*). However, the making of the figures seems quite identical from one place to another, even though sometimes a few differences occur within the procedures themselves: some of the procedures seem to be the "continuation" or the "alteration" of another one. Furthermore, some string figures seem to have a local distribution limited to a group of villages: in Kaibola, Omarakana or Wabutuma, I collected a few procedures which are, to the best of my knowledge, unknown in Oluvilei.

This first visit to other villages throughout Kiriwina also showed me that there were still many practitioners, male and female of all ages, throughout the Trobriand Islands. However, women seem to be most expert, from adolescence to old age. Some of them knew a large number of these procedures. Moreover, string figure-making is generally said by the Trobrianders to be a female activity, even though men usually know how to perform a few string figures—but generally not the more sophisticated ones. Thirty years ago, the Senfts made the same observation among the neighbouring Kaile'una Trobrianders. Although string figure-making was practiced by both females and males from childhood to old-age, statistical outcomes suggested that the most knowledgeable in this activity were the Kaile'una middle-aged women (Senft and Senft 1986, pp. 229–230). Nevertheless, the Senfts argued that it would be wrong to conclude that the practice of string figures would be exclusive to females in the Trobriand Islands. I can confirm this since I had the opportunity to work with a few male practitioners who are well acquainted with the subject. However, I definitely met many more women interested in this activity. Furthermore, it seems that string figure-making is mostly transmitted to children by women. When asked who taught them how to make string figures, my informants invariably answered that they had learnt the procedures mainly from their mother or grandmother.

The local kinship system, which is still in effect today in the Trobriand Islands, often requires women to live in a different village from the one in which they grew up. Therefore, I decided to take a closer look at the Trobriander marriage

[9] See the map of the Trobriand Islands given in the next subsection.

rules to know whether the variations on string figures and their accompanying oral texts—which provide evidence of the circulation of the procedures throughout the archipelago—could be connected to the circulation of women that the kinship system implies.

8.3.5 Kinship System, Districts and Cultural Areas

8.3.5.1 Matrilineal Kinship

In the book *Matrilineal Kinship*, Georges Fathauer detailed a model of social structure and kinship in the Trobriands, based on an analysis of Malinowski's work. Malinowski actually "did not make such systematic analysis himself, [...] but presented enough of the facts in different contexts to allow" it. The Trobriander kinship system is a matrilineal system[10] based on a division into four matrilineal totemic clans (*kumila*) called *Malasi, Lukuba, Lukwasisiga, Lukulabuta*.

> The most comprehensive Trobriand social unit is the kumila, or clan. [...] The Malasi clan ranks above the other three on the basis of a myth which describes the emergence of the animal ancestors of the four clans from the underworld. The people of a clan feel that they are "one body", and they are said to share certain personality and character traits (Fathauer 1974, pp. 236–237).

In his book *Sexual Life of Savages in North-Western Melanesia*, Malinowski gives the original animal ancestors of each clan; which are the dog (*Lukuba*), the pig (*Malasi*), the lizard/iguana (*Lukulabuta*), and the snake/crocodile (*Lukwasisiga*) (Malinowski 1929, pp. 494–500). The clans are sub-divided into some 30–50 totemic sub-clans (*dala*) (Fathauer 1974, p. 237). As far as I know, there is no exhaustive published list of *dala* giving their respective totems and locations all over the islands. Fathauer asserts that this kinship system follows five rules:

Rule 1: Patrilateral cross-cousin marriage (a boy preferably gets married to his father's sister's daughter).
Rule 2: Matrilineal descent system (sub-clan, clan, and rank are transmitted by the mother).
Rule 3: Marriage within the same clan is strictly forbidden.
Rule 4: Spouses must have approximately the same rank.
Rule 5: After the wedding, spouses usually set up home in a village belonging to the man's sub-clan, i.e. his mother's sub-clan.

[10]A kinship system is said to be "Matrilineal" when the lineage is traced through the mother to maternal ancestors.

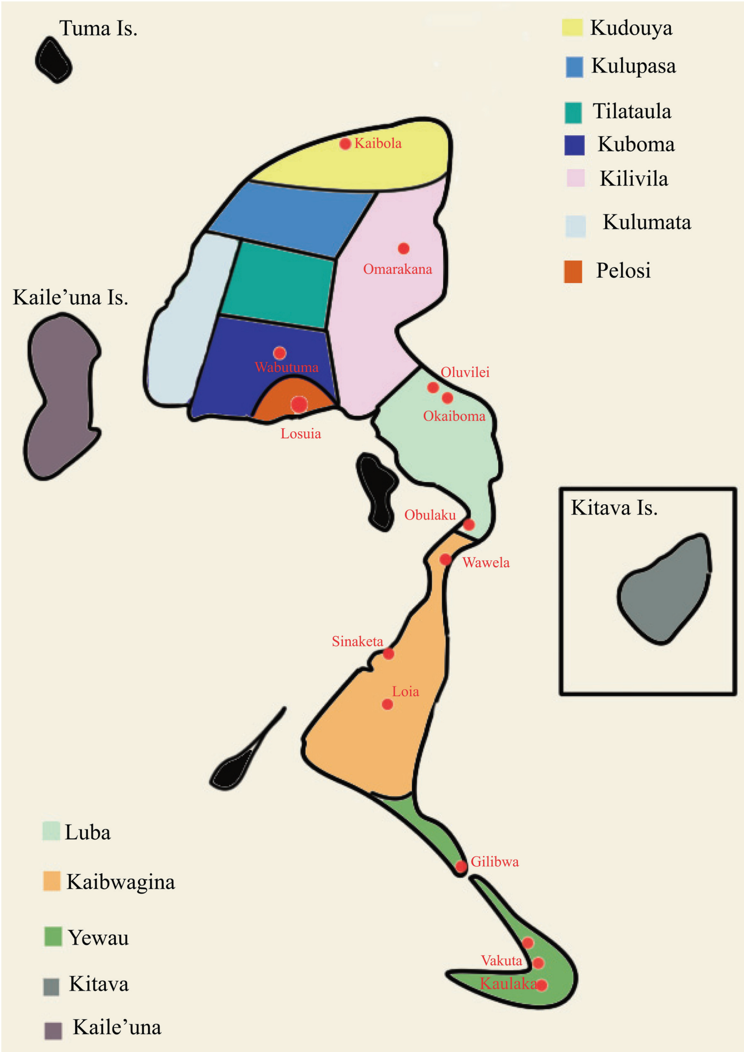
According to Linus Digim'Rina, an anthropologist at the University of Papua New Guinea, Rule 1 is nowadays "really optional, exploited by the well-to-do *dala* groups and families in order to confine the circulation of wealth by inheritance". Moreover, it seems that other factors come into play, such as proximity in residence, character, wealth relativity, and personal choice. However, given Rules 2 and 5, I tried to find out whether clans or sub-clans were attached to an area or a group of villages. I questioned Digim'Rina on whether the villages Oluvilei and Okaiboma belonged to a particular clan or sub-clan. According to him, very few villages are "owned outright" by a *dala* group. For instance, both Okaiboma and Oluvilei are comprised of the four clans, and further compounded in a mixed combination of *dala* groups.[11] Therefore, the study of locations of all clans and sub-clans is of great complexity and requires, according to Digim'Rina, "a meticulously substantive enumeration of clans v. locations (of which they are many), a comprehensive identification of each *dala* group, and its history." So, given the complexity of the phenomenon, the modelling of the circulation of women throughout the Trobriand Islands is a very intricate task that we shall carry out in future works.[12]

8.3.5.2 Districts Versus Cultural Areas

In the summer of 2006, I was informed of the existence of a "division" of the archipelago into districts. I had conjectured that, maybe, this organization into districts could be linked to cultural peculiarities. So, I started wondering whether these districts could be seen as traditional areas, in terms of which, in the next few years, it would be relevant to obtain a large collection of string figures and their accompanying recitatives (*vinavina*) throughout the Trobriand Islands. But, at the beginning, it seemed to me that the inhabitants of Oluvilei did not see these "districts" as cultural or traditional areas, but rather as divisions linked to religious practice. Then John Kasaipwalova led me to reconsider this. According to him, the division was originally related to local cultural differences such as linguistic variations, and the various churches subsequently used these districts to organize their own activities. These twelve districts are: *Kudouya* (Northernmost), *Tilataula* (Central West), *Kilivila* (Central), *Kulupasa* (West), *Kuboma* and *Pelosi* (Southwest), *Kulumata* (Southwest coast), *Luba* (Central South), *Kaibwagina* (South), *Yaiwau* (Vakuta Is.), *Kitava* (Kitava Is.), and *Kaile'una* (Kaile'una Is.). The map in picture 135 gives the rough location of these districts on the Islands.

[11] Personal communication, 2007.

[12] Nevertheless, when questioning my informants, I took meticulously note of the clans and sub-clans of their mother and father, of their grand-father (mother's side), and also the place where they grew up and where their mother and grand-mother grew up. We will see in the future whether interesting outcomes will emerge from such data.



135 – Plan of Omarakana extracted from Malinowski (1929, p. 10)

In his 1929 book, Malinowski noticed the existence of five of these districts on the main island of Boyowa (which is called Kiriwina nowadays): *Tilataula*, *Kuboma*, *Luba*, *Kaybwagina* and *Kiriwina*. I was not informed of a district named *Kiriwina*. According to the map drawn by Malinowski, this district matches the districts *Kudouya* and *Kilivila* all together (see the map[13] in picture 136).

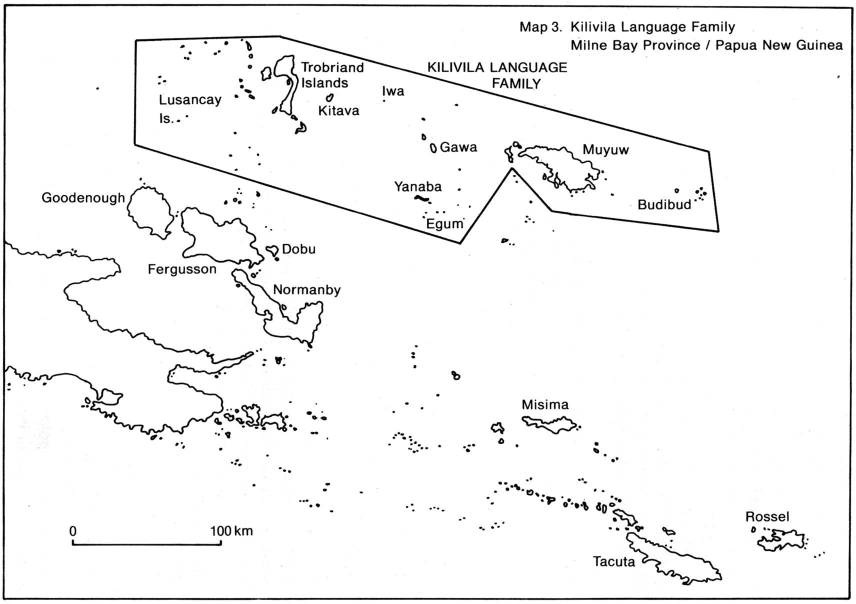
[13]Extracted from the French edition of Malinowski (1922), *Les Argonautes du Pacifique occidental*, translated from English by André and Simone Devyer, Gallimard, 1989, p. 108.

136 – Map of the Trobriand archipelago according to Malinowski

8.3.5.3 Linguistic Areas

The local linguistic variations mentioned by John Kasaipwalova were also attested by Senft. According to Senft, there were different dialects spoken in the archipelago. In his book *Kilivila: The language of the Trobriand Islanders* (1986) he points out that the Kilivila language family encompasses the three languages Budibud (Loughlan Islands), Muyuw (Woodlark Islands and Marshall Bennett Islands) and Kilivila (Lusancay Islands, Trobriand Islands including Kitava, Vakuta, Kaile'una—see picture 137). Futhermore, Senft notices that Kilivila and Muyuw could be split into four dialects.

> The speakers of Kilivila in the Trobriand Islands differentiate at least the following four mutually understandable local varieties or dialects:
>
> Biga galagoki, spoken in [the village] Kavataria on Kiriwina Island [Central Western],
> Biga besagala, spoken in Kiriwina (except Kavataria)
> Biga galanani, spoken in Kuia on Kuiawa Island, on Munuwata Island, on Simsim Island and in Kaduwaga on Kaile'una Island and
> Biga galawala, spoken in [the villages] Kaisiga, Bulakwa, Lebola, Giwa, Koma and Tauwema on Kaile'una Island (Senft 1986, p. 6).



137 – Kilivila Language Family (Senft 1986, p. 7)

Besides this differentiation between the four main dialects, many more varieties are spoken from one place to another. Quoting Ralph Lawton (1978). Senft refers to seven such varieties, five of which are spoken in the Trobriand Islands and the other two are spoken in the nearby islands of Iwa and Gawa respectively:

Kilivila - spoken in the North of Kiriwina Island,
Kuboma - spoken in the Central Western Kiriwina Island,
Luba - spoken in the Central Eastern Kiriwina Island,
Kaibwagina - in the Mid-South of Kiriwina Island,
Yeiwai - spoken on Vakuta Island and in the South of Kiriwina,
Kitava - spoken on Kitava Island,
Iwa - spoken on Iwa Island and
Gawa - spoken on Gawa Island (Senft 1986, pp. 10–11).

We see that the first five dialects above correspond to the names (except for the spelling of "Yaiwau" which becomes here "Yeiwai"), and roughly to the locations of 5 of the 12 districts previously mentioned. This seems to confirm that the division into districts was certainly of a cultural nature and was adopted only later for administrative or religious purposes.

8.3.5.4 Districts and the Circulation of Women

Malinowski defines the five districts he refers to as "political areas", each of them under the authority of a chief. Moreover, he points out that marriage should ordinarily take place within a district.

> Endogamy enjoins marriage within the same political area, that is within some ten or twelve villages of the same district. The rigidity of this rule depends very much on the particular district. For instance, one area in the north-west corner of the island is absolutely endogamous, for its inhabitants are despised by the other Islanders that the latter would not dream either of marrying or having sexual relations within it (Malinowski 1929, p. 82).

My informants in Oluvilei and John Kasaipwalova all confirmed that this rule is still valid nowadays, even though it is not always strictly followed. However, and in spite of the latter remark, we shall consider that these districts are geographical areas within which the circulation of women (roughly) occurs. So, given that women seem to be the main actors of the transmission of string figures, these districts should provide a relevant division of the Trobriand Islands for carrying out a comparative study of string figures throughout the archipelago. We may thus hypothesize that these districts circumscribe cultural areas for the practice of string figure-making.

8.3.5.5 First Results

In the summer of 2007, after one month fieldwork in Oluvilei, I decided to have a closer look at the distribution of string figures and *vinavina*. As mentioned earlier, I had already collected string figures in four districts: *Kudouya* (in Kaibola, North Kiriwina), *Kuboma* (in Wabutuma), *Luba* (in Oluvilei) and *Kilivila* (at Bweka, John Kasaipwalova's place). Then, I walked throughout the Southern part of the island, staying awhile in the villages Wawela (district of *Kaibwagina*), Gilibwa (the village located at the farthest southern point of Kiriwina Island, district of *Yaiwau*), and finally, the villages Vakuta and Kaulaka on the small islet of Vakuta (District of *Yaiwau*). Of course these are only the first steps of a research project that will take years. However, the first data collected all confirm that working in this way should definitely be a relevant approach to study the circulation of string figures in this region. The string figures collected were roughly the same from one place to another. However, one can often notice slight variations within the procedures, carrying different names and/or accompanying with different recitatives. A typical example is given by a string figure called *Kuluwawaya* (red ant) in Oluvilei, and—what I suggest to call—its variations, that I have recorded throughout the archipelago. *Kuluwawaya* is a long process involving a series of eight figures which are shown to the audience.[14] The making of this series is accompanied by a long "text" which follows the procedure.[15] In a noteworthy way, I have collected three other

[14] See procedure 29.*Kuluwawaya* in the accompanying website (*Kaninikula* Corpus).

[15] See Video 1 (*Kuluwawaya*) in the accompanying website.

string figure procedures, *Mwaya tomdawaya* (name of a person)[16] in the island of Vakuta, *Ekuteta kuluwawaya* (red ants pull out) in the village of Wabutuma (central Kiriwina), and *Niwaila* (calmness) in Kaibola (northern Kiriwina), which are all very similar to *Kuluwawaya*. Each of them shares with the others a large part of the procedure. They therefore have in common most of the figures of the series. Moreover, the texts that come with these four series of figures are quite different from one another. Finally, the oral texts accompanying each of *Kuluwawaya*'s three variations are clearly not recited in the same dialect as the one spoken in Oluvilei, for they were not completely intelligible to my informants. So this example seems to indicate that the couple "string figure procedure—oral text" has been modified while passing from one social group to another. It remains to be better understood how these changes can be correlated with local cultural features. Other examples I have collected on the Trobriand Islands show similar transformations. These first outcomes seem therefore sufficient to justify an investigation to determine the general transmission modalities of string figures. A large-scale collection of string figures known in the archipelago will determine the level of this transformation phenomenon's occurrence.

An additional way to conduct further studies on the circulation of string figures throughout the Trobriand Islands and the nearby archipelagos would be to take into account the frequent gatherings between different communities of Milne Bay province resulting from the well known system of trade called "*Kula*".

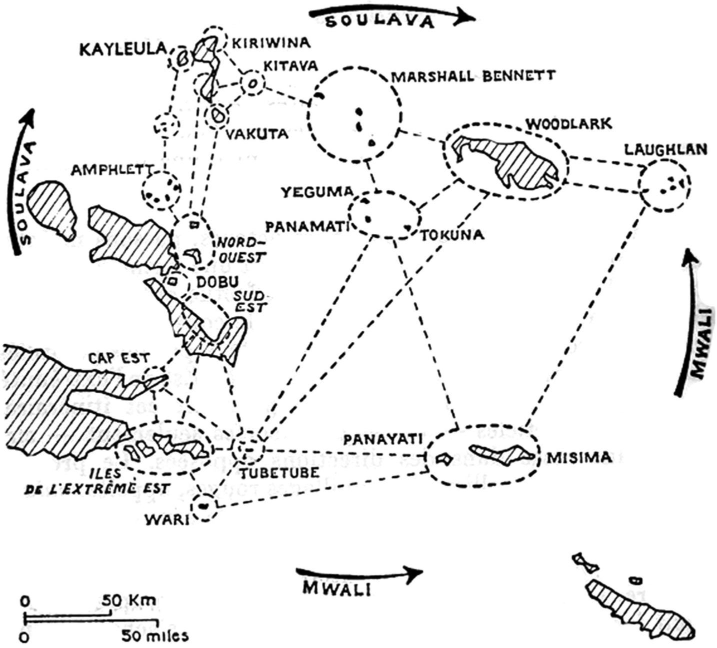
8.3.6 Kula Trade

The "*Kula*" is special system of trade which takes place still nowadays in the so-called "*Kula* ring" (see the map[17] in picture 138). This trading system is described and analysed in detail in *Argonauts of the Western Pacific* (Malinowski 1922), and in the article "Kula: the Circulating Exchange of Valuables in the Archipelagos of Eastern New Guinea" (Malinowski 1920).

> The trading system, [...], which will be described in this paper, differs in this and many other respects from the usual Oceanic forms of exchange. It is based primarily upon the circulation of two articles of high value, but of no real use, these are armshells made of the Conus millepunctatus, and necklets of red shell-discs, both intended for ornaments, but hardly ever used, even for this purpose. These two articles travel, in a manner to be described later in detail, on a circular route which covers many miles and extends over many islands. On this circuit, the necklaces travel in the direction of the clock hands and the armshells in the opposite direction. Both articles never stop for any length of time in the hands of any owner ; they constantly move, constantly meeting and being exchanged.

[16] See procedure 59.*Mwaya Tomdawaya* (*Kaninikula* Corpus) and Video 10 in the accompanying website.

[17] Extracted from the French edition of (Malinowski 1922), Les Argonautes du Pacifique occidental, translated from English by André and Simone Devyer, Gallimard, 1989, p. 140.



138 – Kula trade route

> This trading system, the Kula, embraces, with its ramifications, not only the islands off the East End of New Guinea, but also the Lousiades, Woodlark Island, the Loughlans, the Trobriand Archipelago and the d'Entrecasteaux Group. It touches the continent of New Guinea and extends its indirect influence over several outlying districts, such as Sud-Est Island, Rossell Island, and stretches of the northern and southern coast of the mainland (Malinowski 1920, p. 97).

For many years, the circulation of *Soulava* (necklaces) and *Mwali* (armshells) have generated frequent encounters between people from different communities on the *Kula* ring. Although I have found no evidence so far, we may reasonably think that these encounters provided opportunities to exchange local techniques. It is therefore possible that some string figures have been transmitted in following the *Kula* ring. The latter should thus be a relevant framework to undertake further research in the circulation of string figures, extending the investigations beyond the Trobriand Islands. This research in the circulation and transformations of string figures in Milne bay Province should be a new research project, to be undertaken in the future. For now, let us focus on the materials that I have collected in Oluvilei.

8.4 String Figures-Making in Oluvilei

8.4.1 On the Etymology of the Vernacular Name of String Figure-Making

In the village of Oluvilei, all my informants referred to string figure-making by using the term *kaninikula*. More generally, the same term seems to be used on Kiriwina Island, as well as on Vakuta Island. As mentioned earlier, on Kaile'una Island, string figures are called *ninikula* (Senft and Senft 1986). According to Gunter Senft, this difference is due to dialectal variations that occur from one linguistic area to another in the archipelago.[18]

Anthropologist Linus Digim'Rina suggests that *kanini* may literally mean "to peel/husk/skin with ones teeth", while the term *kula* would be derived here from the verb *kuri*, and mean "how to gain".[19] If the translation of *kanini* by the verb "to peel" is also given by Senft (1986, p. 539)—without mentioning the use of the teeth however—the etymology of *kula* remains an open issue. The anthropologist Johnny Persson suggests for his part that *kula* and *kuna* (rain) might have the same etymological root, referring to the "same imaginary reality based on notions of wealth and fertility" (Persson 1999, p. 199).

According to these information, the literal meaning of *kaninikula* could be "how to gain/to make growing/(a string figure, implicitly) in peeling/operating with ones' teeth". Concerning Digim'Rina's interpretation of the root *kanini*, it is worth noting that it concurs with a characteristic of the practice of *kaninikula* on the Trobriand Islands, where the teeth are often involved in the making of these figures. The previous interpretation of the literal meaning of the term *kaninikula* thus suggests a possible link between the gestural and verbal aspects in the practice of string figure-making, and between the notion of "growing" (how to gain) or "fertility" and the action of "peeling" or "skinning" tubers.

As mentioned earlier, the "oral texts" or recitatives which accompany certain *kaninikula* are called *vinavina* by the Trobriander Islanders. I did not notice any dialectal variations of this term throughout the archipelago. Furthermore, this term is said to be used in the context of string figure-making only.

8.4.2 Plaiting the String for Performing Kaninikula

The string used for the making of *kaninikula* is very thin and quite long (two meters before being tied). It is the result of a tight braiding of fibres (*im*) extracted

[18] See Sect. 8.3.5.3 (Linguistic areas).

[19] Digim'Rina, personal communication, 2010.

from the roots of pandanus trees (*kenivalida*).[20] In Oluvilei, an old man named Buyailakilivila is the only person in charge of making the strings *ulikudu* (lit. thread); he is explicitly recognized as the "specialist" of this technique in the village.[21] This vegetal string is not specially made for string figures, but has many other functions. For instance, it is used to weave traditional skirts (*doba*, made out of banana leaf fibres), necklaces, or for setting up a trap. It is also used for attaching the leaves placed on the deceased's body. Depending on their uses, the strings are of different diameters or lengths. Nowadays, male or female villagers still often ask Buyailakilivila to make strings. He implied that he had learnt the technique of fibre-braiding by watching the elders. The only person to whom he has transmitted this technical skill is his son, a hunter who needs strong strings for his traps. The fact that only one person in the village is in charge of string-making prompts to hypothesize that this activity possibly has a ritual function (that might be transmitted from father to son).

Another hint seems to support this assumption: I was asking Buyailakilivila whether he knew traditional stories or myths that mentioned the practice of string figures. Although he did not know such stories, he told me that he sometimes sings some particular songs (*wosi milamala*) while braiding the strings, as it was (according to him) often the case in the past. These songs are generally associated with the dances *ilowosi* that take place after the yams have been harvested and stored into the houses made for that purpose (*bwema*): performed in circles, these dances are said to open the *milamala* period (over July to September).[22] As mentioned earlier, the spirits of the dead (*baloma*), normally dwelling in Tuma Island, come and visit their former villages during this period (Malinowski 1916). The *wosi milamala* are sung to celebrate the *baloma*'s visit, while providing them with food (Senft 1996). According to Senft, these songs are also aimed to remind the Trobrianders of the social norms that must be respected even during this extraordinary period, which is characterized by "conviviality, flirtation, and amorous adventures" that may lead to "jealousy and rivalry"; if escalating, these may "threaten the community" (Senft 1996, p. 386). According to him, the *wosi milamala* is a form of ritual communication which serves "the function to prevent such a development". It is also noticeable that the *wosi milamala* are usually sung

> after the death of a Trobriander and during the first mourning ceremonies. [...] The songs—especially those that describe the spirits of the dead's carefree "life" in their Tuma "paradise"—may ease the *baloma*'s grief of parting; moreover the songs should also console the bereaved, reminding them of the fact that dying is [...] just a transition from one form of existence to another (Senft 1996, p. 387).

When I asked Buyailakilivila whether he could sing a *wosi milamala* while braiding *ulikudu*, he hesitated for a moment, and finally refused to do it, asserting

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[20] See Video 11 (Extracting pandanus fibre) in the accompanying website (Videos).

[21] See Video 12 (Weaving) in the accompanying website (Videos).

[22] See Video 8 (Ilowosi) in the accompanying website (Videos).

that "when the spirits tell him to sing, he can sing, otherwise he cannot". Further research is needed to clarify the potential ritual link between the activity of string-making and the interpretation of *wosi milamala*, but one may suggest that string-making has a connection with some forms of propitiation regarding the spirits of the dead.

8.4.3 Collecting String Figures: Meeting the "Experts"

In the Trobriand Islands, as well as in the other places where I collected string figures, I never met anyone claiming to have the ability or even the desire to create new string figures, even among genuine "experts". By "experts", I mean people who know almost all the procedures known in the village and who are able to perform them slowly, step by step, operation after operation. It seems to me that there is something which differentiates a good practitioner from an expert. Let me risk an analogy with music. Most musicians (even good ones) memorize a melody as a whole continuous process. So, without reading the music, it is difficult to stop playing at a point and restart at the same point, or to play a short part of the melody without starting at the beginning of it. For a jazzman, who has memorized a fast tempo bebop theme, it is often difficult to play it as slowly as a ballad without breaking up the melody. As far as I know, only a few great musicians are able to do so. This would mean that they memorize music as a continuous object as well as a sequence.

The experts in string figure-making that I met in Oluvilei were Morubikina, an elder in her sixties, her daughter Bosioula and Kenisa's wife, Bowelogusa, two women in her forties. These practitioners know how to make the more complicated string figure procedures that the others often cannot perform. They are therefore considered by other member of the village as a the most knowledgeable in this activity. Morubikina, Bosioula and Bowelogusa taught me most of the *kaninikula* I learnt in the Trobriands.

Following Gunter Senft's advices, I initially offered to pay my informants for working with me. The sessions did not last more than two or three hours, the time I needed to memorize three or four procedures. It is absolutely essential, when learning string figure procedures, to work with a single informant who is willing to spend time with you, repeating the same string figure as many times as necessary, slowly, step by step, in order to allow you to learn and memorize it. It was difficult to make villagers understand that I needed to work with a single person. Almost everybody knows how to make a few *kaninikula* and some people would often try to interrupt the sessions to show what they knew. This behaviour could be directly linked to my visible interest in string figures. However, this could also be indicative of the recognition and prestige associated to the mastering of these figures, as suggested by the high esteem shown by the villagers towards the few persons that I call "experts" in this activity.

Some other people belonging to the close family of my main informants taught me a few *kaninikula*: especially Tokwakuwa, the father of Tomigagaguyau (Bosioula's husband), and his wife Isupwana. Finally, I learnt the rest of the corpus from children. In Oluvilei, children know how to make a few *kaninikula* and the most "expert" among them generally know about ten *kaninikula*, usually the same ones. Moreover, as far as I have seen, the transmission of these procedures occurs mostly between children. This led me to consider a subset of the corpus formed by the procedures that are generally known by pre-adolescent children. Furthermore, I observed that string figures learnt during childhood are sometimes forgotten by adults, even by the most expert individuals, which means that some *kaninikula* seem to be almost exclusively known by children.[23]

I first concentrated my efforts on learning the procedures, putting aside the collecting of *vinavina*. It took me about two weeks to get a corpus of 68 *kaninikula* from Oluvilei. After the collecting process described above, the formal working sessions became informal meetings. Together with Morubikina, Bosioula, Bowelogusa and other villagers, I would practice at night, after dinner, in the light of a kerosene lamp on Kenisa's veranda, chewing betel nuts (*buwa*).[24] During these informal sessions I began to note down some *vinavina* and I made some observations about cultural and cognitive aspects of this practice.

8.4.4 Some Cultural and Cognitive Aspects of Kaninikula

8.4.4.1 On the Past and Present Contexts of the Practice of String Figure-Making

Morubikina grew up in Oluvilei (district *Luba*) in the sixties. She informed me that, in her childhood, people used to practice *kaninikula* mostly during the yam harvest season—roughly from June to July. Nevertheless, Morubikina was the only person to give me this information. My other informants did not mention this period of the year as the right time for practicing *kaninikula*, asserting that string-figure-making mostly takes place during the rainy season. As mentioned earlier, this season of leisure is considered by the villagers as favourable to entertainment, since almost no work can be done in the gardens. In the 1980s, Gunter and Barbara Senft noted the

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[23]See Video 2 (Dauta forgotten) in the accompanying website (Videos).

[24]Betel nuts (*buwa*) are consumed together with a kind of green beans, that Trobrianders called "mustard" (*mweya*), and lime (*pwaka*) obtained from crushed corals. The mixture obtained by mixing these three ingredients causes a red precipitate in the mouth and a stimulating effect. Many Trobrianders are clearly addicted to these substances and consume them all day long. One betel nut is sold approximately for 0.20 Kina. This is actually quite expensive for them, so before each informal working session I would buy betel nuts for everyone to thank them for spending time practicing *kaninikula* with me. The nuts were always accepted very gratefully.

same phenomenon on Kaile'una Island (Senft and Senft 1986, p. 102), where they were struck by the number of people practicing "*ninikula*" during the rainy season.

It is noteworthy that Morubikina's testimony corroborates information given to the anthropologist Diamond Jenness in the 1910s on Goodenough Island, in the D'Entrecasteaux archipelago. These Islands belong to the *Kula* ring, and are relatively close from Kiriwina (see the map of the *Kula* ring—picture 138). In the article "Papuan Cat's Cradles" (Jenness 1920)—already quoted in Part I of this book—Jenness mentions that string figure-making seems to have been prohibited, except during a particular harvesting season. Following an information given to him by the Rev. A. Ballantyne, who was a missionary on Goodenough Island for many years, Jenness underlines that:

> The proper time for playing the game (Cat's Cradles) is at the *mwa'mo* (a root similar to the yam) harvest. At all other times the old men prohibited them lest they should bring disaster on the gardens. As the *mwa'mo* harvest is immediately followed by the planting of yams, which are the principal food of the natives, it would seem that the playing of Cat's Cradles is beneficial for the gardens (Jenness 1920, p. 300).

On Goodenough Island, the practice of string figure might thus have been embedded into a system of prohibition/prescription—linked to positive or negative impacts on gardens—which entailed that string figure-making were prohibited during the rainy season, and encouraged only a few weeks during the dry season. Nevertheless, in the same years (1910s), the fact that Malinowski did not make the same observation in the Trobriand Islands corroborates all my informants' testimonies (with the exception of Morubikina).

> String figures or Cat's-cradles (ninikula) are played by children and adults in the day time during the rainy months from November till January, that is, in the season when the evenings are passed in reciting folk-tales. On a wet day, a group of people will sit under the overhanging roof of a yam house or on a covered platform and one will display his skill to an admiring audience (Malinowski 1929, p. 336).

Even though Malinowski travelled throughout the region (the Trobriand archipelago and nearby islands) to carry out his research about the *Kula*, he was based at Omarakana in the district of *Kilivila*. This village has a central place in his 1929 book (*The Sexual Life of Savages in North-western Melanesia*) in which he devotes a short section to string figures. Hence, one may suggest that he made his observations about string figures in this village of the centre of Kiriwina, where string figure-making usually took place at the beginning of the rainy season in the 1910s.

The above testimonies suggest that, at least in the past, the period for making string figures may have varied from one place to another in the Trobriands and nearby islands. This apparent contrast between neighbouring cultural groups suggests that it should be worthwhile to investigate the plausible causes of these variations.

8.4.4.2 Accompanying Oral Texts as Memory Support

In Oluvilei, I have collected 18 string figure procedures which are accompanied by a *vinavina*. These oral texts are of various lengths and recited or sung either at the end of the process, after having displayed the final figure[25] or throughout the procedure[26] In both cases, the *vinavina* seems inseparable from the operational procedure leading to the final figure. In the first case, it seems that the *vinavina* must be recited at each performance, even though the practitioner makes the figure several times consecutively. In the second case, it seems difficult for the practitioners to make the figure without reciting the *vinavina* and vice versa. From this perspective, one may suggest that *kaninikula* and their associated *vinavina* can constitute genuine memory support for one another: the procedures carried out on the strings have helped to memorize the "texts" and vice versa. The connections between texts (*vinavina*) and procedures shall be further studied in that perspective in particular.

8.4.4.3 *Kaninikula* as Entertainment

From the observations I made in Oluvilei and other places in the Trobriands, it is obvious that Trobrianders still enjoy performing string figures nowadays. *Kaninikula* and their attached *vinavina* are clearly entertaining to the practitioners, but also to the onlookers. Indeed, I was able several times to observe practitioners performing *kaninikula* as if it were a play, in front of an audience. In most cases, these performances clearly aim at making the onlookers laugh. As we will see further on, many *vinavina* sound as a way to talk about sexuality. I noticed, for instance, that any sort of reference to sexual intercourse caused great hilarity in the audience. On other occasions, laughter was provoked by scatological references. Such is the case for a string figure called *Gwadi* (child), which represents a baby carried by the practitioner, who wants to entrust the child to somebody else because it is soiled with its own excrement.[27]

In some other cases, the outcome of a *kaninikula* is a figure which appears suddenly: it is usually at that moment that the audience laughs. When a text goes with a *kaninikula*, it is often at the end of the *vinavina* that people laugh. Furthermore, people generally laugh each time the procedure is performed, even though the process is repeated several times consecutively. This clearly suggests that there are *kaninikula* which are supposed to cause laughter, as if laughter was prescribed at the last stage of the procedure.

[25] See Video 3 (Mina Kaibola) in the accompanying website (Videos).

[26] See Video 1 (Kuluwawaya) in the accompanying website (Videos).

[27] See Video 5 (Gwadi) in the accompanying website (Videos).

8.4.4.4 Cognitive Abilities in String Figure-Making

A few experiences I had in Oluvilei provided me with some indications about the way some string-figure makers perceive string figure processes. Once, as I was learning a procedure from Morubikina, I asked Bowelogusa, who was cooking nearby, whether she knew this *kaninikula* (that I found quite difficult). She answered that she did not, but the following night, she easily displayed the figure during an informal working session. She mentioned that she had learnt to make this string figure simply by watching us at short distance. If this assertion were true (as it seemed to be), one may think that the ability of Bowelogusa to capture and memorize a procedure at some distance, without manipulating the loop of string, is due to many years of practical experience, that have given her a high perception of the operations involved in the procedures and their usual organization in "sub-procedures".

I also noticed, in a similar learning situation, that several Trobrianders can instantly grab and reproduce unfamiliar series of operations in string figure-making. In the village of Wabutuma (in the centre of Kiriwina Island), some people asked me whether I had found elsewhere on Kiriwina some kaninikula which were unknown to them. I decided to demonstrate a procedure that was apparently unknown in Wabutuma, and that I had learnt under the name *kwau* (the shark) in the village of Kaibola, on the south coast of Kiriwina. Moreover, as far as I could see, this *kaninikula* was not comparable to any string figure taught to me in Wabutuma. As this procedure involves two partners, I performed it with Monouya, the person who had guided me throughout the Trobriand Islands, and who had also learnt the procedure in Kaibola. The people in Wabutuma confirmed that this procedure was new to them. But as soon as we ended our demonstration, some observers repeated successfully the same procedure (which seemed quite complex to me). This may indicate that some practitioners are able to internalize very quickly an atypical series of operations.

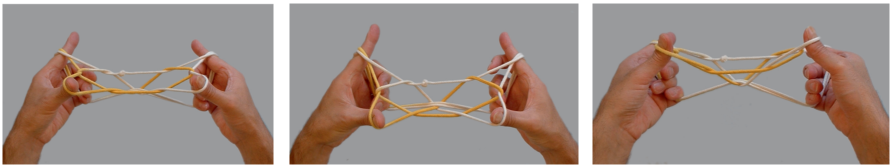
Nicolas Garnier, a French anthropologist at the University of Papua New Guinea, suggested to keep this anecdote in mind and return to this village in a few years in order to see whether or not the figure *kwau* had been integrated into the corpus of string figures of this village. He was unsure that a figure coming from "elsewhere" could be readily memorized and integrated into the original corpus of string figures known in the village.

8.4.5 Expressing Knowledge Through String Figures

Each *kaninikula* has a specific name in Kilivila. Until now, I have collected 68 of these names in Oluvilei. They can be divided into 4 subsets: 7 names refer to the environment (sea, sun, island, river, …), 11 names refer to "objects" made by humans (trap, basket, grass skirt, house, ...), 18 are names of animals, 8 are names of plants, 15 refer to people or human actions, and finally 9 *kaninikula* known in the village have names whose meanings are forgotten (see Annex II). But this classification should be taken cautiously. According to Senft, the name of an animal, a plant, a fruit, or an object for the everyday life, is frequently given in a metaphorical way. By using such names, one can actually refers to genital organs, coitus and sexual intercourse in particular (Senft and Senft 1986, p. 103). Some of these animal names may also refer to the original animal ancestors of the four matrilineal totemic clans: *lukuba* (dog), *malasi* (pig), *lukulabuta* (lizard), and *lukwasisiga* (crocodile or snake).[28] Although no connection has been explicitly recognized by my (former) informants, one may notice that "dog" (*kaukwa*), "pig" (*bunukwa*), and "crocodile" (*uligova*) are also the names of *kaninikula*.

8.4.5.1 String Figures as Representational Images

During the informal string figure-making sessions, Morubikina, Bowelogusa and Bosioula spontaneously commented on the connections between the procedures or the final figures and their respective names. Sometimes, according to my informants, it is the final figure which has been explicitly named. For instance, *Togesi* means "basket", and it is said that the final figure represents such an object (pictures 139a–139c).[29]



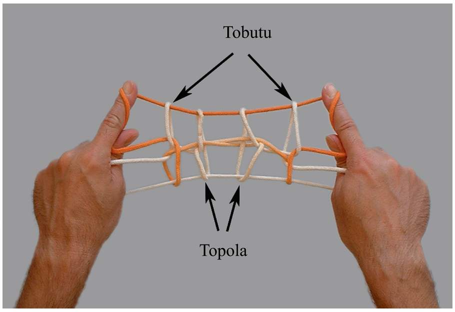
139a – Three views of Togesi 139b 139c

The *kaninikula* named *tobutu—topola*, which has been translated as "Men chasing fish—Men carrying the net"[30] refers to a fishing technique that consists in driving fish towards a net carried by other fishermen. The final design shows four men: the two outer patterns represent *tobutu* whereas the inner ones show *topola* (picture 140).

[28]See above Sect. 8.3.5 (Kinship system and traditional cultural areas).

[29]For further detail, see procedure 4.*Togesi* in the accompanying website (*Kaninikula* Corpus).

[30]For further detail, see procedure 23.*Tobutu topola* in the accompanying website (*Kaninikula* Corpus).

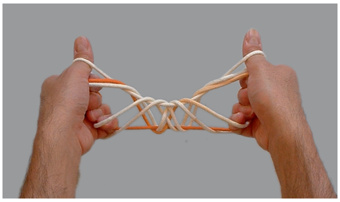


140

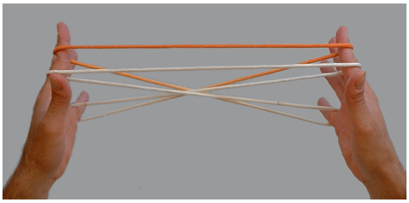
According to the description given by Honor Maude, the same procedure was known among the Solomon Islanders as *whai wane* (four men up a tree gathering nuts)[31] (Maude 1978, pp. 63–64). So, here we have the same procedure with two different names and meanings, from two different but not very distant areas. This is also the case of procedure *Togesi*, which was known, according to Maude, as *Daho* (wooden food bowl) in the Solomons (Maude 1978, p. 106). Given the high occurrence of similar procedures found in both the Trobriand and Solomon Islands, one may suggest that these procedures have circulated throughout the region, receiving different names and interpretations, as if it had been necessary to adapt the names of string figures to local preoccupations.

8.4.5.2 Altering the Final Figure

In some cases, the name of a *kaninikula* is said to be related to the way the final figure is transformed or animated. In the procedure called *Sem* ("shoal of fish"), the first figure shown to the audience is represented in picture 141a. Then, the thumbs are released and the first figure is suddenly deconstructed to return to an intermediate position (picture 141b—$Conf(B)$).[32] My informants connect this change to the suddenness with which a shoal of fish changes direction.



141a

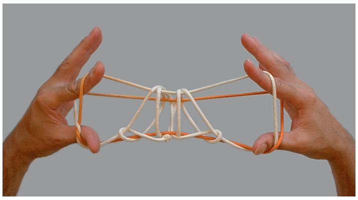


141b

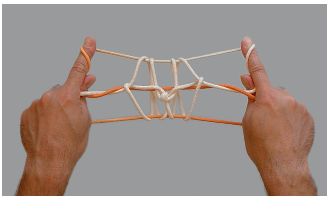
[31] See Sect. 3.4.3.

[32] For further detail, see procedure 28.*Sem* and Video 7 (Sem) in the accompanying website (*Kaninikula* Corpus/Videos).

The procedure called *Kalamolu nageta* (Nageta is hungry) provides another example of a name derived from the alteration of the final figure. The practitioner shows a three-dimensional final figure before turning it into a two-dimensional one.[33] According to Morubikina, the first figure shows a "full stomach" whereas the second figure is an empty one (pictures 141c and 141d).

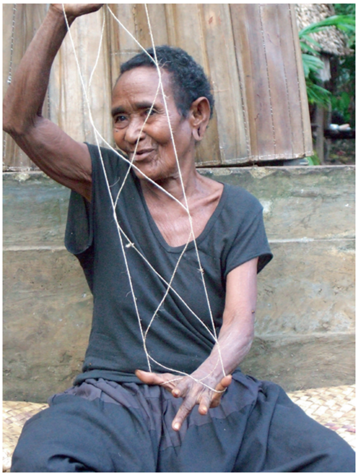


141c – Kalamolu Nageta—3D



141d – Kalamolu nageta—2D

There are also some procedures in which the meaning of the final figure seems to be linked to the way this figure is animated. For instance, the final figure of procedure *Mina kaibola* (Man of Kaibola) has to be manipulated by the practitioner to mime the movements of a paddler[34] (pictures 142a and 142b). However, my informants could not say whether the string figure *Mina Kaibola* refers to a particular story or to the nautical abilities of the men of Kaibola, a village in northern Kiriwina.



142a

142b

[33]For construction, see procedure 38.*Kalamulu nageta* in the accompanying website (*Kaninikula* Corpus).

[34]See Video 3 (*Mina Kaibola*), and, for construction, see also 16.*Mina kaibola* in the accompanying website (Videos/*Kaninikula* Corpus).

8.4.5.3 *Kaninikulas'* Name and Operational Gesture

Sometimes, the link between the *kaninikula* and its name seems to lie within the procedure itself. *Kala tugebi navalulu* is such a string figure procedure.[35] *Kala tugebi* means "carry on the head", and *navalulu* means "woman in childbirth". According to my informant Bowelogusa, this name refers explicitly to the headdress (or linen) worn by women when they first come out of their house after giving birth—they wear this garment in order to prevent evil spirits from entering their bodies and spoil their milk. This is also underlined by a particular operational gesture within the string figure-making process: the first step of procedure *kalatu gebi navalulu* consists in making a small loop which is gripped between the teeth, then the rest of the string is placed over the head as the headdress should be[36] (pictures 143a–143c).

143a

143b

143c

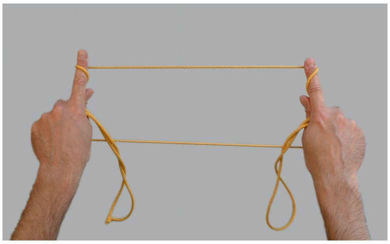
[35] For construction, see procedure 8.*Kala tugebi navalulu* in the accompanying website (*Kaninikula* Corpus).

[36] See Sect. 9.2.1.1 (Variations on Opening M).

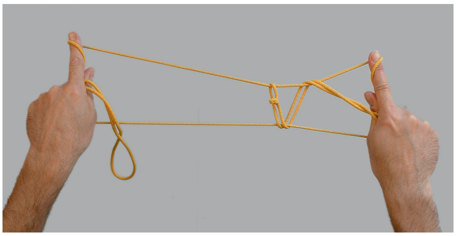
8.4.5.4 String Figures as Memory Support for Prescriptions or Prohibitions

As my main informants from Oluvilei did not seem to identify any particular relation between the procedure and its name in several *kaninikula*, I tried to gather some information from other people in the village. Some testimonies I have thus collected suggest that the making of some *kaninikula* was, or still is, intended to remind the Trobrianders about certain knowledge that can be linked to social rules, stories or events.

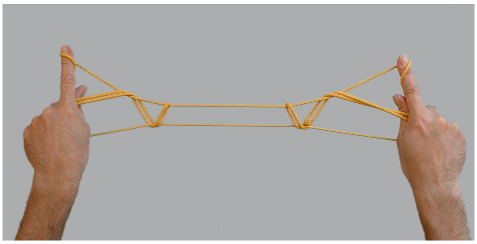
Tolobuwa is the chief of the village. He is in charge of all the events linked to the *Kula* and is considered by Oluvilei's other inhabitants as the "guardian" of their traditions. I organized a working session with him to get his point of view about the names of some string figures. He particularly insisted on a string figure procedure called *Dakuna* (stones) that he considers to be referring to "magic stones". This *kaninikula* consists in a series of three procedures which differ from one another by the alteration of one and only one elementary operation—we will come back to this fundamental technical point later on.[37] The three figures obtained through the latter three consecutive procedures are shown in pictures 144a–144c. This series of figures is punctuated by a *vinavina*. While the first figure is shown to the audience the practitioner says: *dukuyoyo wa* (they fly away). For the second figure she/he says: *dukuyoyo—lukutota* (they fly away—they remain standing). And finally, for the third one: *dukutota* (they remain standing).[38]



144a – *Dakuna*: *dukuyoyo wa*



144b – *Dakuna*: *dukuyoyo - lukutota*



144c – *Dakuna*: *dukutota*

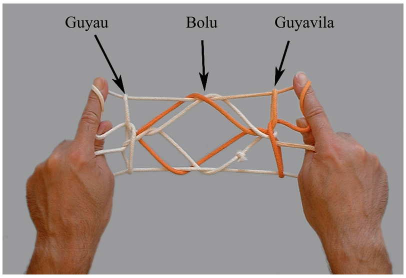
[37] See Sect. 9.4.2.2 (Modification of a single operation within the procedure).

[38] For construction, see procedure 46.*Dakuna* in the accompanying website (*Kaninikula* Corpus).

In the Trobriand Islands, many stones are known to be used for various forms of magic. Some of the most widely known are those brought into the big yam houses (*liku*) so that the tubers remain fresh and beautiful while they are stored in the *liku* (Senft 1997). The stones that string figure *Dakuna* refers to do not seem to have the same purpose however: according to Tolobuwa, each village chief owns magic stones that he receives from his maternal uncle, and that he himself buries near his big yam house (*liku*). Each of these stones is said to contain a giant to whom the chief has to ask frequently for some help with gardening. If the chief does not comply with this prescription the stones move away and never come back (Vandendriessche 2012). Tolubuwa insisted that string figure *Dakuna*'s role is to remind the chiefs that they have to use their magic stones if they don't want to lose them. The string figure procedure *Dakuna* thus appears as a memory support of a ritual prescription linked to the fertility of gardens.

I also questioned Tolobuwa about the meaning of string figure *Guyau—Bolu—Guyavila*.[39] I had learnt the meaning of each word: *guyau* means "chief", *guyavila* is the chief's wife, and *bolu* is a bowl or cup. But the sense of these three words put together was not clear to me. Tolobuwa informed me that every chief in the Trobriands owns a bowl, that he only can use for meals, while his wife is the only one allowed to pour water or soup into it. According to Tolobuwa, these are the rules that are underlined—and thus called to memory—in the string figure called *Guyau—Bolu—Guyavila*.

145 – Tolobuwa and Muyamuya, his wife



146 – Guyau—Bolu—Guyavila

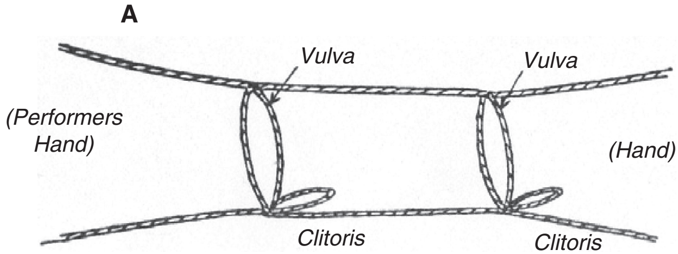
8.4.5.5 String Figures and Sexuality

In their 1986 article, the Senfts demonstrated that a number of string figures known at that time in *Kaile'una* Island were connected to sexuality (Senft and Senft 1986, p. 103). Malinowski had already given a few examples of string figures which

> show pornographic details. In "kala kasesa Ba'u" (the clitoris of Ba'u) the performer, after preliminary manipulations, produces a design [. . .][see below] in which two large loops are

[39]For construction, see procedure 24.*Guyau-Bolu-Guyavila* in the accompanying website (*Kaninikula* Corpus).

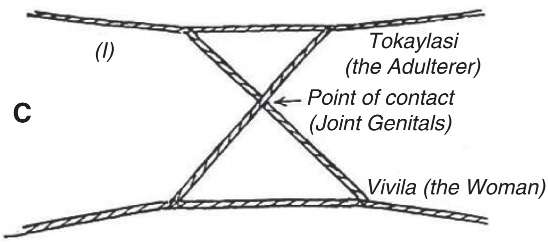
> formed in the main plane of the figure, while at the bottom of each, a smaller loop sticks out at right angles to the main plane. The large loops each represent a vulva and the smaller ones a clitoris. [. . .] The figure complete, the artist skilfully wriggles his fingers, producing a movement first in one and then in the other of the clitoris loops (Malinowski 1929, p. 336).



147 – "Kala kasesa Ba'u": extracted from Malinowski (1929)

In this case, it is the figure itself which symbolizes the genital organs. I personally did not find this *kaninikula*. However, I have learnt how to make the string figure *Tokwelasi*[40] which is one of the four string figures that Malinowski mentions in his 1929 book. In this procedure, the connection to sexuality is explicit, both through the manipulation of the final figure (referring to sexual intercourse) and in the *vinavina*. *Tokwelasi* is the name of a man known as an adulterer, as Malinowski already mentioned it:

> Tokwelasi, the adulterer (C, in Fig. 3), is a complicated set and requires both hands, the two big toes and the heels for its composition. The accompanying commentary is just spoken in ordinary prose. The first figure (C, I) is formed, in its significant section, of two isosceles triangles, one above the other and touching by apex. These triangles represent the adulterer and the wife engaged in the act of copulation. To indicate this, strings are manipulated so that the point of contact moves up and down, while each triangle in turn increases and decreases in size. At the same time the artist declares in unambiguous language; "This is the adulterer; this is the wife, they copulate" (Malinowski 1929, p. 338).



148 – "Tokwelasi": extracted from Malinowski (1929)

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[40] See procedure 55.*Tokwelasi* in the accompanying website (*Kaninikula* Corpus).

My informant, Tokwakuwa (Bosioula's father-in-law), did not mention the signification of the two triangles. However, he confirmed that the manipulation of the figure, moving the hands up and down, represents intercourse between the adulterer and the wife.[41] I was also able to notice that the accompanying text was recited by Tokwakuwa in "ordinary prose". Moreover, he was searching his words at times, and the *vinavina* may vary from one performance to another. One of these variation was the following text, which explicitly refers to an extramarital relationship of a married woman and a man, and also to the punishment: as noted by Malinowski, a husband had the right to kill his adulterous wife, even though the usual punishment was thrashing (1929, p. 121).

Tokwelasi kala biga - Tokwelasi, his language
Tokwelasi esisu ola bwala - Tokwelasi is in his house
Lakwava sola ehelasi - His wife, with her, they commit adultery
Bwala sola bwala ekatudeva - In the house with her in the house, he has fun
Ekatudeva bogwa elagisi sola kala biga - He has fun already, they hear her friend, his speech
Esakaula ila - He runs he goes
Esakaula ila kala biga bogwa - He runs, he goes, his speech already
Tolimwala kala biga - the true husband, his speech
Kutota kuvigivau - You stand up, you do it again
Igau kala biga leolada - Then, his speech on the road
Kalituwa kaligeva kaliga - The prize, forget it, death![42]

The explicit reference to coitus, made at the same time in this *vinavina* and through the manipulation of the string figure, is one of the reasons why Tokwakuwa refused to perform this *kaninikula* on a Sunday—as I was asking him to teach me the words of the *vinavina* he had recited a few days before while making this string figure. On another occasion, again on Sunday, when Tokwakuwa was performing *kaninikula* in front of a large audience in the village,[43] I asked him to make the one called *Tokwelasi*, and he refused once again, reminding me that he could not perform this procedure on the Lord's day. He finally taught me the words some days later, in the intimacy of the evening gatherings on his veranda.

Like Malinowski and the Senfts, I was able to notice a connection between string figure-making and sexuality. However, it was not always easy to make my informants comment on this aspect, as illustrated by the following testimony. There is a string figure procedure which is known as *tubum* in Oluvilei.[44] When I asked Morubikina about the meaning of this word, she said that she did not know it, and she even claimed that, to her knowledge, this string figure procedure was not accompanied by an oral text. Sometimes later, as I was staying in the village of Wabutuma in South Central Kiriwina, some local practitioners told me that this procedure (*tubum*) was called *kwetabum* in Wabutuma, where it was accompanied

[41] See Video 4 (*Tokwelasi*) in the accompanying website (Videos).

[42] G. Senft's translation—personal communication, 2012.

[43] See Video 5 in the accompanying website (Videos).

[44] For construction, see procedure 27.*Tubum* in the accompanying website (*Kaninikula* Corpus).

by a *vinavina*. When I returned to Oluvilei, I asked about the meaning of the words used in this *vinavina*, and about the meaning of *kwetabum*. I was told that this term refers to "a boy sleeping with his grandmother (*bubu*)", which is also clearly evoked in the accompanying oral text. This *vinavina* thus refers to an incestuous relationship. Although not comparable to the sister-brother incest taboo—which is the supreme one (Malinowski 1929, p. 437; Weiner 1988, p. 76)—as noted by Malinowski, "the maternal grandmother and her grandson are also sexually forbidden to each other, but there is no horror about this relationship, such incest appearing as a merely ridiculous possibility (1929, p. 441)." I questioned Tolobuwa (the village chief of Oluvilei) about the meaning of *tubum* in Oluvilei and also asked him about *kwetabum*, the name found in Wabutuma. Since he was unable to answer, he asked Morubikina to come. She joined us and revealed that *tubum* and *kwetabum* have exactly the same meaning as they both refer to the same story. Morubikina did not tell me why she had first hidden this to me, but it might have been that the story *tubum* tells of a behaviour that contemporary Trobrianders do not like to discuss in public, due to the influence of the local protestant Church (the United Church).

It is likely that my informants chose deliberately not to reveal the metaphorical meaning of some *kaninikula* implying sexual or scatological references. It is also probable that I did not collect the whole corpus of *vinavina*: it is often said that there were many more in the past, and Trobrianders admit quite readily that a lot of these texts were connected to sexuality. The *vinavina* may have been forgotten under the ambient Christian ideology, or they may be hidden and transmitted confidentially.

8.4.6 Kaninikula as a Mathematical Activity

I often explained to my informants the purpose of my research on string figures, stressing that my goal is to understand the underlying system of transformations on which *kaninikula* are based and that I was doing so, in order to shed new light on this practice which, in my opinion, can be seen as mathematical. Although Trobrianders did not usually question me (spontaneously) about (the reason for) my interest in string figures, they seemed really interested by my explanations. There is no word for "mathematics" in Kilivila, but the word *makwaginigini*—translated as "writings"—refers more generally to what is learnt at school, including mathematics. So the Islanders who went to school have an idea of what mathematics are (in an Occidental perspective). I noticed several times that these informants were not surprised by a possible connection between mathematics and string figures: on the contrary, this connection seemed quite natural to them.

On Kiriwina Island, there is a high-school where a Trobriander, “Miss Veronica”, has been teaching mathematics for many years through a curriculum which is quite similar to the Europeans ones. I was eager to know how she felt about considering *kaninikula* as the expression of a mathematical practice. Miss Veronica, who has a strong reputation as a teacher in the Province, was very interested in the studies carried out by mathematicians on string figures. She manifested a great interest in the concept of heart-sequence in particular. When I mentioned the probable connection between *kaninikula* and mathematics, Miss Veronica answered that there is no doubt that such a link does exist. She went even further, asserting that string figure-making (*kaninikula*) is not only connected to mathematics, but “is actually mathematical”.

Miss Veronica and I have decided to collaborate in the next few years, in order to produce pedagogical material based on string figure-making for teaching concepts such as symmetry, algorithm, and transformation. I hope that our coming discussions will help to clarify the reasons why she perceives such a clear connection between mathematics and string figures.

I stayed a total of about ten weeks in the Trobriand Islands, which enabled me to start looking at some of the cultural aspects of string figure-making. We have seen what promising ethnography could be carried out in order to study how this activity is embedded within the Trobrianders’ society. By contrast, my stay in the Chaco among the Guarani-Ñandeva was too short to undertake such ethnographical investigations. However, I did stay long enough to make a significant collection of string figures worth comparing to these of the Trobrianders. Moreover, while gathering the collection, I had the opportunity to make a few observations on the cultural and cognitive aspects of this activity, paving the way for further ethnography.

8.5 Fieldwork in the Chaco, Paraguay

8.5.1 The Mission Santa Teresita

After a short stay in the Capital Asunción, I travelled 600 kilometers by coach from East to West, through the Paraguayan Chaco, with Herminia and her young daughter. When travelling to the West, during the dry season, the temperature increases gradually, reaching more than 45°C (113°F). The Chaco is one of the hottest regions of the planet. The long straight road which connects Asunción to the small town of Mariscal Estigaribia (one hour by car from Filadelfia, the biggest town in the region) stretches through a flat landscape of marshy plains and thorn bush.

149 – Chaco, Paraguay

The village where Herminia's family lives is actually a mission called Santa Teresita. It is formed by three indigenous communities: the Nivacles, the Occidental Guaranis, and a group of Guarani-Ñandeva.[45] Identified as farmer-breeders and hunter-gatherers until the 1930s, the Guarani-Ñandeva make a living out of subsistence farming, livestock farming and occasional hunting. Besides, a large part of their livelihood is secure nowadays, as they are employed on a seasonal basis to work on the big farms that belong to the Mennonites.[46]

Herminia's parents live in a small brick house with their three sons, their second daughter and her little boy. Beside their house is a kitchen, where fire is made for cooking. During the Spring, people live outside and sleep on the ground outside the house, which is then used essentially to store food and clothes. There is neither electricity nor running water, but drinking water can be drawn from a well at the centre of the village. I was not immediately aware of the daily difficulties experienced by this community. Herminia and I went shopping daily to buy food in the little town of Mariscal, located a few kilometers from the mission. I bought food for all the ten persons who lived in the house, and it cost me roughly 100,000 guaranís (15 euros) every day. Once, as I returned "home" after a two-day trip to

[45]The Guarani-Ñandeva community of Santa Teresita is composed of some uxorilocal family groups who traditionally inhabited a territory further north near the Bolivian frontier, and who were displaced in the 1940s after the Chaco War.

[46]The Mennonites are a German Christian group who settled in the Chaco centuries ago (Rudel 1990, p. 153).

collect string figures in another village, I realized how much my daily contribution improved the family's usual diet: it was the end of the day, the shops were all closed, and dinner was corn gruel for everyone. I remembered what Jean-Pierre Estival had said to me once while I was preparing for this field trip: "They are often hungry in the Chaco". An ethnological study by Jean-Pierre Estival shows that this people survive thanks to the way their community is organized: although their traditional economy and food habits have been greatly modified, food consumption is still ruled by egalitarian principles that allow access to food to everybody and prevent its accumulation in the hands of a few individuals (Estival 2001). Wages and all supplies are shared and distributed among all members of the community. For instance, when Eugenio (one of Herminia's brothers), acting in absence of the village chief, set the fee that I had to pay (700,000 guaraníes/approx. 100 euros) to be allowed to stay in the village, this money was redistributed among the seven families of the community.

8.5.2 The Tukumbu Corpus

8.5.2.1 General Description: First Observations

I carried out research on string figures among the Guarani-Ñandeva communities of the Santa Teresita mission as well as in the village of Laguna Negra, located roughly 20 kilometers from the mission.[47] String figure making is called *tukumbu* in the Guarani-Ñandeva language and "juegos de hilo" or "figuras de hilo" in Spanish in the whole region Braunstein 1992a,b,c.

8.5.2.1.1 Collecting String Figures

Thanks to Herminia and her family, I was introduced directly to individuals that are recognized as string figure "specialists" by the other members of the community. According to Jean-Pierre Estival, this spared me the several months that are usually necessary before one can be looked upon as a trustworthy person. Sometimes I visited the practitioners at home, but quite often they came to see me. Most of the adults in the community, male or female, often remembered three or four "juegos de hilo", rarely more. However, there were some exceptions: I was pleased to meet Kety, a woman in her forties who lives in Laguna Negra and is a genuine "expert". Like Victor Rolom (Ndapigu) from Santa Teresita, who is over 80 years old, some elderly people have kept alive the memory of these procedures and know a large number of *tukumbu*.

[47]The settling of a Guarani-Ñandeva community in Laguna Negra dates back to the 1980s. It occurred under the influence of the Mennonites, who sought to attract indigenous workforce near their farms.

Most children knew a few string figures. Some of them, like Mauru, a teenager (in 2005) from Santa Teresita, were obviously string figure enthusiasts. As in the Trobriand Islands, it seems that there is a subset of the string figures corpus that is often forgotten by adults but known by children. Unfortunately, I did not have enough time to verify this carefully. However, I sometimes had the opportunity to observe adults unsuccessfully trying to remember a simple string figure that their own children were making in front of them.[48]

150 – Kety

151 – Victor

Soon after the beginning of this fieldwork, I was confronted with the necessity to pay my informants. This situation was new to me. I had not yet been to the Trobriand Islands and my first and only experience was the fieldwork I had carried out two months earlier in the Marquesas Islands, French Polynesia. In the Marquesas, nobody asked me for any money. The economic situation there is of course not comparable. But I believe that it was not the only reason. String figure-making is rarely practiced nowadays in the Marquesas, so elderly people were very glad to revive their youth by giving information about this traditional and almost forgotten practice. I guess that this is the main reason why they did not ask to be paid. But in the Chaco, people, and Herminia in particular, made me understand that the time spent with my informants should be remunerated as any other job would be. This brought out a few problems with young people: some youths tried to "sell" me string figures that they had certainly invented themselves for the occasion. Even though these attempts to create new string figures could be an interesting subject of study, it became quite a problem when I was trying to collect the original corpus' procedures.

One of Herminia's brothers, Ernesto, a man in his thirties, agreed to act as interpreter during the working sessions. Most Indians in this community spoke Spanish more or less, depending on their age—the younger persons generally speak better Spanish than their elderly. In general, meetings were conducted in the

[48] See Video 14 (Pata de avestruz forgotten) in the accompanying website (Videos).

Guarani-Ñandeva language and translated into Spanish. Unfortunately, as I was then a beginner in Spanish, I failed to grasp many linguistic subtleties. However, I filmed all the interviews, which will enable me to come back to them later. The working sessions were essentially devoted to collecting *tukumbu*. I have learnt and recorded 41 string figures in the Chaco. Presumably there are still many other procedures to be collected. My older informants, Victor Rolom in particular, told me that they had known many other string figures in their youth. Some of them were very complicated to learn, so it took me a long time to memorize them. I often had to come back to my informants after the session, in order to go over some part of a procedure that I had forgotten. This difficulty came from the fact that, in this region, string figures are technically quite different from those I had discovered in the Marquesas, or those from the South Pacific (PNG, Solomon Islands) and the Arctic (Greenland) that I had previously analysed in my preliminary works (Vandendriessche 2004, 2007).

8.5.2.1.2 Cultural and Cognitive Aspects

Most of the time I concentrated on learning string figure procedures, but I also had the opportunity to observe some noteworthy facts about the local cultural and cognitive aspects of this practice. For instance, my informants did not mention any vernacular term used for the transmission of *tukumbu*. Furthermore, I had several opportunities to witness transmission between two Guarani-Ñandeva people. Each time, though, this happened between onlookers during a working session, as if my interest in string figures had given them the desire to practice. Every time I witnessed transmission, it was carried out without a word, silently, the learner concentrating on the hands of the instructor.

I met many people who acknowledged that string figure-making requires concentration and a certain intellectual effort. Some older people asserted that, in their grand-parents' days, there was often one person in the community who was known as a creator of *tukumbu*. Victor told me that his grand-father was such a creator, and that he hid his hands when showing his new creations so that it was not possible to figure out the procedures immediately.

String figures in the Chaco, unlike these in the Trobriands, seem to be performed for their own sake, without any apparent connection to stories or songs. The children I met did not know any songs of that kind. Enrique Hernandez, an 87 year-old shaman from Laguna Negra, asserted that such songs or stories have never existed. This was also confirmed by Victor. Nevertheless, Josephina Bertinez (Herminia's aunt), a woman in her forties, told me that, in the past, string figures were often connected to sexuality, but she was not able or did not want to give any examples. This suggests that in the past there may have been connections between string figures and other aspects of life. Further research should be carried out in that perspective.

While working with Victor, I often noticed that it was difficult for him to perform a string figure slowly, step by step, to facilitate my learning of it. He seemed compelled to make the figure continuously, as fast as possible. Most of the time, my asking him to go more slowly caused a lapse of memory. Victor seemed to remember these procedures as a continuous process rather than a sequence. But possibly, given his degree of skill, this was simply due to his old age. Unlike Victor, Kety could break the procedures down and perform them slowly. She knew a large number of *tukumbu*. The first time we met and worked together, I had the feeling that she wanted to introduce herself as an "expert" as well as to assess my own ability. Indeed, the first string figure she taught me is one of the most complicated procedures that I learnt in the Chaco, or even perhaps anywhere else. It is the three-dimensional figure called "Avestruz".[49]

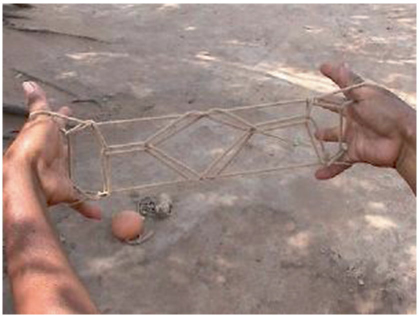
152 – "Avestrus" displayed by Kety

It took time for us to be able to work together effectively. Kety tried to correct my mistakes by operating directly on the strings instead of showing me the procedure again. This meant that I could not memorize the different steps of the sequence. However, even though it did not help me at all to make progress, the ability of Kety to operate directly on the strings was clearly an expression of the way she comprehends the making of string figures. The following observation confirmed this. Kety, in certain cases, seemed to be able to picture in her mind certain configurations of the strings resulting from the action of sub-procedures. She could therefore pay attention to the movements of the hands as well as to the consequences of these movements on the strings. This hypothesis emerged while she was teaching

[49]See Video 16 (Avestruz) in the accompanying website (Videos). For construction, see also 24.Avestruz (*Tukumbu* Corpus).

me the string figure *Samuù* (Arbro grande). *Samuù* is a quite long procedure[50] which first leads to a sort of "braid". This is then opened out to show the final figure (pictures 153a and 153b).

153a – *Samuù* by Kety -The final "braid"



153b – Final figure of *Samuù*

I tried to obtain the final figure of *Samuù* by repeating several times the difficult sequence leading to the "braid". Kety was not looking attentively at my hands, but she was systematically able to predict, just by glancing at the braid, whether or not it would lead to the correct final figure. I repeated the experiment several times, hiding my construction of the "braid", and once again Kety answered correctly each time. I realized that she probably had a mental representation of the "braid" in question. The fact that Kety was able to visualize the different configurations of the string during the process could explain her ability to perform string figure algorithms step by step, slowly, pausing at each normal position. Yet, some skilled practitioners, like Victor, are clearly not able to do this, which could mean that the ability to mentally visualize the different configurations of the strings while making a string figure is the skill which differentiates the "expert" from those who are merely good practitioners. To explore this phenomenon, further research in the field of cognitive sciences would almost certainly lead to interesting results.

I mentioned above that in Laguna Negra I met Enrique, who is a shaman, very knowledgeable in string figure-making. Like Victor, he referred to Guarani-Ñandeva string figure practitioners of his grand-parents' generation, and told me they were able to invent new string figures and transmitted their creations to others. Enrique explained the lack of stories or songs connected to *tukumbu* by asserting that this activity is sufficient in itself. Moreover, he clearly sees "*tukumbu*" as a reflexive and difficult activity.

[50]See Video 17 (*Samuù*) in the accompanying website (Videos). For construction, see also procedure 25.*Samuù* (*Tukumbu* Corpus).

154 – Enrique teaching me “Hombre”

Enrique taught me two beautiful series of figures: “Hombre” and *Ovecha ija*.[51] I found it more difficult than usual to learn how to make these two string figures, and it took me a while to understand what was happening before my eyes. Generally, one finger (or “functor” in Storer’s terminology) is associated with one elementary operation of the process and this is how I personally memorize (and encode) the making of a string figure. Enrique did not necessarily apply this “rule” systematically. When asked to perform the same procedure several times in succession, he would sometimes use different fingers, from one procedure to the other, for the same elementary operation. I was quite disoriented by the fact that my instructor did not strictly respect the connection “elementary operation—functor”. At first I thought that Enrique was concentrating more on the movements of the strings than on movements of fingers. Yet, when viewing his performance on video afterwards, I noticed a detail that I had overlooked during the working session: Enrique has a shorter index finger on his right hand, which was probably cut off accidentally. It was clear that he had modified his way of making string figures because of his handicap.

8.5.2.2 Names of the *Tukumbu*

Each *tukumbu* has a name. Generally, these names were told to me in Spanish. However, 16 of these names were given to me spontaneously in the vernacular language. Four of the forty-one *tukumbu* I collected involve a series of figures that

[51] See procedures 37.Series III and 38.Series IV in the accompanying website (*Tukumbu* Corpus).

I classified under the names Series I, II, II, and IV.[52] Besides, every intermediate figure displayed in series II (two intermediate figures and the final one), series III (three intermediate figures and the final one) and series IV (two intermediate figures and the final one) has a name. There is thus a list of 48 names in total. This list can be divided into three main subsets: Objects, Animals and Vegetables. The reader will find the details of this classification listed in Annex II. Fifteen names refer to "objects", either natural or made by humans; 23 are either the name of an animal, a part of the body of an animal, or an object made by an animal, such as a "nest" or a "trail"; 8 are the names of vegetables. The last two names refer to human beings: *Timaka* (Guarani-Ñandeva word for "knee") and Hombre (Spanish word for "man"). Unlike in the Trobriands, I did not spend enough time in the Chaco to question my informants about the meaning of the names given to string figures. It will be necessary to do so in order to make this classification correspond as closely as possible to the actors' viewpoint.

8.5.2.3 Before Going Further: Some Comparative Remarks

Although I have used the same categories to classify the names of string figures from the Trobriands and the Chaco, the ratios are often different from one corpus to the other, as shown in the tables below.

Chaco	
Subsets	Percentages
Objects	31.3
Animals	47.9
Vegetables	16.6
Human being	4.2

Trobriands	
Subsets	Percentages
Objects	30.6
Animals	27.4
Vegetables	11.3
Human being People—action	22.6
Meaning unknown	8.1

There are noteworthy differences between the percentages of the "Animals" and "Human being" categories. Yet, the ratio of "objects" is almost the same in both cases. Although it is difficult to understand the reasons for such similarity and variation, this data shows that the meaning of the "images" produced with the string can vary in a significant manner from one corpus to another. Moreover, the social functions of string figure-making in the Chaco seem quite different from those in the Trobriand Islands. We have seen in this chapter that, in the Chaco, there are both male and female "experts", whereas in the Trobriands I met mostly female "experts". In the Trobriand Islands, string figures (*kaninikula*) are often

[52]See procedures 6.Series I (Vivora), 15 Series II (Huella de vaca—Huella de avestruz—Hamaca), 37.Series III (Sapalio—Tatu—Tronco), 38.Series IV (Pala—Huella de wanako—Ovecha ija) in the accompanying website (*Tukumbu* Corpus).

accompanied by an oral text (*vinavina*) and appear in everyday life as theatrical entertainment. In some cases, their role can also be to remind people of some social prescriptions or prohibitions. By contrast, the Guarani-Ñandeva seem to consider string figure-making as a difficult and serious activity, requiring concentration, memory and dexterity.

In the Chaco, I did not collect any string figure procedures requiring two players, whereas in the Trobriands, I have found four procedures of this kind, generally known by children. This corroborates the impression that in the Trobriands, string figure-making is more of a group activity than an individual activity, as it seems to be in the Chaco.

8.5.3 Before Going Further

As mentioned earlier, I collected 68 *kaninikula* in Oluvilei. I stayed in the village long enough to reach the conclusion that there are scarcely any more. However, the videos I made then showed thereafter that there are still some *kaninikula* to be collected.[53] From this corpus of 68 string figures collected in Oluvilei, I will exclude ten procedures: four of these *kaninikula* are performed by two partners (*Sowa*, *Takwau*, *Tapwawa*, *Tagegila*) and six are what we have called a "trick". For the following comparative study, I have chosen not to focus on this kind of string figure. As part of this resulting corpus of 58 string figures, 13 procedures put together form the previously mentioned sub-group of *kaninikula* known by children.

In the following, I will refer to this set of 58 *kaninikula* and to the one constituted by the 41 *tukumbu* introduced above, as the Oluvilei corpus (or Trobriands corpus) and the Santa Teresita corpus (or Chaco corpus) respectively. Of course, as previously said, these corpora are certainly not exhaustive. And they are obviously different from the set of string figures actually known in the villages, even though the gathering was guided with the intention of exhaustiveness. The reader will find the instructions of every procedure of these corpora in the accompanying website. Every string figure is referenced with a number followed by its name, and the instructions are accessible from the pages entitled "*Kaninikula* Corpus" and "*Tukumbu* Corpus".

References

Ascher M (2002) Mathematics elsewhere: an exploration of ideas across cultures. Princeton University Press, Princeton/Oxford

Austern L (1939) The seasonal gardening calender of Kiriwina, Trobriands Islands. Oceania 9:237–253

[53] At the end of my stay, in the summer of 2007, I filmed Morubikina, asking her to perform all the string figures she knew. When I asked Morubikina to perform the string figure *Kaukwa*, she probably misunderstood the name I had given to her and did not make the string figure I was expecting. I did not pay attention to this misunderstanding at the time. When I watched the video later on, I realized that she had performed a *kaninikula* that I had not collected yet.

Braunstein J (1992a) El piojo (pediculus humanus). sobre la arbitraria relacion entre el significado y la representacion en los juegos de hilo. Estudios de la division etnografia 5(1):3–11
Braunstein J (1992b) Figuras juegos de hilo de los Indios Maka. Hacia una Nueva Carta Etnica del Gran Chaco III:24–81
Braunstein J (1992c) Figuras de hilo de los Mataco Orientales. Hacia una Nueva Carta Etnica del Gran Chaco IV:36–66
Braunstein J (1996) Langages de ficelle: Au fil d'une enquête dans le Chaco argentin. Techniques et cultures 27:137–151
Estival J-P (2001) Culture et consommation dans une communauté guarani-ñandeva du Chaco Techniques et culture 38:195–212
Fathauer GH (1974) Trobriand, Chap. 4. In: Schneider DM, Gough K (eds) Matrilineal Kinship. University of California Press, Berkeley, p 234–269
Jenness D (1920) Papuan cat's cradles. J R Anthropol Inst 50:299–326
Kasaipwalova J (1975) Sopi: the adaptation of a traditional aesthetic concept for the creation of a modern art school on Kiriwina. Discussion Paper no 5, Institute of Papua New Guinea Studies, Port Moresby
Lawton R (1978) Some aspects of the language of Kiriwina. Mimeo, Canberra
Malinowski B (1916) Baloma; the spirits of the dead in the Trobriand Islands. J R Anthropol Inst Great Britain Ireland 46:353–430
Malinowski B (1920) Kula: the circulating exchange of valuables in the archipelagoes of eastern. Man 20:97–105
Malinowski B (1922) Argonauts of the Western Pacific: an account of native enterprise and adventure in the archipelagoes of Melanesian New Guinea. G. Routledge and Sons/E.P. Dutton, London/New York
Malinowski B (1927) Lunar and seasonal calendar in the Trobriands. J R Anthropol Inst Great Britain Ireland 57:203–215
Malinowski B (1929) The sexual life of savages in Northwestern Melanesia: an ethnographic account of courtship, marriage and family life among the natives of the Trobriand islands British New Guinea. G. Routledge and sons, London
Maude H (1978) Solomon Island string figures. Homa Press, Canberra
Persson J (1999) Sagali and the kula: a regional system analysis of the massim. Lund monographs in social anthropology, vol 7. Department of Sociology, Lund University, Lund
Rudel C (1990) Le Paraguay. Editions Karthala, Paris
Senft G (1986) The language of the Trobriand Islanders. Mouton de Gruyter, Berlin/New York
Senft G (1987) Rituelle Kommunikation auf den Trobriand Inselin, Zeitschrift fur Literaturwissenschaft und Linguistik 65:105–130
Senft G (1996) Past is present—present is past: time and the harvest rituals on the Trobriand Islands. Anthropos 91:381–389
Senft G (1997) Magical conversation on the Trobriand Islands. Anthropos 92:369–391
Senft G, Senft B (1986) Ninikula fadenspiele auf den Trobriand inseln Papua New Guinea. Baessler-Archiv 34(1):93–235
Sturzenegger O (1992) Juegos de hilo de los Nivaklé. Hacia una Nueva Carta Etnica del Gran Chaco III:82–100
Vandendriessche E (2004) Les jeux de ficelle: Témoins d'une activité mathématique dans des sociétés traditionnelles de l'Arctique et de l'Océanie. Master thesis, Paris Diderot University
Vandendriessche E (2007) Les jeux de ficelle: une activité mathématiques dans certaines sociétés "traditionnelles". Revue d'Histoire des Mathématiques 13:7–84
Vandendriessche E (2012) Kaninikula, mathématiques aux îles Trobriand. Scientific Documentary, CNRS Images, http://videotheque.cnrs.fr/index.php?urlaction=doc&id_doc=4149&rang=1
Weiner AB (1988) The Trobrianders of Papua New Guinea. Holt, Rinehart and Winston, New York

Chapter 9
Comparison of the Trobriander and Guarani-Ñandeva String Figure Corpora

As mentioned in the introduction, the conceptual tools introduced in Chaps. 3 and 5 provide a methodology to carry out a comparative analysis of different string figures corpora. In this chapter, we will first concentrate on the elementary operations as well as on the short sub-procedures—i.e. the sub-procedures containing a small number of elementary operations—involved in the Trobriands corpus and in the Chaco corpus. After having listed all of these operations, their occurrences will be compared from one corpus to another. This will enable us to bring to light certain distinctive features in each of these corpora.

9.1 Elementary Operations and Short Sub-procedures

9.1.1 Inventory: Description and Vernacular Terms

9.1.1.1 The Oluvilei Corpus, Trobriands

In Part I of this book, the concepts of "elementary operation" and "sub-procedure" have been introduced as an observers' conceptual tools for analytical purposes. The following description will show how these concepts echo through the use of a few vernacular terms referring to movements in Trobriander string figure-making, suggesting a local perception of the notions of elementary operations and sub-procedures. These terms were given to me by my informants. Thereafter, I was able to notice that this terminology is (explicitly) used from time to time while teaching *kaninikula* procedures to individual learners, but it seems to be seldom the case. The *kaninikula* procedures are indeed taught or shown most often without any technical comments.

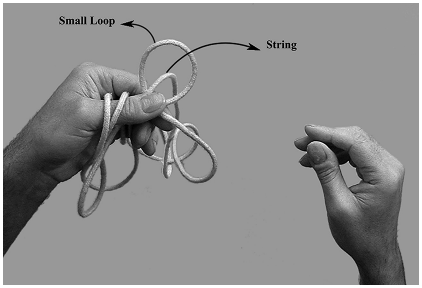
E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_9

9.1.1.1.1 Elementary Operations with Vernacular Terms

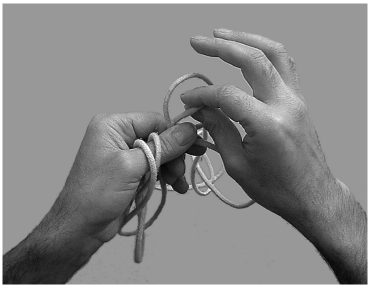
- *kutasuki* or *kukwau* mean "you pick up" (or "you hook up", operation which occurs only twice within the corpus) and *Kuwaimali* means "you return to position".[1]

ku + verb is the general grammatical form of the vernacular expressions used by the practitioners in the context of string figure-making. In the term *kutasuki* above *ku* means "you" and *tasuki* is the verb "to pick up"; so *ku-tasuki* means "you pick up". This grammatical form seems to be linked to the use of this terminology in situations of transmission from one individual to another.

- *kutum* means " you cover up": it is used to designate operation "hooking down".[2]
- *kukilai* or *kukilova* mean "you release" a string or a loop.[3] When a loop carried by a big toe is released, it is the expression *kuvalai* which is used instead of *kukilai*.
- The term *lupulapu* is the only expression referring to an elementary operation which has not been given to me in the form *ku* + verb. It refers to the "picking up of a string through a small loop", as described in pictures 155a–155c, and seems to be used exclusively in the context of string figure-making.[4] Furthermore, an apparent distinctive feature of this operation is its low occurrence in the corpus. It is performed several times as part of an iterated sub-procedure within one (and only one) string figure called *Budi-Budi*.[5]



155a – *Lupu lapu*


155b – "Picking up a string …

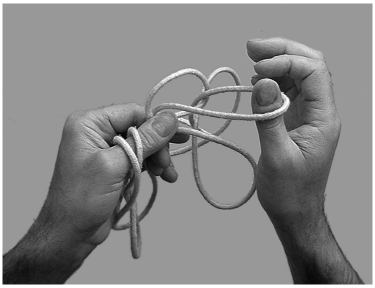
[1]See pictures 6a and 6b, Sect. 3.1.

[2]See pictures 6c and 6d, Sect. 3.1.

[3]See pictures 6f and 6h, Sect. 3.1.

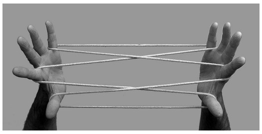
[4]G. Senft, personal communication, 2010.

[5]For further detail on the sub-procedure in question, see procedure 53.*Budi Budi* in the accompanying website (*Kaninikula* Corpus).

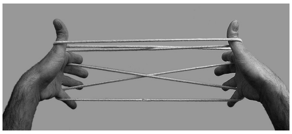


155c – . . . through a loop”

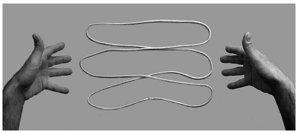
– *kusui* means “you go inside” a loop. It corresponds to operation “Inserting a finger into a loop”.[6] In the Oluvilei corpus this insertion can be made “distally” (from the distal side of the loop) or “proximally” (from the proximal side of the loop). There is no vernacular term that enables to distinguish these two situations.
– *kwatupini* means “you twist” (a loop).[7] The expression *kwatupini* also follows this general rule: the verb is actually *katupini* (to twist), the expression *ku-katupini* (you twist) is shortened to *kwatupini*.
– *kutaya* means “you lay (the figure) out”. It is usually the configuration of Opening A which is laid out on the knees (pictures 156a–156c).



156a

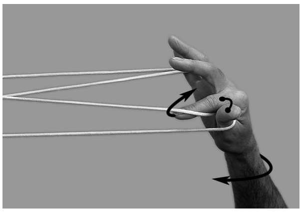


156b

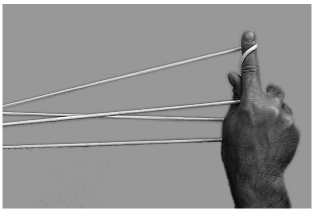


156c

– *kukwili* refers to operation “rotating hands or fingers”. The term *kukwili* is used to indicate both “vertical rotation” or “horizontal rotation”. Vertical rotations occurs, for instance, at the end of the “Caroline extension” (pictures 157a and 157b):



157a

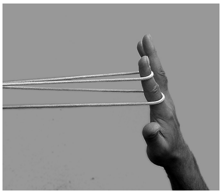


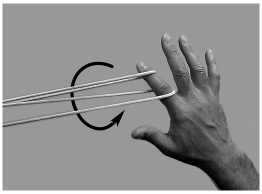
157b

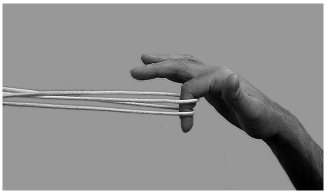
[6]See picture 6k, Sect. 3.1.

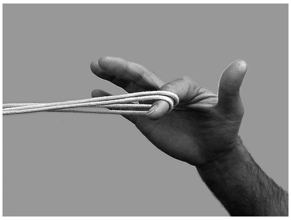
[7]See pictures 6i and 6j, Sect. 3.1.

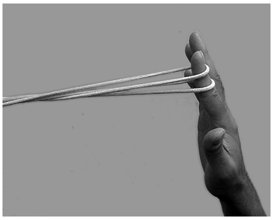
A horizontal rotation is shown in the following pictures 158a–158e:


158a


158b


158c


158d

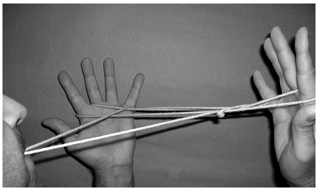

158e

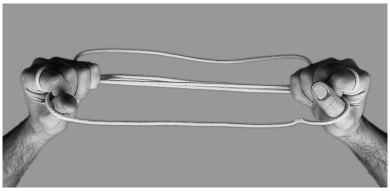
To my knowledge, the above list of vernacular terms referring to elementary operations is exhaustive: except for four of them, every elementary operation which occurs within the corpus has a name in Kilivila.

9.1.1.1.2 Elementary Operations Without Vernacular Terms

The four exceptions are the following elementary operations:

- "Extending" the string.[8]
- "Grabbing" one or two strings between two fingers: the string is sometimes grasped (taken up) between two fingers (generally between the thumb and index as in operation *lupulapu* described above).
- "Seizing" a string with the teeth: the string is sometimes seized with the teeth to create another loop (picture 159a).
- "Grasping" several strings with several fingers, the hand or the teeth (picture 159b).


159a – Seizing a string with the teeth

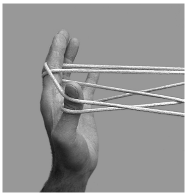

159b – Grasping several strings

[8]See pictures 6l and 6m, Sect. 3.1.

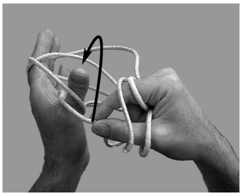
9.1.1.1.3 Short Sub-procedures and Vernacular Terms

Although numerous sub-procedures come into play in the making of *kaninikula*, it seems that only three of them—consisting in a small number of elementary operations and having a high occurrence in the corpus—are explicitly named in Kilivila. In particular, no vernacular name seems to designate either Opening A or Opening M (Murray Opening)—the openings which occur the most within the corpus (see below Sect. 9.2.1). Of course, we may wonder about the pertinence of the concept of sub-procedure when the sub-procedures are not named by the actors. As we will see later on, a sub-procedure can sometimes be analysed as a "passage" between two normal positions (or stable positions). When such is the case, the concept of sub-procedure becomes a "material" concept which obviously reflects the actors' viewpoint.

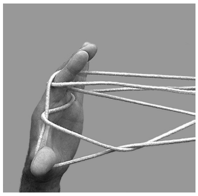
– *kwatuponiniya* refers to what we have previously encountered as a "Caroline extension" (pictures 157a and 157b above).
– *kwalili* is the expression that designates sub-procedure "Navaho". Picture 160b shows how the thumb and index of the right hand grasp the left proximal thumb loop and pass it over the left thumb. In the Trobriands, this is often done with the use of the teeth instead of the thumb and index.



160a

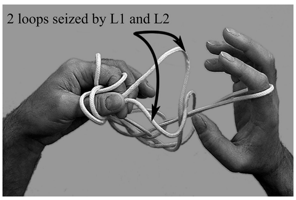


160b

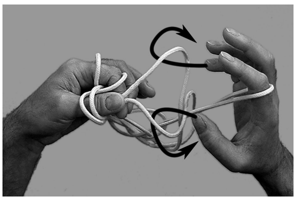


160c – kwalili

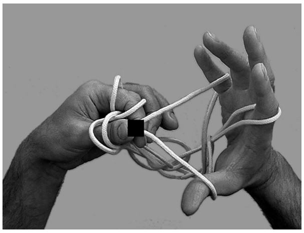
– *sosewa*: when two loops are seized between the thumb and index of one hand (the left one in the pictures below), *sosewa* is a sub-procedure which consists in inserting simultaneously the thumb and little finger of the other hand into these loops, which are finally transferred to these fingers (pictures 161a–161d).



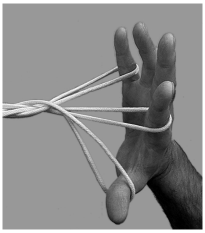
161a



161b



161c

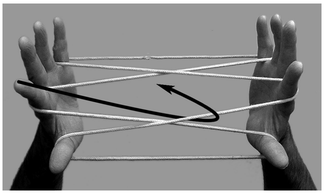


161d

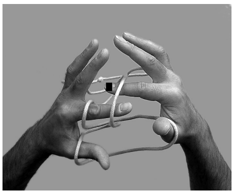
The latter three “technical” terms do not seem to be used in any other context. Furthermore, unlike the vernacular terms referring to the elementary operations, the practitioners spontaneously use these three expressions in situations of transmission to an individual learner.

9.1.1.1.4 Other Short Sub-procedures Without Vernacular Term

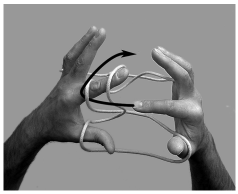
- “Transferring” a loop from one finger to another finger of the same hand.[9] This sub-procedure has a high occurrence within the corpus. Sub-procedure “transferring a loop to the wrist” also occurs several times: thumb loops can be transferred to the wrist as in procedure *Kapiwa*, already described in Chap. 6[10]; the index loops can also be transferred to the wrists as in procedures *Vivi* and *Lilu*.[11]
- The sub-procedure that I will call “Exchanging two loops” consists in exchanging a loop with another loop on the opposite hand, after passing one of these loops into the other. Pictures 162a–162e show the “exchange” of the index loops.



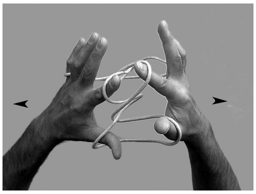
162a



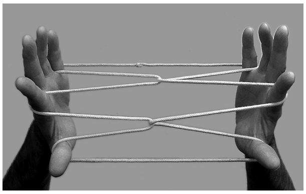
162b



162c



162d



162e

- The next and last short sub-procedure of the corpus—that I will call the “twist of a finger”—is a succession of two elementary operations. Within the Trobriands

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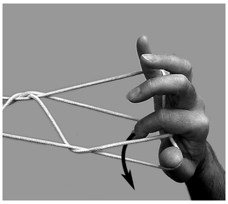
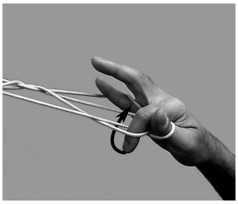
[9]See pictures 9a–9c, Sect. 3.2.1.

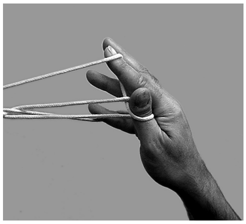
[10]Section 6.3. See also the description of procedure 6.*Kapiwa* in the accompanying website (*Kaninikula* Corpus).

[11]See procedures 26.*Vivi* and 41.*Lilu* in the accompanying website (*Kaninikula* Corpus).

corpus it is the two indices which perform symmetrically this sub-procedure. Successively, the indices pick up a string and then hook up another one, as shown in pictures 163a–163c.


163a


163b


163c

9.1.1.2 The Chaco Corpus

According to my Guarani-Ñandeva informants, there is not a single vernacular term used to name any of the elementary operations or of the sub-procedures revealed by the ethnomathematical analysis of the corpus. Except for one, all the elementary operations involved in the Chaco corpus are the same as the elementary operations involved in making Trobriander string figures.

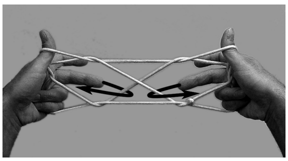
These are the different ways to pick up the string:

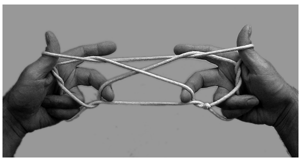
– “Picking up”—“Hooking up”—“Hooking down”—“Seizing a string with the teeth”—“Grabbing a string between two fingers”—“Grasping several strings with hand, fingers or teeth”.

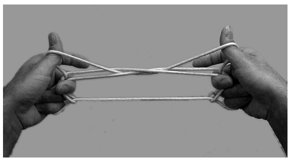
The other usual operations:

– “Inserting a finger into a loop” (distally or proximally)
– “Releasing a loop” carried by a finger or a big toe
– “Rotations of hands or fingers” (horizontal or vertical)
– “Twisting a loop”

I call “Enlarging” the only one Guarani-Ñandeva elementary operation which does not occur within the Oluvilei corpus. It is the following elementary operation: a finger grabs one or several strings on its palmar side from the centre of the figure towards the hand. Generally, both hands operate symmetrically, as shown in pictures 164a–164c.


164a


164b


164c

The following short sub-procedures involved in the Trobriander string figure algorithms can also be found in the Chaco corpus:

– "Transferring a loop" from one finger to another of the same hand
– "Transferring a loop to the wrist"
– "Twisting a finger"
– Sub-procedure "Navaho" (performed by using thumb and index as in pictures 160a–160c above)
– "Exchanging two loops"

The "Caroline extension" and the sub-procedure called *sosewa* in Oluvilei are not involved in the Chaco corpus. This concludes the inventory of the elementary operations and the short sub-procedures at work in the Oluvilei and Chaco corpora. Let us now turn on the statistical analysis of these operations' occurrence in each corpus.

9.1.2 Statistical Comparison

9.1.2.1 Elementary Operations

As mentioned earlier, I have created a symbolic notation to encode string figure algorithms. Working in this way, a corpus of string figures becomes a list of formulae which can be analysed statistically with computer tools. For that purpose, a short program (written in Basic) enables to count the total number of times a given sequence occurs within a corpus. It also enables to determine automatically the sequences of elementary operations which occur more than once within a corpus i.e. the sub-procedures. The tables below give the elementary operations' frequencies in both corpora. When an operation is done symmetrically with both hands—either simultaneously or one hand after another—the elementary operation in question was counted only once.

Statistical comparison

	Trobriands		Chaco	
Elementary operation	Occurrence	Frequency (%)	Occurrence	Frequency (%)
Picking up	443	23.3	184	19.2
Hooking up	45	2.4	21	2.2
Hooking down	29	1.5	47	4.9
Releasing	424	22.3	218	22.8
Extending	131	6.9	116	12.1
Returning to position	98	5.2	32	3.3
Enlarging	0	0	7	0.7
Grabbing	171	9.0	73	7.6
Seizing	29	1.5	7	0.7
Grasping	65	3.4	1	0.1
Twisting	4	0.2	7	0.7
Inserting	329	17.3	220	23
Horizontal rotation	20	1.1	20	2.1
Vertical rotation	110	5.8	2	0.2
TOTAL	1,898	100	957	100

As seen above, both corpora contain the same elementary operations, except for "enlarging".[12] This operation has a low occurrence within the Santa Teresita corpus. Therefore, operation "enlarging" cannot affect this corpus in a significant manner.

The main elementary operations are the same within the two corpora ("picking up", "inserting", "releasing") and they occur with quite similar frequencies. Operation "hooking up" also occurs with roughly equal frequencies, whereas operation "hooking down" is more frequently used in the Chaco than in the Trobriands.[13] For operation "extending", the difference between the two corpora is also strongly marked. It is partly due to the fact that the making of a *tukumbu* is very often punctuated by the two phases "tight / slack" observed by José Braunstein, which led him to introduce the concept of "normal position" (see Chap. 3). Another reason is that operation "extending" in the Chaco is generally applied to extend the final figure, whereas in the Trobriands many final figures are drawn thanks to short sub-procedure *kwatuponiniya* (Caroline extension), which naturally extends the strings under a "vertical rotation". Furthermore, sub-procedure "*kwatuponiniya*" occurs very often within the *kaninikula* corpus. This also entails the high occurrence of operation "vertical rotation" within this corpus, whereas this rotation almost never occurs in the Chaco.

The total number of elementary operations that the tables above provide enables us to determine the mean number of elementary operations of the string figures of a given corpus. I call it the "parameter of length". This parameter is of 32.7 in the Trobriands and 23.3 in the Chaco. So, it clearly appears that the *kaninikula* of the Trobrianders are usually made of longer sequences than the *tukumbu* of the Guarani-Ñandeva.

Let us now compare statistically the way by which the fingers are involved in the three main elementary operations "picking up", "inserting" and "releasing". The statistical results are given in the three tables below.

Within both corpora, the ring fingers operate rarely. In the Trobriands, it is also the case of the middle fingers, whereas in the Chaco they are often involved in the three main elementary operations. In the Chaco, the indices are used the most to perform these three operations, whereas in the Trobriands it is the thumbs. In brief, the above tables clearly show that, in the Trobriands, the operations "picking up",

[12] Actually, I found it in the Trobriands, but outside Oluvilei, within procedures called "*Niwaila*" (Central Kiriwina) and "*Magiaweda*" (Vakuta Island). On Vakuta, this operation is called "*kutapwagi*" which means "you enlarge".

[13] I noticed that the use of operation "hooking down" is rarely mentioned in ethnographical papers about string figures from the West Pacific. In the corpus that I collected in the Marquesas Islands, it occurs slightly more than in the Trobriands, and slightly less than in the Chaco (3.4 %). It also occurs apparently much more in the Arctic corpora (Jenness 1924; Victor 1940; Paterson 1949). These observations led me to hypothesize that operation "hooking down" occurs more and more as we go along from the Western to Eastern part of the Pacific. Of course, further statistical data will be necessary to confirm this.

Picking up		
Finger involved	Trobriands frequency (%)	Chaco frequency (%)
Thumb	44.3	24.4
Index	31.2	38.3
Middle finger	2.6	21.7
Ring finger	1.5	2.8
Little finger	20.4	12.8

Inserting		
Finger involved	Trobriands frequency (%)	Chaco frequency (%)
Thumb	44.5	20.8
Index	24.6	35.8
Middle finger	3.3	22.6
Ring finger	1.1	3.1
Little finger	26.5	17.6

Releasing		
Finger involved	Trobriands frequency (%)	Chaco frequency (%)
Thumb	37.7	26.4
Index	35.9	33.6
Middle finger	1.3	18.2
Ring finger	0	3.6
Little finger	25.1	18.2

"inserting" and "releasing" are performed by mostly three fingers—the thumb, index and little finger—whereas in the Chaco the middle finger is also involved in a significant way.

9.1.2.2 Short Sub-procedures

The two following tables indicate the total number of occurrences of a given short sub-procedure within each corpus. For a comparative purpose, the third column gives the mean occurrence of these sub-procedures per string figure.

Chaco		
Short sub-procedures	Frequency	Mean occurrence per string figure
Transfer	42	1.02
Twist of a finger	8	0.2
Navaho	7	0.17
Exchange	6	0.15
Transfer to the wrist	5	0.12

Trobriands		
Short sub-procedures	Frequency	Mean occurrence per string figure
Kwatuponiniya (Caroline extension)	99	1.71
Transfer	53	0.91
Sosewa	19	0.33
Kwalili (Navaho)	16	0.28
Exchange	3	0.05
Twist of a finger	3	0.05
Transfer to the wrist	3	0.05

Remember that sub-procedure "Transfer" (or "Transferring a loop") enables to transfer a loop from one finger to another. It is thus no surprise that this short sub-procedure often occurs in both corpora. However, notice that its mean occurrence is about the same in the Trobriands and in the Chaco. Sub-procedure "Navaho" (named *kwalili* in Oluvilei) occurs slightly more in the Trobriands than in the Chaco. It is the opposite for sub-procedures "Exchange" and "Transfer to the wrist". The contrast is more significant as to sub-procedure "Twist of a finger", the frequency of which is proportionally four times higher in the Chaco than in the Trobriands. Finally, the high occurrence in the Trobriands of both short sub-procedures sub-procedures *kwatuponiniya* ("Caroline extension") and *sosewa*, which I did not encounter in Santa Teresita, appears to be a distinguishing feature between the two corpora.

9.1.2.3 Sub-corpora in the Trobriands

In the Trobriands, there are two significant sub-corpora which can be compared statistically to the general corpus of Oluvilei. The first is the set of string figures generally known by children, and the second is the corpus of string figures known by Morubikina—an elderly person who has been introduced to me as a *kaninikula* expert in the village of Oluvilei (see Chap. 8). In the following discussion, these two sub-corpora will be termed Corpus C and Corpus M respectively. Morubikina can perform at least 48 string figures. We have seen above that Corpus C is composed of 13 procedures. I identified the latter, asking 12 children from Oluvilei to perform all the *kaninikula* they knew. Ten procedures that can be found within the general corpus of Oluvilei are unknown to Morubikina. Five of these ten string figures belong to Corpus C. This tends to confirm that some string figures that are practiced during childhood are sometimes forgotten when learning more complicated ones. The table below gives the statistical data on the elementary operations of the three corpora (General Corpus, Corpus M, Corpus C).

Statistical comparison						
	General corpus		Morubikina		Children	
Elementary operation	Occurrence	Frequency (%)	Occurrence	Frequency (%)	Occurrence	Frequency (%)
Picking up	443	23.3	397	23.6	46	22.5
Hooking up	45	2.4	35	2.1	6	2.9
Hooking down	29	1.5	26	1.5	5	2.5
Releasing	424	22.3	373	22.2	44	21.6
Extending	131	6.9	111	6.6	20	9.8
Returning to position	98	5.2	94	5.6	6	2.9
Grabbing	171	9.0	146	8.7	18	8.8
Seizing	29	1.5	25	1.5	7	3.4
Grasping	65	3.4	65	3.9	1	0.5
Twisting	4	0.2	4	0.2	0	0
Inserting	329	17.3	291	17.3	35	17.2
Horizontal rotation	20	1.1	18	1.1	5	2.5
Vertical rotation	110	5.8	95	5.7	11	5.4
TOTAL	1,898	100	1,680	100	204	100

We see that frequencies are quite stable from the General Corpus to Corpus M. Small differences can be found when comparing with Corpus C (“extending”, “returning”, “grabbing”, “seizing”, “grasping”) even though these variations are not statistically significant. The three corpora are more contrasted as to the “parameters of length” (the mean number of elementary operations per string figure) given in the table below. It appears that the procedures known by children are roughly half as long as the ones in the two other corpora. Furthermore, the length parameter for Corpus M reflects that Morubikina knows and demonstrates the longest procedures of the corpus.

	Oluvilei	Morubikina	Children
Parameter of length	32.7	35	15.7

The tables below show the occurrences of the use of fingers to perform operations “picking up”, “inserting” or “releasing” within the three corpora (General corpus, Corpus M, Corpus C). Once again, we see that there is no significant difference between Corpus M and the general Oluvilei corpus, whereas some differences in Corpus C are obvious.

– For operation “picking up”, the difference lies in the use of the thumbs (higher occurrence) and little fingers (lower occurrence).
– For operation “inserting”, it lies in the use of the indices, middle and ring fingers. The two latter are proportionally rarely used in the general Oluvilei corpus, whereas they are involved for this operation more frequently in Corpus C.
– For operation “releasing”, it is mainly in the use of the middle fingers and indices, that Corpus C differs from the two other ones.

Picking up			
Finger involved	General corpus frequency (%)	Morubikina frequency (%)	Children frequency (%)
Thumb	44.3	45.4	54.1
Index	31.2	29.5	32.4
Middle finger	2.6	2.9	0
Ring finger	1.5	1.6	0
Little finger	20.4	20.6	13.5

Inserting			
Finger involved	General corpus frequency (%)	Morubikina frequency (%)	Children frequency (%)
Thumb	44.5	42.9	42.6
Index	24.6	25.1	14.8
Middle finger	3.3	3.2	7.4
Ring finger	1.1	1.2	5.6
Little finger	26.5	27.5	29.6

Releasing			
Finger involved	Trobriands frequency (%)	Morubikina frequency (%)	Children frequency (%)
Thumb	37.7	38.5	35
Index	35.9	34	20
Middle finger	1.3	0.5	10
Ring finger	0	0	0
Little finger	25.1	27	35

As for elementary operations, the occurrences of short sub-procedures are very similar within the general Oluvilei corpus and Corpus M. Let us notice the lower occurrence of sub-procedures *kwatuponiniya*, *kwalili* and transfer, within Corpus C, and the non-use of sub-procedure *sosewa*. This is probably due to the high level of dexterity required to implement the latter short sub-procedures.

	General corpus		Morubikina		Children	
Short sub-procedures	Frequency	Mean per procedure	Frequency	Mean per procedure	Frequency	Mean per procedure
Kwatuponiniya (Caroline extension)	99	1.71	85	1.77	8	0.62
Transfer	53	0.91	46	0.96	5	0.38
Sosewa	19	0.33	19	0.40	0	0
Kwalili (Navaho)	16	0.28	14	0.29	2	0.15
Exchange	3	0.05	2	0.04	1	0.08
Twist of a finger	3	0.05	3	0.06	0	0
Transfer to the wrist	3	0.05	3	0.06	1	0.08

Overall, the latter comparative statistical data show that no distinguishing features can be found between the general Oluvilei corpus and its subset, Corpus M. On the contrary, some differences can be found between Corpus C and the Olivilei adult-corpora. This outcome suggest a progressive learning of string figure-making during childhood. Firstly, a comparison of the length parameters seems to indicate that the procedures known by children are shorter than the ones in the full Oluvilei corpus. Secondly, the fingers involved to perform elementary operations, as well as the occurrence of certain operations, may vary significantly from one corpus to another.

Another interesting example seems to confirm how progressive the learning of string figure-making is: string figure *kuluwawaya* is the longest of the Oluvilei corpus.[14] As seen in Chap. 8, this procedure allows to display a series of nine intermediate figures. I noted that some children know how to make the first figure of the series without being able to perform the complete procedure, which would probably be learnt in a second stage.

9.1.2.4 Before Going Further

The previous comparative study of the elementary operations and short sub-procedures involved in both the Chaco and Trobriands corpora of string figures has brought to light some invariant and distinguishing features in the way the string figure algorithms have emerged within two geographically and culturally distant societies. Apart from a few exceptions, the same elementary operations and short sub-procedures can be identified in the Trobriands as well as in the Chaco. While some of them occur in both corpora with roughly the same frequency ("picking

[14] See procedure 29.*Kuluwawaya* in the accompanying website (*Kaninikula* Corpus).

up", "inserting", "releasing", "transfer" ...), the statistical data previously analysed demonstrate that the two corpora differ in the use, or non-use, of a few elementary operations and short sub-procedures. The latter point has clearly a significant impact on the procedures of both corpora. This impact is readily visible: it is the case of the use, or non-use, of the "Caroline extension", which offers a characteristic manner to display the final figure. However, this impact may sometimes be more subtle and remains difficult to discern clearly. In the future, we shall go deeper into this analysis, using the previous methodology and focusing on many other corpora of string figures. It is a huge task from which we may expect significant outcomes to emerge regarding operations at work in the making of string figures.

The previous analysis demonstrated that some elements of characterization can be found through the study of elementary operations and short sub-procedures. We now need to study how these elementary operations were combined by the practitioners to create sub-procedures. This will show that the use of some singular sub-procedures considerably clarifies differences between various corpora of string figures. We will begin by focussing on the sub-procedures that José Braunstein defined as "passages" (from one normal position to the next—see Chap. 3). I will first describe the passages that allow to pass from initial positions to the first normal positions i.e. openings. Then, we will look at passages from the first to the second normal position, and sometimes to the third normal position. The concepts of "sub-procedure" and "normal position" are efficient tools to classify the string figure algorithms of both the *kaninikula* and *tukumbu* corpora. In the following sections, we will see that some sub-procedures and normal positions were used as a basis for creating new string figure procedures and thus enabled the production of transformation systems. This viewpoint makes it possible to represent each of these corpora of string figures as a tree diagram. The arborescent structure of string figure corpora reflects how these procedures were created—and, to a certain extent, their history.

9.2 Description and Comparative Analysis of the Openings

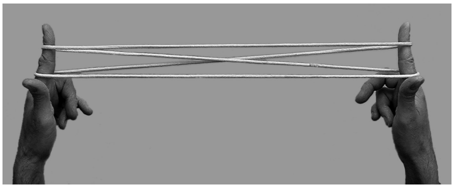
The concept of "Opening" is an efficient tool to analyse and compare different corpora of string figures. The following analysis will show that, on the one hand, the same (or similar) openings can be found in different corpora collected in geographically and culturally distant areas. On the other hand, within a given corpus, some openings can be regarded either as variations on other openings or as singular creations that are not connected to any other opening. The description below will suggest that both the latter types of openings (variations or singular creations) could be characteristic of a given corpus. Therefore, they could be of fundamental importance in differentiating one corpus from another.

9.2.1 Openings of the **Kaninikula**

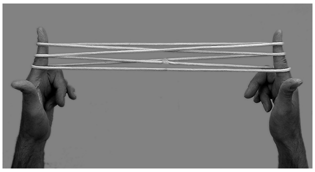
Two main openings come into play in the Trobriands corpus: Opening A and Opening M (Murray opening). 33 *kaninikula* begin with Opening A and 8 with Opening M. We already encountered and described these two openings.[15]

9.2.1.1 Variations on Opening M

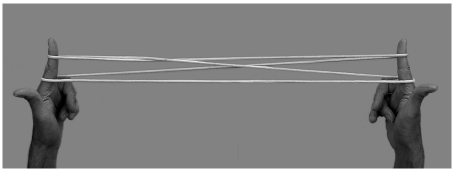
There are four openings which can be analysed as variations on Opening M. I will note them Opening M_i, for $i \in \{1, \ldots, 4\}$.[16] Although, at first glance, the operations involved in both Opening M_1 and Opening M_2 seem quite different from those of Opening M, these three openings have in common that their final configurations are made only with loops carried by indices (pictures 165a–165c).



165a – Opening M



165b – Opening M_1



165c – Opening M_2

Opening M_1 is the opening of a single *kaninikula* (37.*Waga*). At the end of the process, there are three loops on the index fingers (picture 165b). When the distal (upper) index loops are released from the latter configuration, one obtains the final configuration of Opening M, as summarized by the following formula: $\underline{O}.M_1 : \square u2\infty \; \Leftrightarrow \; \underline{O}.M$. Basically, Opening M_1's final configuration can be seen as Opening M's one to which two loops are added, one on each index.

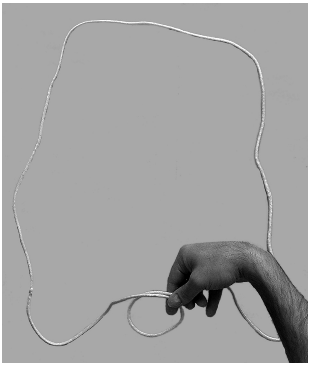
Opening M_2 is the opening of two string figure procedures in the corpus (48.*Subuvinu* and 10.*Kweviviya*). From the configuration shown in picture 165c one can see that we easily get back to the final configuration of Opening M, simply by

[15] See Sect. 2.2.1 (Opening A) and Sect. 3.3.1.3 (Opening M).

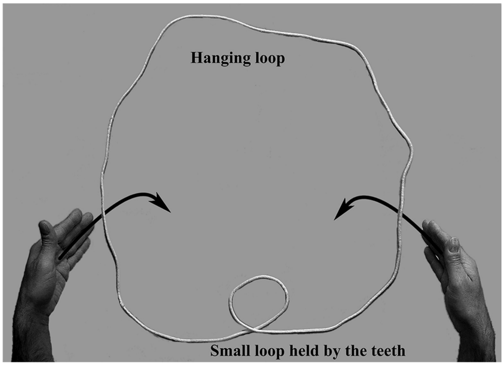
[16] See the accompanying website (*Kanininkula* Corpus/openings and continuation).

rotating 360° clockwise the left distal (upper) index loop. Therefore, the relationship between Opening M and Opening M_2 can be summarized by the following formula: $\underline{O}.M_2 : \ll L2\infty \;\Leftrightarrow\; \underline{O}.M$

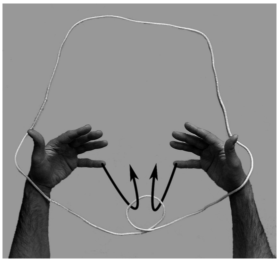
Two string figures (3.*Dauta* and 8.*Kalatu gebi navalulu*) begin by making a small loop which is held by the teeth. At first glance, the operations involved in the openings of these two procedures seem quite different than the ones of Opening M. However, the fact that they begin in the same manner (by making a same small loop) led me to take a closer look at them. In a noteworthy way, these two openings can be seen as variations on Opening M in a sense that I will precise below.



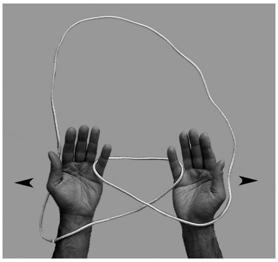
166a



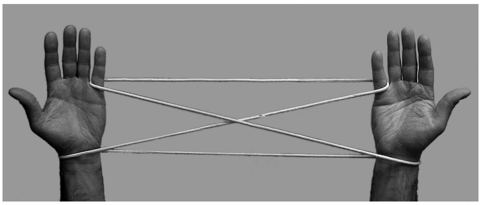
166b



166c



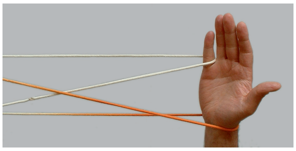
166d

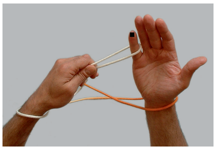


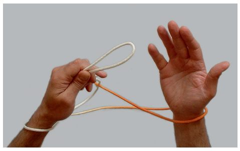
166e

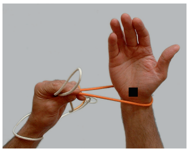
Procedure 3.*Dauta* begins as follows: First, a small loop is made (picture 166a). Then, the small loop is held by the teeth and the other part of the string forms a hanging loop. Both hands are then inserted away from you into the hanging loop (picture 166b). Finally, the little fingers are inserted away from you into the small loop held by the teeth (picture 165c). The string is extended, leading to the first normal position of the procedure (pictures 166d and 166e).

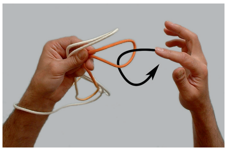
Except for the loops' positions, which are not carried by the same functors, the configuration obtained (picture 166e) seems quite similar to the one obtained through Opening M. It is actually possible to pass from one configuration to the other, thanks to the few transfers and rotations of loops described as follows: starting from the configuration shown in picture 166e, and operating one hand after the other, remove the little finger loop (white one—picture 167a–c) with the thumb and index of the opposite hand, then remove the wrist loop, rotate the latter 180° anticlockwise and put it back on the index of the same hand (pictures 167d–167f).

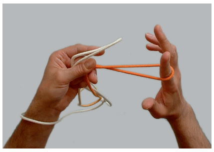

167a


167b

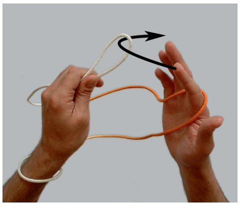

167c

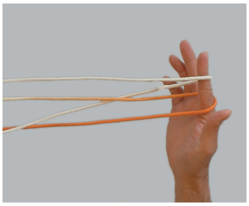

167d


167e

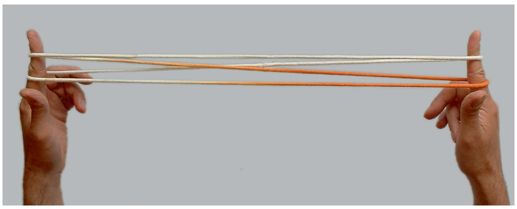

167f

The previous sequence can be summarized by the following formula: $>Rw\infty \longrightarrow 2$. Then, the little finger loop is rotated clockwise and placed on the index (pictures 167g and 167h). This can be encoded: $<R5\infty \longrightarrow 2$.


167g


167h

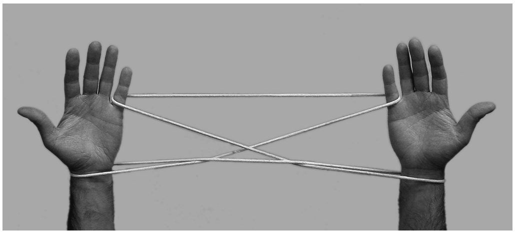
By repeating the same sequence on the other hand, we obtain the expected configuration (picture 167i- Configuration after Opening M).


167i

According to this phenomenon, I shall consider the opening of *Dauta* as a variation on Opening M. Therefore, I will note it Opening M_3. In considering that the operations on the loops can be theoretically done simultaneously on both hands, we get the following equivalence:

$$\underline{O}.M_3 : \left\{ \begin{array}{l} > w\infty \longrightarrow 2 \\ < 5\infty \longrightarrow 2 \end{array} \right\} \Leftrightarrow \underline{O}.M$$

Similarly, such a connection can be found between Opening M and the opening of 8.*Kalatu gebi navalulu* (picture 168)[17] which also starts by making a small loop in the same manner as for Opening M, Opening M_2 and Opening M_3.



168 – Opening M_4 of *Kalatu gebi navalulu*

As for Opening M_3, it is also possible to obtain the final configuration of Opening M by operating on the loops of the configuration shown in picture 168. Given that connection, I call the opening of 8.*Kalatu gebi navalulu* Opening M_4. In operating directly on the loops through basic fingering, one can verify the following equivalence (left as an exercise):

$$\underline{O}.M_4 : \left\{ \begin{array}{l} < wl \longrightarrow 2 \\ < 5\infty \longrightarrow 2 \end{array} \right\} \Leftrightarrow \underline{O}.M$$

These equivalences between openings are my analysis. It is definitely an observer's viewpoint. I do not know yet whether my informants perceive this. Further research still needs to be carried out in that perspective.

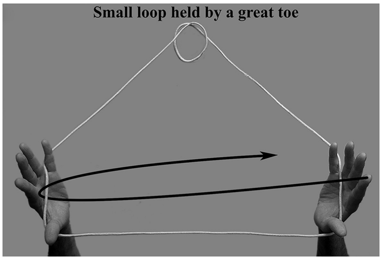
9.2.1.2 Variations on Opening A

Six string figures of the corpus begin with a singular opening that one can see as a variation on Opening A, in the sense that each of them can be obtained by altering or adding some elementary operations to the sub-procedure Opening A (24.*Guyau-Bolu-Guyavila*, 1.*Meta*, 22.*Kemagu*, 18.*Sakaupakuli*, 56.*Melitabu*,

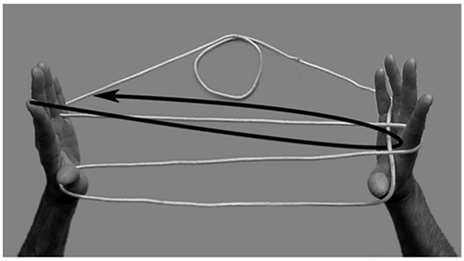
[17] See procedure 8.*Kalatu gebi navalulu* in the accompanying website (*Kaninikula* Corpus).

19.*Tokopokutu*). Among these six string figures, only two share exactly the same opening (18.*Sakaupakuli* and 56.*Melitabu*). So, we get five variations on Opening A that I will note Opening A_i, for $i \in \{1, \ldots, 5\}$. The reader will find the details of these variations on Opening A in the accompanying website.

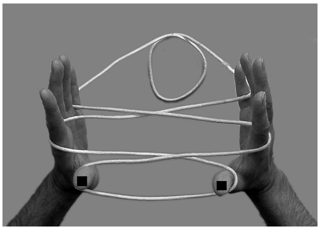
Opening A_4, in procedure 24.*Guyau-Bolu-Guyavila*, is a very interesting case. It begins by making a small loop as for Opening M. Then, this small loop is transferred to a big toe (picture 169a). The rest of the string is taken up into Position I, and Opening A is then performed (pictures 169a and 169b). The thumbs are released and the small loop is transferred to the thumbs (pictures 169c–169e).



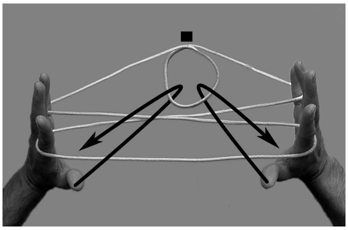
169a



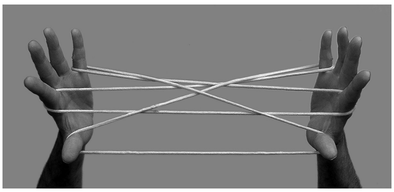
169b



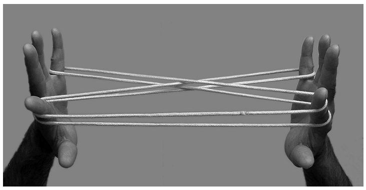
169c



169d



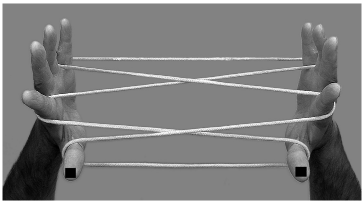
169e – Opening A_4



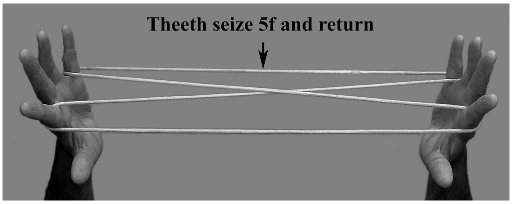
169f – Conf(B)

9.2.1.3 Digression: Opening A_4 and *Conf*(*B*)

The configuration obtained through Opening A_4 can readily be transformed into configuration *Conf*(B), analysed in Chap. 6 (picture 169f), by transferring the thumb loops to the indices.[18] Formally, we have the following equivalence: $\underline{O}.A_1 : \overrightarrow{1\infty} \longrightarrow 2 \Leftrightarrow \mathit{Conf}(B)$. We have seen that $\mathit{Conf}(B)$ is the second normal position of the string figure algorithm 54.*Salibu*. Then, within the same corpus, two different methods lead to the same configuration. However, one can see that these two methods are actually very similar. In procedure *Salibu*, the thumb loops of the configuration obtained through Opening A are released (picture 170a) and the string $5f$ is picked up and held by the teeth (picture 170b).

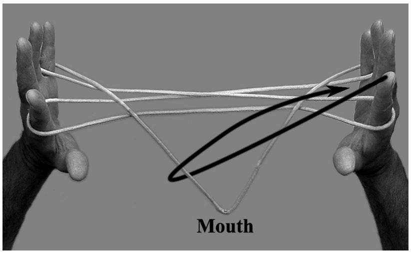


170a

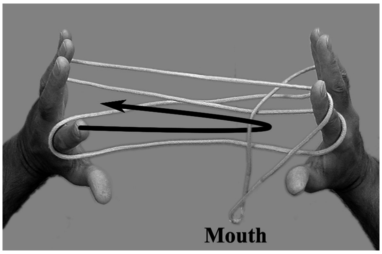


170b

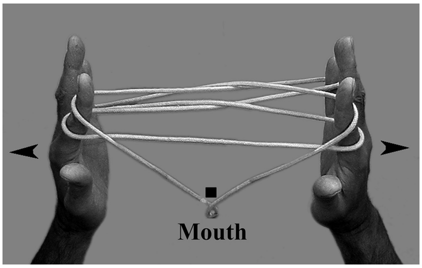
Then, teeth strings are picked up by the indices as shown in pictures 170c–170e below. This simultaneously entails the making of a (small) loop, held by the teeth (instead of a big toe as it occurs in Opening A_4), and the transfer of this loop to the indices (instead of the thumbs in Opening A_4). Picture 170f is a copy of picture 170d, in which the (small) loop in question is emphasized.



170c

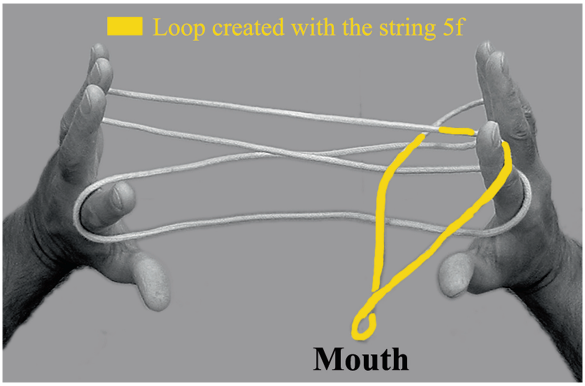


170d



170e

[18] See Sect. 6.4 (*Na Tifai* from the Tuamotus).



170f

In this sequence, a (small) loop is in fact created just after the sequence $\underline{O}.A$: □1, whereas it is made at the beginning of the process in Opening A_4. We can formalize this point as follows:
Making of *Conf*(B) within *Salibu*:

$$\underline{O}.A : \square 1 : \text{“\textit{Making of the small loop}”: \textit{small loop}} \longrightarrow 2$$

Making of *Conf(B)* within *Guyau-Bolu-Guyavila*:

$$\text{“\textit{Making of the small loop}''} : \underline{O}.A : \square 1 : \textit{small loop} \longrightarrow 1$$

This shows the “commutativity” of the two sub-sequences $\underline{O}.A$: □1 and “*Making of the small loop*”. Once again, these formal properties emerged from my work later, after my return from the Trobriand Islands. It would be of fundamental importance to know whether my informants are aware of these two methods to make *Conf*(B), and how they explain the reason of such a phenomenon.

There are six other openings in the Oluvilei Corpus that differ from one another and cannot be connected, as far as I can see, to either Opening A or Opening M. I named them Opening S_i, for $i \in \{1, \ldots, 6\}$. They are described in the accompanying website as part of procedures 3.*Sopi*, 7.*Kakanukwa*, 49.*Toliu*, 16.*Mina kaibola*, 14.*Doga doga*, 15.*Bwala*.

In Annex IV, a table summarizes the previous classification of the openings involved in the Oluvilei corpus. This classification enables us to see the corpus as the union of three subsets: procedures starting with Opening A or a variation on it, procedures starting with Opening M or a variation on it, and a subset of six *kaninikula* starting with six distinct and singular openings. Among the 16 openings of the corpus, only four of them occur in more than one procedure: Opening A, Opening A_1, Opening M and Opening M_2. Each of these four openings can therefore be seen as a “sub-procedure”.

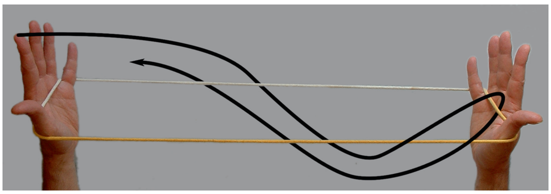
9.2.2 *Openings of the Tukumbu*

9.2.2.1 Variations on Opening A

Seventeen string figures of the Chaco corpus start with Opening A. Moreover, six openings can be seen as a variation on it. The two following openings are very similar from Opening A. One is the opening called Opening B by Ball[19] which consists in exchanging the role of the two indices in Opening A. So, it is the left index, instead of the right one, which moves first, picking up the opposite palmar string. The configuration obtained at the end of this opening is the mirror image of the configuration obtained through Opening A ($Conf(\underline{O}.A)$).[20] Therefore, I will note it Opening A_m in order to point out its mirror relationship with Opening A. I have noticed that Opening A_m is actually used instead of Opening A by some Guarani-Ñandeva practitioners. However, I have never met anyone making Opening A and Opening A_m alternately. We may reasonably think that this phenomenon depends on whether people are right or left-handed.

The second variation is obtained by picking up the palmar string with the middle fingers instead of the indices. This variation, that I noted Opening A_*, occurs only once within the corpus (10.*Tampra*). The configuration obtained at the end is obviously the same as $Conf(\underline{O}.A)$. More precisely, we formally have the following equivalence: $\underline{O}.A \Leftrightarrow \underline{O}.A_* : \overleftarrow{3\infty} \rightarrow 2$.

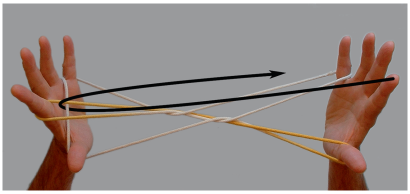
There are three other variations on Opening A, that I note Opening A_i, with $i \in \{6, \ldots, 9\}$, completing the list of the variations Opening A_i encountered in the Oluvilei corpus. These three openings occur respectively within 37.Series III (*Sapalio-Tatu-Tronco-Hombre*), 4.*Pata de avestruz*, 26.*Palo santo*, 33.*Tukatuka*. For instance, the fifth variation on Opening A, thus encoded Opening A_8, occurs within procedure 26.*Palo santo*. The difference between Opening A_8 and Opening A_m lies in the way the left index grabs the right palmar string. Starting from Position I, the left index passes, towards you, proximal to the ulnar little finger strings ($5f$) and the radial thumb strings ($1n$), then hooks up the right palmar string and returns to position, following the same path (picture 171a). Then, Opening A_8 and Opening A_m end in the same way (pictures 171b and 171c).



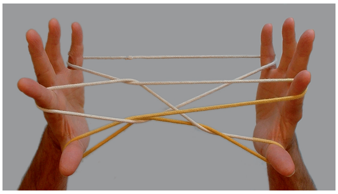
171a

[19]See Sect. 4.3.1.1 (Opening A and B).

[20]See Sect. 4.3.1.1.



171b

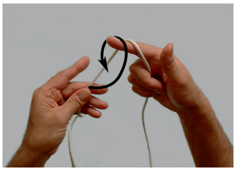


171c

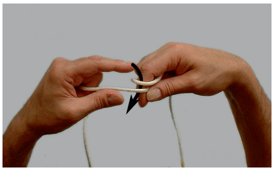
9.2.2.2 Navaho Opening

Ten string figures of the corpus begin with an opening that I will call Opening N, since the ethnographical literature usually refers to Navaho Opening for a procedure which is very similar to it.[21] We will come back to that important point later on.

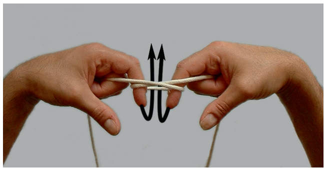
Opening N goes like this: the string is wrapped round the right index (picture 172a). Then, the left index is inserted proximally (i.e. from proximal side) into the right index loop (picture 172b). Both hands are rotated horizontally clockwise (for an observer located on the left side of the practitioner), and the thumbs are inserted, away from you, into the long drooping loop (pictures 172c and 172d). Finally, the string is extended (picture 172e).



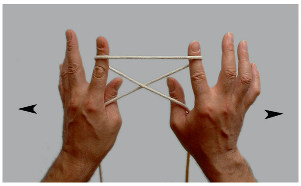
172a



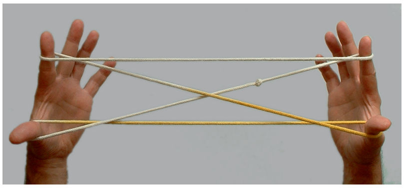
172b



172c



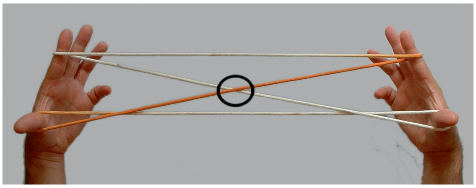
172d



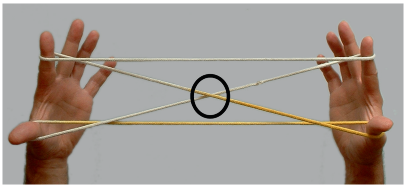
172e

I have collected two other openings that can be analysed as variations on Opening N. The first one—that I named Opening N_m—is obtained by exchanging the role of the indices, as seen for Opening A and Opening A_m. The string is wrapped round the left index and it the right index is inserted into the left index loop. The final configurations obtained after Opening N_m and Opening N ($Conf(\underline{O}.N)$ and $Conf(\underline{O}.N_m)$ respectively) are linked by a mirror symmetry. Moreover, the difference between these two configurations lies in the central crossing as shown in pictures 173a and 173b.

[21] We have already encountered Navaho Opening in Sect. 4.4.4.



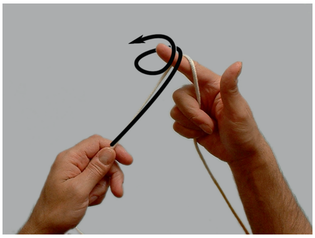
173a – Opening N_m



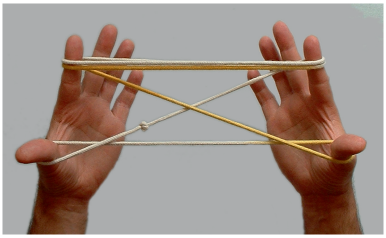
173b – Opening N

Like Opening A and Opening A_m, Opening N_m is generally used as an alternative of Opening N. Furthermore, the use of Opening N_m (resp. Opening N) is associated with the use of Opening A_m (resp. Opening A). This seems to confirm that this phenomenon depends on whether the practitioner is right or left-handed.

Another variation—that I note Opening N_1—occurs in procedure 7.*Piel de Vivora*. It consists in wrapping the string twice (instead of once) round the right index. Then, it ends as Opening N (pictures 174a and 174b).



174a



174b – Opening N_1

9.2.2.3 Other Openings

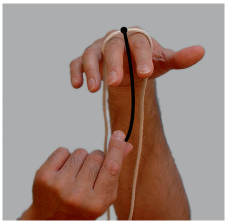
The *tukumbu* starting with Opening A or N, or variations on them, form a set of 31 string figure algorithms. In the Chaco corpus, the openings of the other ten string figure procedures can be classify into three subgroups as follows: four of these string figure procedures start by laying out the string on the index or/and middle finger on one hand only. Three other procedures begin by taking up the string in Position I on one hand only. And finally, the last two procedures start by placing the long loop around a wrist. These openings testify to a great ingenuity. Let us look at some examples.

9.2.2.3.1 Openings L: Laying Out the String on the Index or/and Middle Finger

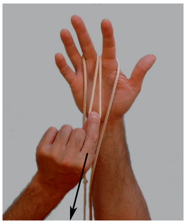
The series of figures that I have called 15.Series II (*Huella de vaca, Huella de avestruz, Hamaca*) begins by laying out the string on the right index and middle finger as shown in the picture 175a. Then, the dorsal string of the right index *R*2 (which is also the dorsal string of the right middle finger *R*3) is seized by the left index $L2$ and the left thumb $L1$ between the fingers $R2$ and $R3$, and the string is extended (pictures 175a and 175b). It is then the palmar string which is seized again by fingers $L1$ and $L2$ between the right radial (near) middle finger string $R3n$ and the right ulnar (far) index string $R2f$, the string is extended and the fingers $L1$ and $L2$ are released (pictures 175c and 175d).

The right thumb $R1$ and the right little finger $R5$ pick up simultaneously the drooping strings $R2n$ and $R3f$ respectively (picture 175e). Then, fingers $L1$ and $L2$ pass under the string $R1f$ and $R5n$ respectively, hook down the string $R2n$ and $R3f$ respectively and the string is extended (pictures 175f and 175g).

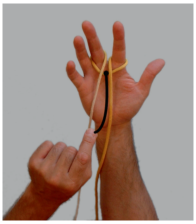
Finally, fingers $L1$ and $L5$ are simultaneously inserted into the hanging loops and pick up the string on the wrist, as shown in the picture 175h. The string is then extended (picture 175i). I will refer to this opening as Opening L_1.



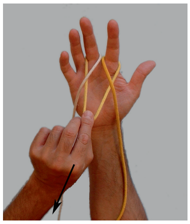
175a



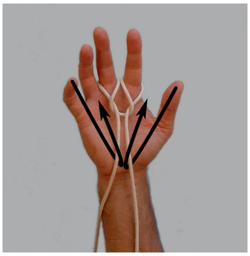
175b



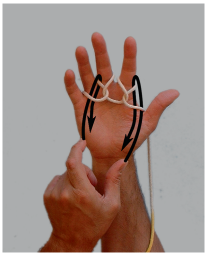
175c



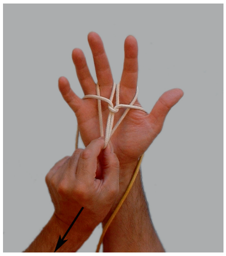
175d



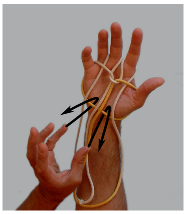
175e



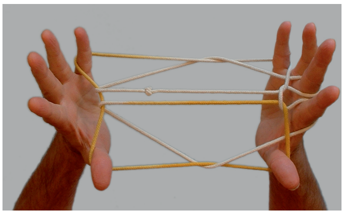
175f



175g

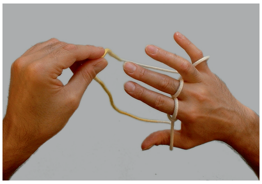


175h

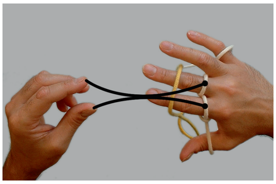


175i – Opening L_1

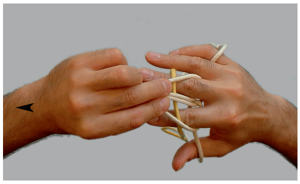
Procedure 5.*Murcièrlago* starts as Opening L_1 until the step in which $L1$ and $L2$ pass under strings $R1f$ and $R5n$ respectively and hook down strings $R2n$ and $R3f$ respectively (picture 175f). This step is replaced by the following one: the hanging loop is placed on the dorsal side of the right index $R2$ and the middle finger $R3$ (pictures 176a and 176b). The left index $L2$ and the thumb $L1$ grab the dorsal ulnar (lower) strings $lR2d$ and $lR3d$ simultaneously (picture 176b), passing over the dorsal distal (upper) strings $uR2d$ and $uR3d$ (picture 176d). The latter operation is then equivalent to "Navaho both $R2$ and $R3$". Finally, the string is extended (pictures 176d and 176e).



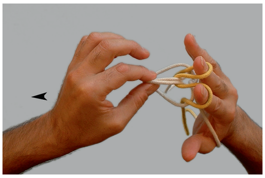
176a



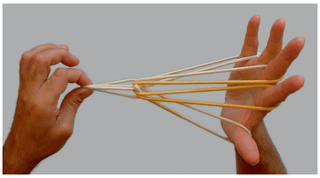
176b



176c



176d



176e – Opening L'_1

This opening will be noted as Opening L'_1 in order to stress the similarity with Opening L_1. Starting in the same manner, they can be seen as variations on one another.

String figure 22.*Hueso de Iguana* also starts by laying out the long loop onto the right index $R2$.[22] I refer to this opening as Opening L_2. String figure 28.*Mbopi* starts with an opening which can be seen as a variation on the previous one. I note it Opening L'_2.

9.2.2.3.2 Openings P: Taking Up the String in the Position I on One Hand Only

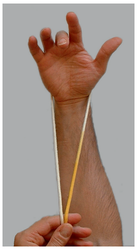
Both string figure procedures 8.*Guitarra* and 38.Series IV (*Pala, Huella de wanako, Ovecha ija*) start in the same way by taking up the string in Position I on the right (or left) hand before completing the opening that I note Opening P_1.

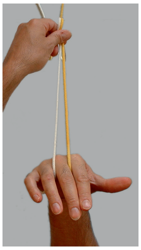
The string figure procedure 9.*Sapalio* also starts by taking up the string in Position I on the right or left hand. However, it continues in a very different way than the previous ones. I note this opening Opening P_2. The last opening of this subgroup—that I note Opening P_3— can be found at the beginning of string figure 40.*Hamaca*.

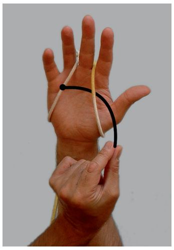
[22] See the accompanying website (*Tukumbu* Corpus).

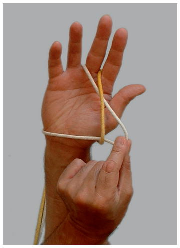
9.2.2.3.3 Openings W: The Long Loop Around a Wrist

Two string figure procedures of the corpus start with such an opening. 13.*Mukune* starts by placing the string around the right wrist (picture 177a). Then, the fingers $L1$ and $L2$ grab the long loop at some distance from the right hand and drag the loop to the back of this hand, passing ulnar and radial right wrist strings between the couples of fingers ($R3$, $R4$) and ($R2$, $R3$) respectively (picture 177b). Proximally, the fingers $L1$ and $L2$ pass under the radial right middle string ($R3n$), then grab the ulnar right middle finger string ($R3f$) and return (pictures 177c and 177d).

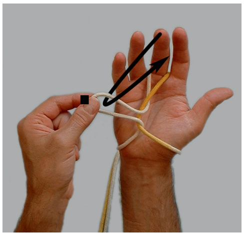

177a

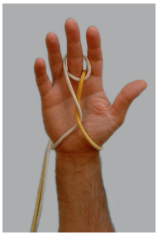

177b

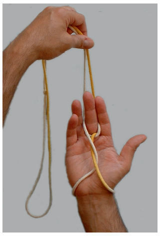

177c

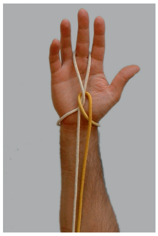

177d

Distally, the right middle finger $R3$ is inserted into the loop carried by fingers $L1$ and $L2$, which are then released (pictures 177e and 177f). The long hanging loop is taken back to the palmar side of the right hand (pictures 177g and 177h).

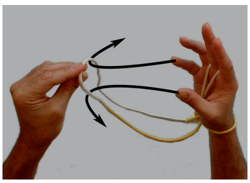

177e

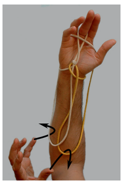

177f

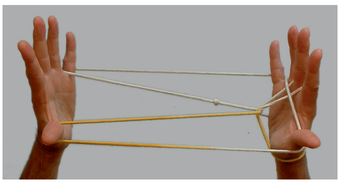

177g


177h

The long hanging loop is then placed in Position I, on the right hand, as shown in picture 177i. Finally, fingers $L1$ and $L5$ are inserted into the hanging loops as shown in picture 177j and the figure is extended (picture 177k). I will refer to this opening as Opening W_1.


177i


177j


177k

The second opening of this kind—that I note Opening W_2—occurs in procedure 24.*Avestruz*.[23] In Annex IV, the previous classification of the Chaco corpus openings is summarized.

9.2.3 Comparison

9.2.3.1 Altering the Openings

In both corpora, Opening A has by far the greater occurrence. Moreover, it occurs proportionally more often in the Oluvilei corpus (36 % of the openings in the Chaco and 56 % in the Trobriands). While studying ethnographical papers on string figures, I have often noticed that Opening A has a high occurrence in various corpora collected in many different geographical areas. Is this due to the propagation of string figures from one society to another throughout the planet, or has Opening A appeared simultaneously and independently in several places around the world? It is hard to tell. Nevertheless, the existence of exactly the same sequence of movements in geographically and culturally distant societies raises many questions. If a large majority of practitioners of string figures on the planet were interested in this opening, and maybe invented it and created variations on it, we may hypothesize that is due to its high fecundity.

In the Trobriands and the Chaco, Opening A's fecundity appears at two levels: the first is the existence of many procedures starting with this opening. The second level lies in the fact that Opening A has probably inspired some string figure creators to invent new openings. The classifications above suggests that Opening A has served as a base to create nine other openings, through a few more or less pronounced alterations (Opening A_i, for $i \in \{1, \ldots, 9\}$). This phenomenon occurs in every corpus that I have collected and/or studied so far. Moreover, every opening thus created occurs only once within the corpus, except for Opening A_1 which occurs twice. This leads me to think that these variations were motivated by the will to create new string figures and explore the possibility of transforming a string figure procedure by altering its opening. Two pairs of string figures, 17.*Sakausasa* and 18.*Sakaupakuli* (in the Trobriands) and 25.*Samuù* and 26.*Palo Santo* (in the Chaco), seem to confirm this. *Sakausasa* and *Samuù* both start with Opening A, whereas *Sakaupakuli* and *Palo Santo* start with a variation on it (Opening A_1 and Opening A_8 respectively). In both cases, only the opening is altered, without modifying the rest of the procedure. The intention was possibly to discover the impact of such alteration on the final figure.

In each corpora, adding to Opening A, there is another opening which occurs quite often: Opening M in the Trobriands, and Opening N in the Chaco. Like Opening A, these two openings generated some variations—Opening M_i, for $i \in \{1, \ldots 4\}$ and Opening N_1. This observation seems to indicate how the practitioners

[23] See the accompanying website (*Tukumbu* Corpus).

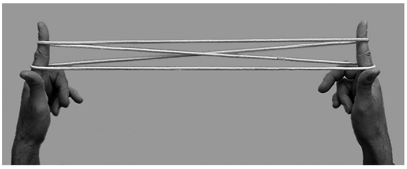
sometimes have investigated these complex spatial configurations: starting from a few "simple" openings as a base, the practitioners or creators would have explored the possible alterations and their topological impacts.

The use of openings A, N and M has been attested in many regions of the planet. Opening N is known in many places throughout the Americas, whereas Opening M was recorded in Melanesia, Australia and Micronesia. By contrast, the previous analysis seems to indicate that the variations on these openings have been created more locally.

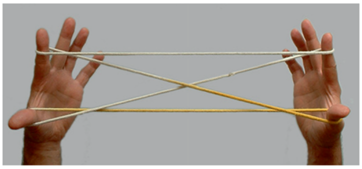
9.2.3.2 From One Opening to Another

9.2.3.2.1 From Opening N to Opening M

There is a great similarity between the configurations $Conf(\underline{O}.N)$ and $Conf(\underline{O}.M)$, obtained through Opening N (Chaco) and Opening M (Trobriands) (pictures 178a and 178b). It is actually possible to pass from $Conf(\underline{O}.N)$ to $Conf(\underline{O}.M)$ through a few transfers of loops.



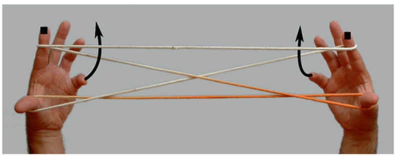
178a – Opening M



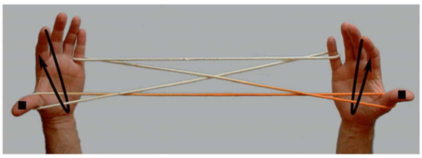
178b – Opening N

From $Conf(\underline{O}.N)$ to $Conf(\underline{O}.M)$:

- Starting from $Conf(\underline{O}.N)$, transfer the index loops to the little fingers ($\underline{O}.N$: $\overrightarrow{2\infty} \longrightarrow 5$—picture 179a)

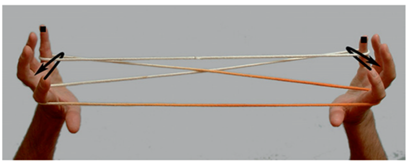


179a

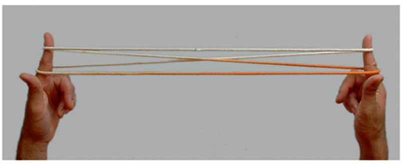


179b

- Then, rotate the thumb loops anticlockwise and transfer them to the indices ($>\overrightarrow{1\infty} \longrightarrow 2$—picture 179b)
- Finally, transfer the little finger loops to the indices in distal position ($\overleftarrow{5\infty} \longrightarrow 2$—pictures 179c and 179d)



179c



179d

This proves that both these openings are linked by the following equivalence:

$$\underline{O}.M \Leftrightarrow \underline{O}.N : \overrightarrow{2\infty} \longrightarrow 5 : > \overrightarrow{1\infty} \longrightarrow 2 : \overleftarrow{5\infty} \longrightarrow 2 \mid$$

So, the differences between *Conf*($\underline{O}.N$) and *Conf*($\underline{O}.M$) lie in the way the loops are put on the fingers (on the indices in Opening M, on the thumbs and indices in Opening N), and in the way the thumb loops (Opening N) or the proximal index loops (Opening M) are twisted, as indicated by transfer $>\overrightarrow{1\infty} \longrightarrow 2$ in the equivalence above. Furthermore, this similarity between openings N and M led both Chaco and Trobriander practitioners in the same direction, thus creating two very similar string figure algorithms[24] (see Sect. 9.4.7.2 below).

Searching a passage from an opening to another, as previously done for Opening M and N, sometimes leads to theoretical outcomes that raise questions about the creation of the openings.

9.2.3.2.2 Passage from Opening A Towards Other Openings

For the passage from *Conf*($\underline{O}.N$) to *Conf*($\underline{O}.M$), only the short sub-procedure "transferring a loop" and operation "rotating a loop" are involved. In order to search a passage between *Conf*($\underline{O}.A$) and configurations such as *Conf*($\underline{O}.N$) or *Conf*($\underline{O}.M$), we obviously need to introduce operation "releasing a loop" which allows to reduce the number of loops on fingers. Of course, this operation usually changes drastically the configuration. However, we have seen that this operation has a high occurrence in both corpora. Therefore, we may reasonably think that the release of a loop was commonly used by the actors to investigate these configurations of strings.

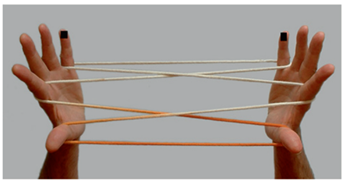
Conf($\underline{O}.N$) can be obtained from *Conf*($\underline{O}.A$) under the operations "releasing" and "rotating" a loop. More precisely, we have the following relation:

$$Conf(\underline{O}.N) \equiv Conf(\underline{O}.A) : \square 5 : \left\{ \begin{matrix} < 2\infty \\ < 1\infty \end{matrix} \right\} \mid$$

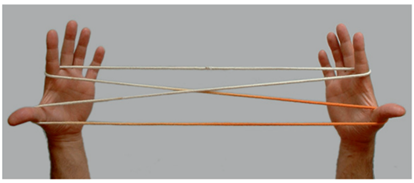
The previous formula is illustrated by the following pictures (180a–180d):

From *Conf*($\underline{O}.A$) to *Conf*($\underline{O}.N$):

– Starting from *Conf*($\underline{O}.A$), release the little finger loops (*Conf*($\underline{O}.A$) : $\square$5—pictures 180a and 180b)



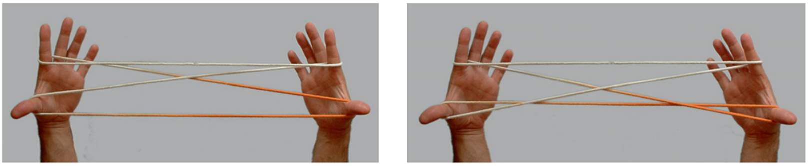
180a



180b

[24]See 29.*Kuluwawaya* (Trobriands) and 6.*Vivora* (Chaco) in the accompanying website (*Kaninikula* corpus/*Tukumbu* corpus).

– Then, the index loops are rotated 180° clockwise (<2∞—picture 180c) and the thumb loops are also rotated 180° clockwise (<1∞—picture 180d).



180c 180d

Hence the equivalence:

$$\underline{O}.N \Leftrightarrow \underline{O}.A : \square 5 : \left\{ \begin{matrix} < 2\infty \\ < 1\infty \end{matrix} \right\} \mid$$

Of course, *Conf*($\underline{O}.M$) can also be obtained from *Conf*($\underline{O}.A$) by simple operations on the loops. More precisely, this can be done according to the following equivalence:

$$\underline{O}.M \Leftrightarrow \underline{O}.A : \square 1 : < 5\infty \rightarrow 2 \mid$$

These theoretical results and the predominance of Opening A in the corpora of string figures lead to conjecture that some openings, which seem at first sight very different from Opening A, would have been derived from it. For instance, it is not improbable that one day a practitioner performed the sequence $\underline{O}.A : \square 5 : \left\{ \begin{matrix} < 2\infty \\ < 1\infty \end{matrix} \right\} \mid$ leading to *Conf*($\underline{O}.N$). He or she could have found this configuration worth being memorized, and thus tried to work out a more direct way to get it.

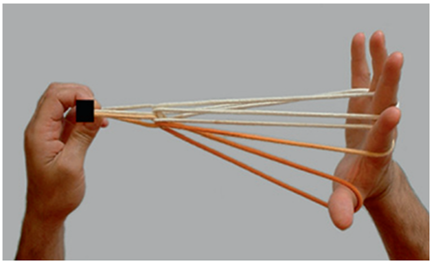
9.2.3.2.3 Contrasting Openings

Although we can consider that the two main openings are roughly the same in both the Trobriands and Chaco corpora (since Opening M and Opening N are very similar, as previously demonstrated), the variations on these two openings are very different from one corpus to the other. The same phenomenon can be observed as to the openings which are not obviously connected to openings A, N or M: the openings that I note Opening S_i in the Trobriands corpus and openings L_i, P_i and W_i in the Chaco corpus, are generally very different from one corpus to the other. There are two exceptions, though: Opening P_1 from the Chaco leads exactly to the same configuration as Opening S_3, even though the procedures are not the same. Opening P_3 and Opening S_4 are also very similar.[25]

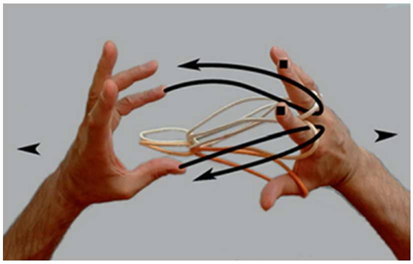
[25] See these openings in the accompanying website (*Kaninikula* and *Tukumbu* corpus).

Within the Chaco corpus, the openings (L_1,L_2,P_2 and W_1) are remarkable. In all cases, the goal is clearly to make a complex "knot" from which a few elementary operations only allow to obtain the final figure. This phenomenon never occurs in the Trobriands corpus. In order to illustrate that point, let us go into the details of 5.*Murcièlago* (Flying fox) which starts with Opening L_1 previously described above.

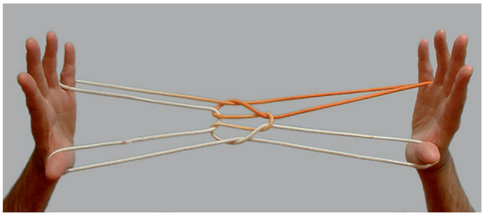
Starting from the configuration $Conf(\underline{O}.L_1)$, the left hand is released. Then, the right index and middle finger loops are transferred simultaneously to the left thumb and the little finger respectively, and the figure is extended (pictures 181a–181c).



181a



181b



181c

The aim of this kind of opening is clearly not, unlike Opening A, M and N, to put the string in a "simple" configuration which would be the starting point of the procedure. But rather, these singular openings are more deeply involved in the making of the final figure, since only a few elementary operations suffice to display the final design.

After having classified the procedures of both corpora in terms of openings, we shall now try to continue this classification by focussing on the passages from one normal position to another. Within the subsets previously obtained in terms of the various openings, one can identify several subgroups by grouping the string figure algorithms which have in common the opening and the passage from the first to the second normal position, and sometimes, the passage from the second to the third normal position.

9.3 Passages from One Normal Position to Another

In order to allow a comparative study of the sub-procedures which can be seen as passages, we need to define a way of encoding them.

SP will mean "sub-procedure" and will be followed by 3 arguments (a, n, p).

- "a" will indicate a geographical area where the sub-procedure has been recorded.
- "n" will be an integer indicating that the sub-procedure in question is a passage from the $(n-1)$th normal position to the nth one.
- Finally, "p" will be the name of one procedure of the corpus containing the sub-procedure at the stage defined by the previous argument.

The choice of argument "p" is not made to stress a singular procedure among others. I simply chose the first procedure that I have learnt in the field and which contains the sub-procedure in question.

9.3.1 Trobriands Corpus

The set of string figure algorithms starting with either Opening A or Opening M can be divided into several subgroups. These algorithms will be classified in terms of the sub-procedures (passages) which enable to reach the second normal position.

9.3.1.1 After Opening A

Within the subset of *kaninikula* starting with Opening A or Opening M, one can identify five such subgroups. Let us describe these subgroups in detail.

9.3.1.1.1 The *Misima* Subgroup

44.*Misima*, 31.*Totuwana kala niya kuliyava*, 46.*Dakuna* and 45.*Solava* put together form a subgroup. According to the above convention, the sub-procedure which characterizes the procedures belonging to the *Misima* sub-group is noted $SP(trob, 2, misima)$. In Chap. 3, I have already described this procedure as a sub-procedure which was given a name by the Goodenough Islanders.[26]

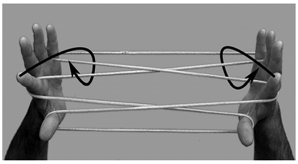
9.3.1.1.2 The *Mweya* Subgroup

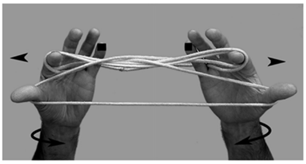
40.*Mweya*, 4.*Togesi* and 5.*Beba* put together form a subgroup. After Opening A (Step 1) the common passage from *Conf*($\underline{O}.A$) to the second normal position goes like this:

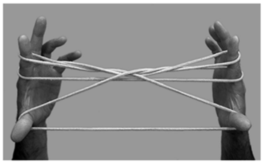
---

[26]Section 3.2.3.2. This sub-procedure can also be found within 51*Kapwatala kapwatawaku*, however, in this case, as the passage from the third to the fourth normal position. See below, Sect. 9.4.2 (Modification of the first normal position).

Step 2: Distally, insert 2 into 5 loops. Rotate 2 anticlockwise (picture 182a).
Step 3: Return to position, palms facing each other, while releasing 5. Extend (pictures 182b and 182c).


182a

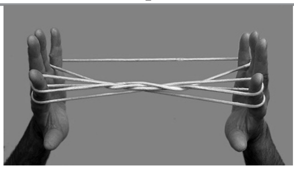
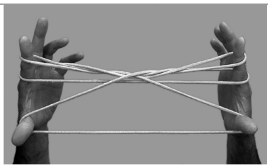
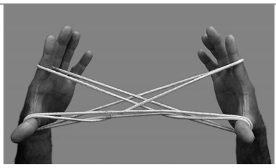
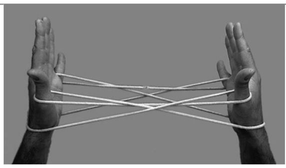

182b


182c

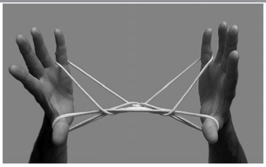
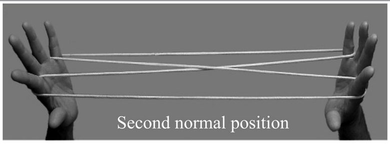
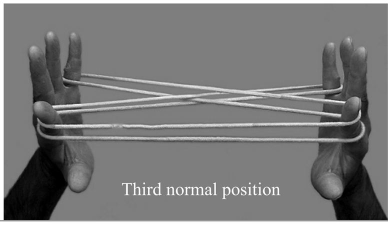
There are three other such subgroups that I call the *Tubum*, *Vivi*, *Udi* and *Salibu* subgroups, as summarized in the following table.

9.3.1.1.3 Summary

The following table summarizes the six second normal positions which characterize the subgroups introduced above.

Subgroups	Second normal position	Kaninikula
Misima		44.Misima—31.Totuwana kala niya kuliyava 46.Dakuna—45.Solava 51.Kapwatala kapwatawaku
Mweya		40.Mweya—4.Togesi—5.Beba
Tubum		27.Tubum—20.Samuan leya
Vivi		26.Vivi—41.Lilu

(continued)

Subgroups	Second normal position	Kaninikula
Udi		47.Udi—35. Kaukwa— 28. Uligova
Salibu	  	54.Salibu—25.Sem 24.Guyau-Bolu-Guyavila [$\underline{O}.A_1 \Leftrightarrow SP(trob, 3, salibu)$] 53. Budi Budi [$SP(trob, 2, budi\ budi) = SP(trob, 2, salibu)$]

Remark 1 I have already demonstrated that Opening A_4 of procedure 24.*Guyau-Bolu-Guyavila* also leads to *Conf*(B)[27]—the third normal position of 54.*Salibu*—*modulo* the transfer $\overrightarrow{1\infty} \rightarrow 2$. Formally, we have $\underline{O}.A : SP(trob, 2, salibu) : SP(trob, 3, salibu) \Leftrightarrow \underline{O}.A_4 : \overrightarrow{1\infty} \rightarrow 2$. Sequence $\underline{O}.A_4 : \overrightarrow{1\infty} \rightarrow 2$ is a shortcut of sequence $\underline{O}.A : SP(trob, 2, salibu) : SP(trob, 3, salibu)$. Therefore, I classify procedure 24.*Guyau-Bolu-Guyavila* in the subgroup of *Salibu*.

Remark 2 Although 28.*Uligova* does not pass through exactly the same 47.*Udi*'s second normal position, I consider it as member of the same subgroup. The first reason of doing so is that *Uligova*, *Udi* and *Kaukwa* share the same sub-procedure $SP(trob, 3, udi)$, which allows to reach the third normal position. Secondly, the second normal positions of procedures *Uligova* and *Udi* are very similar. This similarity is hardly visible when comparing the successions of elementary operations involved in sub-procedures $SP(trob, 2, udi)$ and $SP(trob, 2, uligova)$. However, it can be shown that the heart-sequences of these sub-procedures are the plane-reflexion of one another.

In the set of 33 *kaninikula* that start with Opening A, 18 form the 6 subgroups summarized in the table above. The other 15 procedures cannot be classified in this manner. Before ending this classification, by adding the passages which follow

[27] See above Sect. 9.2.1.2 (Variations on Opening A).

Opening M, let us look more closely at the six cases summarized in the table above. By analysing and comparing the heart-sequences of the sub-procedures leading to these configurations, it will be demonstrated that they can be seen as the result of a systematic exploration of the possible movements of configuration *Conf*($\underline{O}.A$)'s six loops.

9.3.1.2 Digression: Heart-Sequence Analysis

9.3.1.2.1 *Misima*

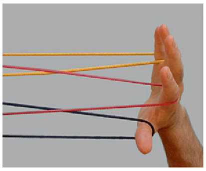
We have already encountered sub-procedure $SP(trob, 2, misima)$ in Sect. 7.1.1.1 while studying the transformation from the Papuan string figure "Stars" to the figure "Egg". Its heart-sequence is given by

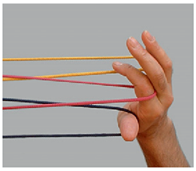
$$\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2 \mid$$

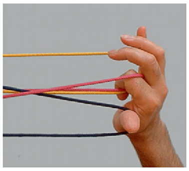
9.3.1.2.2 *Mweya*

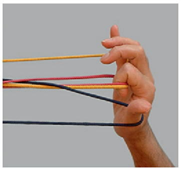
Let us now determine the heart-sequence of $SP(trob, 2, mweya)$ described above. The insertion of the indices into the little finger loops 5∞ and their rotation entail that 2∞ rotate 360° anticlockwise, 5∞ (yellow) turn around 2∞ (red) while rotating 180° anticlockwise (pictures 183a–183f): formally,

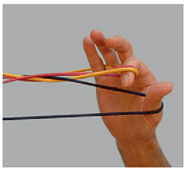
$$\left\{ \begin{array}{c} \gg 2\infty \\ \underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty) : \; > 5\infty \end{array} \right\}$$

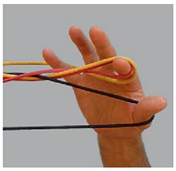

183a

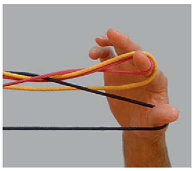

183b

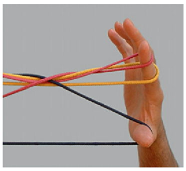

183c


183d


183e


182f


183g


183h

Even though, in practice, the two sequences $\gg\ 2\infty$ and $\underleftarrow{5\infty}(2\infty)\ :\ \overrightarrow{5\infty}(2\infty)\ :\ >5\infty$ are performed simultaneously, it can be demonstrated that these two sequences when applied consecutively ($\gg\ 2\infty\ :\ \underleftarrow{5\infty}(2\infty)\ :\ \overrightarrow{5\infty}(2\infty)\ :\ >5\infty$) lead to the same configuration. Then, the little fingers release their loops 5∞ (yellow) which slip off on the indices. Working in this way, and under the extension of the string, 5∞ become the lowest loops on the indices (pictures 183g and 183h): formally, we will note $\overrightarrow{5\infty} \rightarrow 2(proximal)$. So the heart-sequence can be written:

$$\underline{O}.A : \gg 2\infty : \underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty) :\ > 5\infty :\ \overrightarrow{5\infty} \rightarrow 2(proximal) \mid$$

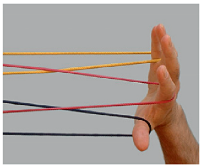
The sequence $>5\infty :\ \overrightarrow{5\infty} \rightarrow 2(proximal)$ can be written more simply $>\overrightarrow{5\infty} \rightarrow 2(proximal)$. So, the heart-sequence becomes:

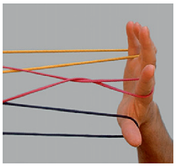
$$\underline{O}.A : \gg 2\infty :\ \underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty) :\ >\ \overrightarrow{5\infty} \rightarrow 2(proximal) \mid$$

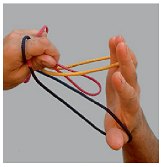
The latter can be rewritten by considering the "insertion" that the sequence $>\overrightarrow{5\infty} \rightarrow 2(proximal)$ implies. Let us write down an equivalent heart-sequence of $SP(trob, 2, mweya)$ including this "insertion". This rewriting will be essential for the coming discussion. One can see that $\overrightarrow{5\infty} \rightarrow 2(proximal) \mid$ is obviously equivalent to the insertion of 2∞ (red) into 5∞ (yellow) from below. More precisely, $>\overrightarrow{5\infty} \rightarrow 2(proximal) \mid$ is equivalent to $>5\infty : \underrightarrow{2\infty} \uparrow (5\infty) : \overrightarrow{5\infty} \longrightarrow 2 : \overrightarrow{2\infty} \longrightarrow 2$.

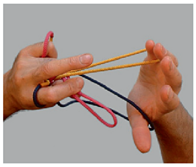
The insertion $\underrightarrow{2\infty} \uparrow (5\infty)$ can actually be done just after the sequence $\underline{O}.A : \gg 2\infty$ without altering the final configuration shown in picture 183h.

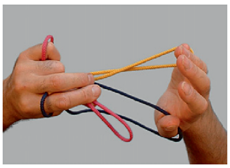
After Opening A, let us begin the sub-procedure by rotating 360° anticlockwise the loops 2∞ (red): $\underline{O}.A : \gg 2\infty$ (pictures 184a and 184b).

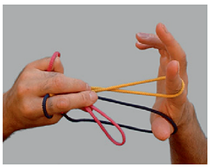

184a

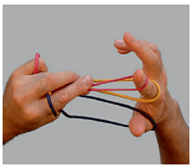

184b

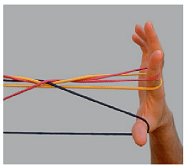

184c


184d


184e


184f


184g


184h

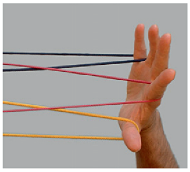
Then, 2∞ (red) must be inserted from above into 5∞ (yellow): $\overrightarrow{2\infty} \downarrow (5\infty)$ (pictures 184c and 184d). The insertion is done from above instead of from below, since 5∞ has not been rotated yet. In fact, the aim is to write down an equivalent sequence by operating first on the loops 2∞ instead of 5∞, as it was the case in the former heart-sequence.

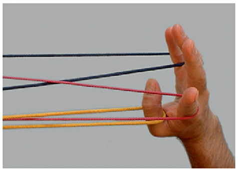
5∞ is then rotated 180° clockwise and transferred to the indices: $>\overleftarrow{5\infty} \longrightarrow 2$ (pictures 184e–184f). Finally, the former index loops, that I will note $ex2\infty$, are placed on the tips of the indices (in distal position): $\overleftarrow{ex2\infty} \longrightarrow 2$. Then the string is extended (pictures 184g and 184h). So, we obtain an equivalent heart-sequence for $SP(trob, 2, mweya)$ which is based mostly on the motion of 2∞ instead of 5∞:

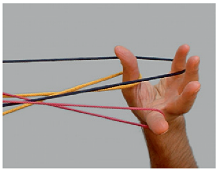
$$\underline{O}.A : \gg \overrightarrow{2\infty} \downarrow (5\infty) : > \overleftarrow{5\infty} \longrightarrow 2 \ : \overleftarrow{ex2\infty} \longrightarrow 2 \,|$$

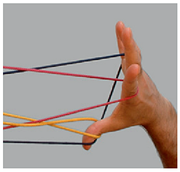
9.3.1.2.3 *Tubum*

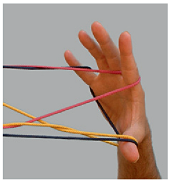
The heart-sequence of $SP(Trob, 2, tubum)$ is quite similar than the previous one.[28] However in this case, it is the loops on the thumbs 1∞ and the little fingers 5∞ which are involved in the process. One can see, as illustrated in pictures 185a–185h, that the thumbs operate on 5∞ (black) in order to make them rotate on themselves and turn around 1∞ (yellow): formally, $\underleftarrow{5\infty}(1\infty) : \overrightarrow{5\infty}(1\infty) : \gg 5\infty$.

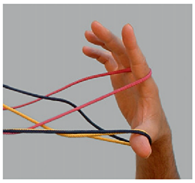

185a

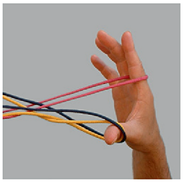

185b

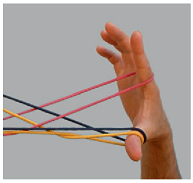

185c


185d


185e


185f


185g


185h

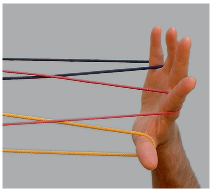
This movement also causes a 360° rotation of 1∞ (pictures 185a–185e): formally, $\gg 1\infty$. The little fingers are released and the loops 5∞ are transferred

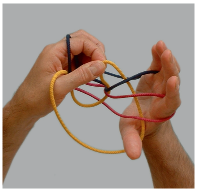
[28] See this sub-procedure in the accompanying website (*Kaninikula* corpus/Opening A/*Tubum* subgroup).

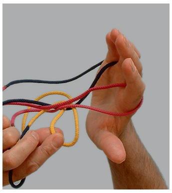
to the thumbs (pictures 185f–185h). During the movement, the string is extended. The effect of the latter extension is that 5∞ (black) falls down in proximal position on the thumbs: formally, $\overrightarrow{5\infty} \rightarrow 1(proximal) \mid$. The heart-sequence of $SP(Trob, 2, tubum)$ can then be written:

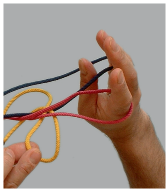
$$\underline{O}.A : \gg 1\infty : \underleftarrow{5\infty}(1\infty) : \overrightarrow{5\infty}(1\infty) : \gg \overrightarrow{5\infty} \rightarrow 1(proximal) \mid .$$

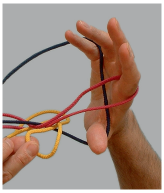
As in $SP(trob, 2, mweya)$ the transfer $\overrightarrow{5\infty} \rightarrow 1(proximal)$ can be seen as an insertion. Moreover, we obtain exactly the same configuration by performing this insertion at the beginning of the process, as demonstrated below. Starting from Opening A, 1∞ (yellow) can be inserted into 5∞ (black) from below: $\underline{O}.A : \underrightarrow{1\infty} \uparrow (5\infty)$ (pictures 186a–186c).

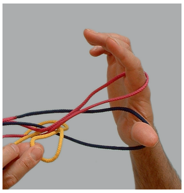

186a

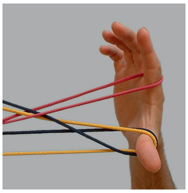

186b

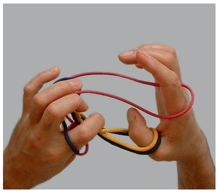

186c

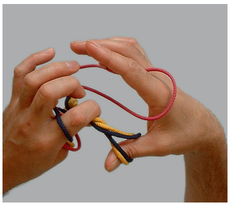

186d

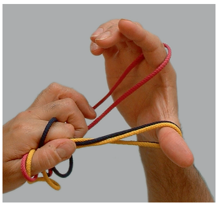

186e

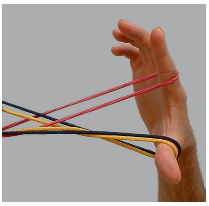

186f


186g


186h


186i


186j


186k

Then, proximally, 5∞ (black) can be transferred to the thumbs formally, $\underleftarrow{5\infty} \longrightarrow 1$ (pictures 186d–186f). $ex1\infty$ (yellow) is also transferred to the thumbs becoming in this way the distal loops on the thumbs: formally, $\overleftarrow{ex1\infty} \longrightarrow 1$ (pictures 186g). Then, both thumb loops 1∞ are rotated 360° anticlockwise: $\gg 1\infty^{(2)}$ (pictures 186h–186k). So, we get an equivalent heart-sequence for

$SP(Trob, 2, tubum)$ which is mostly based on the movements of 1∞ instead of 5∞:

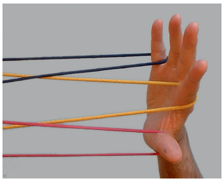
$$\underline{O}.A : \underset{\longrightarrow}{1\infty} \uparrow (5\infty) : \underset{\longleftarrow}{5\infty} \longrightarrow 1 : \gg 1\infty^{(2)} \mid$$

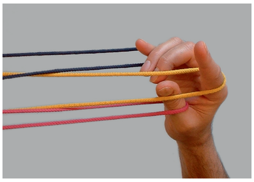
Notation: the exponent 2 in the formula $\gg 1\infty^{(2)}$ means that there are two loops on each thumb that are rotated.

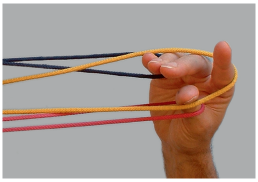
9.3.1.2.4 *Vivi*

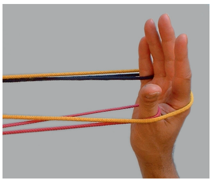
Sub-procedure $SP(trob, 2, vivi)$ consists in transferring the index loops to the wrists.[29] This sequence $\underline{O}.A : 2\infty \longrightarrow w \mid$ actually entails the simultaneous insertion, from below, of both the little finger and thumb loops (5∞—black and 1∞—red) through index loop (2∞—yellow—pictures 187a–187e). Formally, this can also be written as follows:

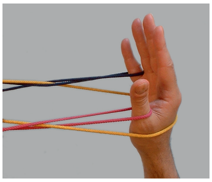
$$\underline{O}.A : \left\{ \begin{array}{l} \underset{\longleftarrow}{5\infty} \uparrow (2\infty) \\ \underset{\longrightarrow}{1\infty} \uparrow (2\infty) \end{array} \right\} \mid .$$


187a


187b


187c


187d


187e

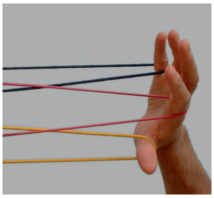
9.3.1.2.5 *Udi*

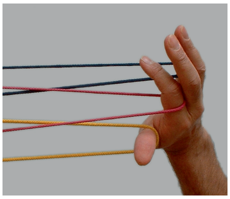
Sub-procedure $SP(trob, 2, udi)$ causes the following movements of loops.[30]

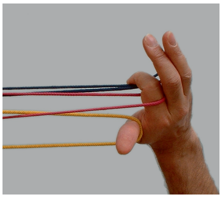
[29] See this sub-procedure in the accompanying website (*Kaninikula* corpus/Opening A/*Vivi* sub-group).

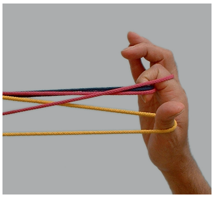
[30] See this sub-procedure in the accompanying website (*Kaninikula* corpus/Opening A/*Udi* sub-group).

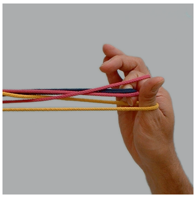
- The indices make thumb loops 1∞ (yellow) pass proximal to both the index loops 2∞ (red) and the little finger loops 5∞ (black) (pictures 188a–188f): formally, $\underrightarrow{1\infty}(2\infty \wedge 5\infty)$.
- Then, thumb loops 1∞ (yellow) pass distal to little finger loops 5∞ (black) towards you (pictures 188g and 188h): $\overleftarrow{1\infty}(5\infty)$.

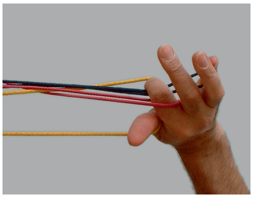

188a

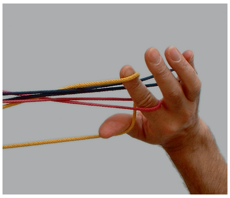

188b

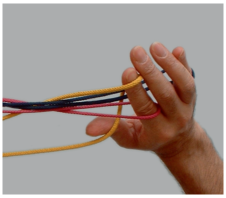

188c

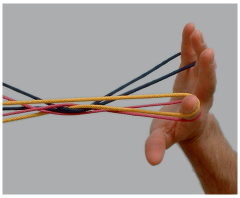

188d


188e


188f


188g


188h


188i

- During the movement, thumb loops 1∞ (yellow) are rotated 180° clockwise and transferred to the indices, becoming in this way the distal loops on the indices: $<\overleftarrow{1\infty} \rightarrow 2$ (picture 188i). Formally, we get the following sequence:

$$\underline{O}.A : \underrightarrow{1\infty}(2\infty \wedge 5\infty) : \overleftarrow{1\infty}(5\infty) : < \overleftarrow{1\infty} \rightarrow 2.$$

Remark. As mentioned in Remark 2 above, the heart-sequences of sub-procedure $SP(trob, 2, uligova)$, involved within 28.*Uligova*, and sub-procedure $SP(trob, 2, udi)$, are the plane-reflexion of one another. It can be shown that the heart-sequence of $SP(trob, 2, uligova)$ is given by

$$\underline{O}.A : \overrightarrow{1\infty}(2\infty \wedge 5\infty) : \underleftarrow{1\infty}(5\infty) : > \overleftarrow{1\infty} \rightarrow 2 : \gg 2\infty^{(2)}$$

9.3.1.2.6 Summary

The table below summarizes the previous demonstrations.

Sub-procedures	Heart-sequences
$SP(trob, 2, misima)$	$\underline{O}.A : \overrightarrow{1\infty} \uparrow (5\infty) : \overleftarrow{1\infty} \rightarrow 2 \mid$
$SP(trob, 2, mweya)$	$\underline{O}.A : \gg 2\infty : \underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty) : > \overrightarrow{5\infty} \rightarrow 2(proximal) \mid$ $\Leftrightarrow$ $\underline{O}.A : \gg 2\infty : \underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty) :> 5\infty :$ $\underrightarrow{2\infty} \uparrow (5\infty) : \left\{\begin{array}{l} \overrightarrow{5\infty} \longrightarrow 2 \\ \overrightarrow{2\infty} \longrightarrow 2 \end{array}\right\} \mid$ $\Leftrightarrow \underline{O}.A : \gg \overrightarrow{2\infty} \downarrow (5\infty) : > \overleftarrow{5\infty} \longrightarrow 2\ : \overleftarrow{ex2\infty} \longrightarrow 2 \mid$
$SP(trob, 2, tubum)$	$\underline{O}.A : \gg 1\infty :\ \underleftarrow{5\infty}(1\infty) : \overrightarrow{5\infty}(1\infty) : \gg \overrightarrow{5\infty} \rightarrow 1(proximal) \mid$ $\Leftrightarrow$ $\underline{O}.A : \underrightarrow{1\infty} \uparrow (5\infty) :\ \underleftarrow{5\infty} \longrightarrow 1 : \gg 1\infty^{(2)} \mid$
$SP(trob, 2, vivi)$	$\underline{O}.A : 2\infty \longrightarrow w \mid\Leftrightarrow \underline{O}.A : \left\{\begin{array}{l} \underleftarrow{5\infty} \uparrow (2\infty) \\ \underrightarrow{1\infty} \uparrow (2\infty) \end{array}\right\} \mid$
$SP(trob, 2, udi)$	$\underline{O}.A : \underrightarrow{1\infty}(2\infty \wedge 5\infty) : \overleftarrow{1\infty}(5\infty) : < \overleftarrow{1\infty} \rightarrow 2\ \mid (Udi, Kaukwa)$ $\underline{O}.A : \overrightarrow{1\infty}(2\infty \wedge 5\infty) :\ \underleftarrow{1\infty}(5\infty) : > \overleftarrow{1\infty} \rightarrow 2 :$ $\gg 2\infty^{(2)} \mid (Uligova)$
$SP(trob, 2, salibu)$	$Conf(\underline{O}.A)^*\ : \left\{\begin{array}{l} > \overrightarrow{2\infty} \rightarrow 5 \\ > \underleftarrow{5\infty} \rightarrow 2 \end{array}\right\} : \overrightarrow{1\infty} \rightarrow 2 \mid$

9.3.1.2.7 Analysis

Let us focus on the "insertions" that occur in the sequences noted in the table above.

Insertion	Procedures
$\overrightarrow{1\infty} \uparrow (5\infty)$	*Misima*
$\underrightarrow{2\infty} \uparrow (5\infty)$ *or* $\overrightarrow{2\infty} \downarrow (5\infty)$	*Mweya*
$\underrightarrow{1\infty} \uparrow (5\infty)$	*Tubum*

Obviously, all the possible "insertions" of the six loops of the configuration *Conf*($\underline{O}.A$), do not occur in the table above. There are actually 16 such "insertions" which are given in the following table.

Insertion after $\underline{O}.A$	Sequence
$2\infty\ into\ 1\infty$	$\underleftarrow{2\infty} \uparrow (1\infty) - \overleftarrow{2\infty} \downarrow (1\infty)$
$2\infty\ into\ 5\infty$	$*\underrightarrow{2\infty} \uparrow (5\infty) - \overrightarrow{2\infty} \downarrow (5\infty)*$
$1\infty\ into\ 2\infty$	$\underrightarrow{1\infty} \uparrow (2\infty) - \overrightarrow{1\infty} \downarrow (2\infty)\ -\ \varnothing$
$5\infty\ into\ 2\infty$	$\underleftarrow{5\infty} \uparrow (2\infty) - \overleftarrow{5\infty} \downarrow (2\infty)\ -\ \varnothing$
$1\infty\ into\ 5\infty$	$\underrightarrow{1\infty} \downarrow (5\infty) - \overrightarrow{1\infty} \downarrow (5\infty) - *\underrightarrow{1\infty} \uparrow (5\infty) - \overrightarrow{1\infty} \uparrow (5\infty)*$
$5\infty\ into\ 1\infty$	$*\underleftarrow{5\infty} \downarrow (1\infty) - \overleftarrow{5\infty} \downarrow (1\infty) - \underleftarrow{5\infty} \uparrow (1\infty) - \overleftarrow{5\infty} \uparrow (1\infty)*$

One can observe that insertions "$1\infty\ into\ 2\infty$" and "$5\infty\ into\ 2\infty$" leave almost invariant the configuration $Conf(\underline{O}.A)$. Formally, we have the four following equivalences:

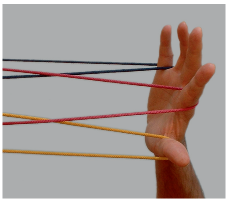
(1) $\underline{O}.A : \underrightarrow{1\infty} \uparrow (2\infty) : \ll 1\infty \Leftrightarrow \underline{O}.A$ (see pictures 188a–f below)

(2) $\underline{O}.A : \overrightarrow{1\infty} \uparrow (2\infty) : \gg 1\infty \Leftrightarrow \underline{O}.A$

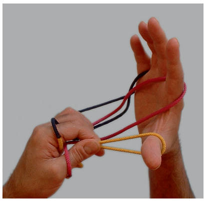
(3) $\underline{O}.A : \underleftarrow{5\infty} \uparrow (2\infty) : \gg 5\infty \Leftrightarrow \underline{O}.A$

(4) $\underline{O}.A : \overleftarrow{5\infty} \uparrow (2\infty) : \ll 5\infty \Leftrightarrow \underline{O}.A$

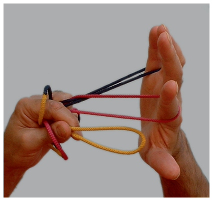
Illustration of the formula (1) as an example: The sequence $\underline{O}.A : \underrightarrow{1\infty} \uparrow (2\infty)$ is illustrated by the following pictures 189a–189f. In the final configuration shown in picture 189f, one can easily see that a 360° clockwise rotation ($\ll 1\infty$) allows to return to the initial position $Conf(\underline{O}.A)$.



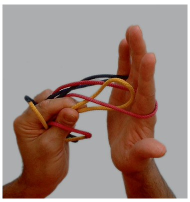
189a



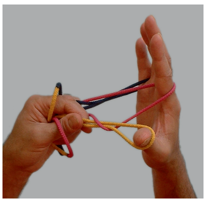
189b



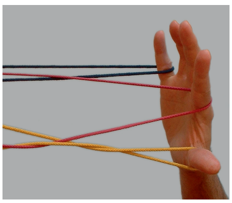
189c



189d



189e



189f

The insertions "1∞ into 2∞" or "5∞ into "2∞" occur only twice in the Oluvilei corpus. We have seen that procedures 26.*Vivi* and 41.*Lilu* begin with the sequence

$$\underline{O}.A : \left\{ \begin{array}{l} \underleftarrow{5\infty} \uparrow (2\infty) \\ \underrightarrow{1\infty} \uparrow (2\infty) \end{array} \right\} \mid$$

in which $\underleftarrow{5\infty} \uparrow (2\infty)$ and $\underrightarrow{1\infty} \uparrow (2\infty)$ are simultaneously performed under the sequence $\underline{O}.A \,:\, 2\infty \longrightarrow w \mid$. It can be demonstrated that these simultaneous insertions may be omitted in the heart-sequence. Therefore, it seems that the only goal of this operation is to free the indices in order to allow them to operate. In fact, *Vivi* and *Lilu* can be performed by manipulating the loops without doing transfer $2\infty \longrightarrow w$. When doing so, it can be shown that the insertions which follow $\underline{O}.A$ must be $\underleftarrow{5\infty} \uparrow (1\infty)$ and $\underleftarrow{5\infty} \downarrow (1\infty)$ in 26.*Vivi* and 41.*Lilu* respectively.

A second occurrence of the sequence $\underline{O}.A \,:\, \underleftarrow{5\infty} \uparrow (2\infty)$ can be found, in the corpus, in the making of 34.*Samula kayaula*. The latter belongs to a subset of three string figures, 34.*Samula kayaula*, 32.*Vivilua* and 33.*Kenabosu*, which all start with Opening A. These three procedures are almost identical, but they differ in their second normal positions. The difference is due to the addition of one or two different elementary operations (rotation of loop) done just after Opening A: in *Vivilua*, the index loops 2∞ of *Conf*($\underline{O}.A$) are rotated once 360° anticlockwise; in *Kenabosu* the same rotation is carried out twice; in *Samula kayaula*, this rotation does not occur. The beginning of the three heart-sequences are given by:

Samula kayaula $\rightarrow \underline{O}.A : \underleftarrow{5\infty} \uparrow (2\infty) : > \overleftarrow{5\infty} \rightarrow 2 \ldots$

Vivilua $\rightarrow \underline{O}.A : > 2\infty : \underleftarrow{5\infty} \uparrow (2\infty) : > \overleftarrow{5\infty} \rightarrow 2 \ldots$

Kenabosu $\rightarrow \underline{O}.A : \gg 2\infty : \underleftarrow{5\infty} \uparrow (2\infty) : > \overleftarrow{5\infty} \rightarrow 2 \ldots$

In *Vivilua* and *Kenabosu*, sequence $\underleftarrow{5\infty} \uparrow (2\infty)$ markedly modifies the configuration obtained through $\underline{O}.A : > 2\infty$ or $\underline{O}.A : \gg 2\infty$.

In *Samula kayaula*, on the contrary, we saw above that the sequence $\underline{O}.A : \underleftarrow{5\infty} \uparrow (2\infty)$ is equivalent to $\underline{O}.A \,:\, \ll 5\infty$, then the heart-sequence of the beginning of *Samula Kayaula* becomes $\underline{O}.A : \ll 5\infty : > \overleftarrow{5\infty} \rightarrow 2 \ldots$, which is equivalent to $\underline{O}.A \,:\, < \overleftarrow{5\infty} \rightarrow 2$. So, it would be theoretically possible not to not perform the first operations of *Samula Kayaula*, which causes the insertion $\underleftarrow{5\infty} \uparrow (2\infty)$. However, it was not the choice made by the creators of these procedures. The aim was probably to make clearly appear the likeness between these three *kaninikula*, and their mode of generation, making thus easier the transmission of these three procedures.

Within the set of the 16 possible "insertions" shown in the table above, only 12 are efficient, causing something more than a simple rotation. Among these—adding the cases of *Vivi* and *Lilu* discussed above ($\underleftarrow{5\infty} \uparrow (1\infty)$ and $\underleftarrow{5\infty} \downarrow (1\infty)$)—half of them occur at least once within the set of the six subgroups of string figures introduced in this section. However, we can enlarge our investigation to the subset of *kaninikula* which start with Opening A, as we did previously with the string figures *Vivilua*, *Samula kayaula* and *Kenabosu*. Without going into the details, the sequence $\underleftarrow{L5\infty} \uparrow (L1\infty)$ can be found in 9.*Gwadi*, and the sequence $\overleftarrow{5\infty} \uparrow (1\infty)$ in 43.*Ilowosi*.

This leads to a total number of eight efficient insertions, performed after Opening A over a total of 12 potential insertions. In the table above, I noted these eight insertions between asterisks. In this table, we see that the sequences $\underline{O}.A : \underleftarrow{2\infty} \uparrow (1\infty)$ and $\underline{O}.A : \overleftarrow{2\infty} \downarrow (1\infty)$ do not occur in the corpus. However, the mirror image of these movements do ($\underline{O}.A : \underrightarrow{2\infty} \uparrow (5\infty)$ and $\underline{O}.A : \overrightarrow{2\infty} \downarrow (5\infty)$). It is the same for the sequences $\underline{O}.A : \underrightarrow{1\infty} \downarrow (5\infty)$ and $\underline{O}.A : \overrightarrow{1\infty} \downarrow (5\infty)$ whose mirror sequences are $\underleftarrow{5\infty} \downarrow (1\infty)$ and $\overleftarrow{5\infty} \downarrow (1\infty)$. So the eight potential sequences of the $\underline{O}.A : [Insertion]$ type, which do not occur in the corpus, either are not efficient—producing nothing more than a rotation of a loop—or are the mirror images of sequences involved in the corpus. Therefore, we may hypothesize that the exploration of the different sequences of the type $\underline{O}.A : [Insertion]$ has been made in a systematic way by the string figures' creators.

Similar observations can be made—in the context of Opening A—about the different manners of turning a loop around another one. The result is given in the following table and shows that many cases have been explored by the creators.

Sequence	String figure
$\underleftarrow{5\infty}(2\infty) : \overrightarrow{5\infty}(2\infty)$	*Mweya* Subgroup
$\underleftarrow{5\infty}(1\infty) : \overrightarrow{5\infty}(1\infty)$	*Tubum* Subgroup, 6.*Kapiwa*
$\underrightarrow{1\infty}(5\infty) : \overleftarrow{1\infty}(5\infty)$ $\overrightarrow{1\infty}(5\infty) : \underleftarrow{1\infty}(5\infty)$	*Udi* Subgroup
$\overrightarrow{2\infty}(5\infty) : \underleftarrow{2\infty}(5\infty)$	42.*Nebogi*
$\underleftarrow{5\infty}(1\infty) : \overrightarrow{5\infty}(2\infty)$	38.*Kalamolu nageta*

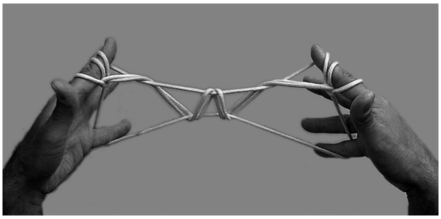
That is an encouraging outcome. However, a lot of work still needs to be carried out. We focussed here on the first passage after Opening A. We shall continue this investigation by looking at the next passages. Of course, the number of cases increases rapidly at each adding stage. At first glance, it seems that all the potential sequences do not occur within the Oluvilei corpus. However, in order to confirm this, it will be necessary to explore all the possibilities. This could be achieved in a future work, by creating a computer program. The goal of such program should be to implement automatically a given heart-sequence in order to obtain, instantly on a video screen, the configuration resulting from this sequence. It would certainly enable us a better understanding of how the string figure corpora were constituted, shedding light on the choices made by the creators. They sometimes might have tried to saturate a "logical space", as the example above seems to indicate, exploring the combinatorics of the loop insertions. After that digression, let us pursue our inventory of second passages by focussing on the set of *kaninikula* starting with Opening M.

9.3.1.3 After Opening M

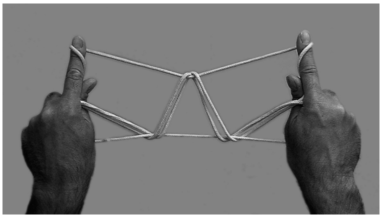
In the set of the eight *kaninikula* which begin with Opening M, two subgroups can be identified.

9.3.1.3.1 *Kuluwawaya* Subgroup

The *Kuluwawaya* Subgroup can be formed with the following five procedures of the corpus: 29.*Kuluwawaya*, 11.*Posisiskwa*, 36.*Bunukwa*, 39.*Seda* and 21.*Butia*. All these string figure algorithms have the same passage from the first to the second normal position—$SP(trob, 2, kuluwawaya)$—and from the second to the third normal position—$SP(trob, 3, kuluwawaya)$.[31]



190a – Kuluwawaya: second normal position



190b – Kuluwawaya: third normal position

The figure in picture 190a is known and widespread throughout the South Pacific. In the Trobriands, this figure is not named, and can be seen as an intermediate figure of the long series of figures *kuluwawaya*.[32] It is also the case for the figure displayed in the third normal position (picture 190b).

In Oluvilei, sub-procedure $SP(trob, 2, kuluwawaya)$ is often known by children, even though they do not usually know how to make any string figure of the *kuluwawaya* subgroup. As mentioned earlier, this remark could be of fundamental importance to better understand the mode of transmission of *kaninikula* throughout childhood. As this example suggests, the learning of long procedures may some-

[31] See the sub-procedures in the accompanying website (*Kaninikula* corpus/Opening M/*Kuluwawaya* subgroup).

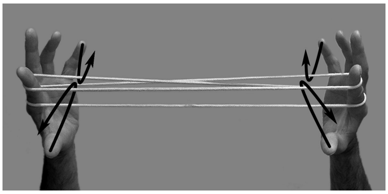
[32] This seems to be also the case in other places in Melanesia: Noble found this figure in Numba area, Managalas and Musa district, and he calls it W-patterns since it has "no special ancient name of significance"; it is "used as a step in other more complex patterns (Noble 1979, p. 15). By contrast, in 1912, Jenness found it under the name *Dodoki ukiu* (A gathering-in) on Goodenough Island, D'Entrecasteaux archipelago (Jenness 1920, p. 317).

times be related to the concepts of "passage" and "normal position". Some long procedures may gradually be taught to children, one passage after another.

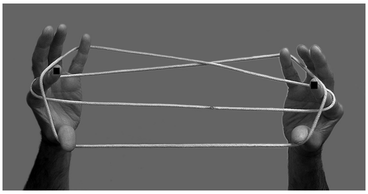
9.3.1.3.2 The *Tobutu topola* Subgroup

The second subgroup is formed by the two procedures 23.*Tobutu topola* and 30.*Tosalilagelu*. For these two string figures, the sub-procedure which follows Opening M (Step 1) consists in creating a palmar string (Steps 2 and 3). Then, Opening A is performed, using the middle fingers instead of the indices (Steps 4 and 5):

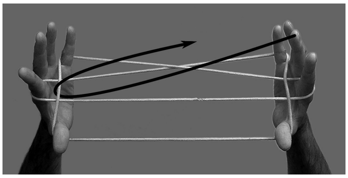
Step 2: 1 and 5 are inserted simultaneously into upper 2 loops. Then, 1 pick up upper $2n$ whereas 5 pick up upper $2f$ (picture 191a).
Step 3: Release upper 2 (picture 191b).
Step 4: $R3$ picks up left palmar string (picture 191c).
Step 5: Distally, insert $L3$ into $R3$ loop. $L3$ picks up right palmar string and return. Extend (pictures 191d and 191e).



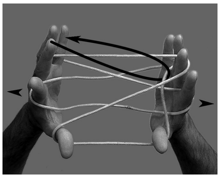
191a



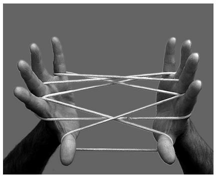
191b



191c



191d



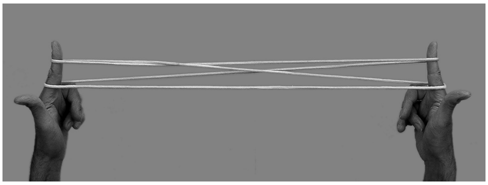
191e

One can see that the latter sub-procedure results formally from the combination of Openings A and M. I do not know yet how exactly this formal property is perceived nowadays by Trobriander practitioners. However, Openings A and M are the two main openings of the corpus, so we can reasonably think that this combination has been made consciously by the creators of string figures.

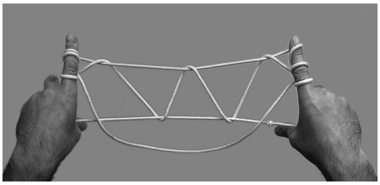
9.3.1.4 After Opening M_2

After Opening M_2 both string figure procedure 10.*Kweviviya* and 48.*Subuvinu* continue in the same way through a sequence already mentioned above and noted

$SP(trob, 2, kuluwawaya)$. Starting from first normal position $Conf(\underline{O}.M_2)$ instead of $Conf(\underline{O}.M)$, we obtain a different second normal position as shown in pictures 192a and 192b:



192a – $Conf(\underline{O}.M_2)$



192b – Second normal position of *Subuvinu*

This remark shows that the same sub-procedure $SP(trob, 2, kuluwawaya)$ has been applied on two different "substrata" ($Conf(\underline{O}.M)$ and $Conf(\underline{O}.M_2)$). It is very likely that the configuration $Conf(\underline{O}.M)$ has been altered into the $Conf(\underline{O}.M_2)$—by the rotation of the left distal (upper) index loop[33]—and thereafter, the same sub-procedure might have been implemented from this new configuration.

Let us now turn to the description and analysis of the passages from the first to the second normal position which can be identified in the Chaco corpus. The comparison with the Trobriands Corpus will then lead to important outcomes.

9.3.2 *Chaco Corpus*

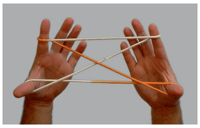
9.3.2.1 After Opening N: The *Sanja* Subgroup

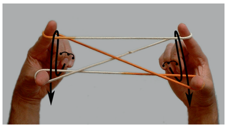
Within the subset of the ten *tukumbu* that begin with Opening N, there is a subgroup formed by the five procedures 2.*Sanja*, 12.*Casita*, 21.*Kaure'i*, 34.*Tatoui* and 36.*Karumbe*. These *tukumbu* have in common the same passage from configuration $Conf(\underline{O}.N)$ to the second normal position. Using the notation previously introduced, I named $SP(chaco, 2, sanja)$ this passage, which goes like this:

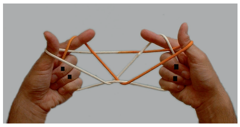
Step 1: Opening N (picture 193a)
Step 2: Proximally, 3,4 and 5 all together are inserted into 1 loops and hook down string $2n$ (picture 193b).
Step 3: Release 3 and 4 (picture 193c).
Step 4: Release 1 (picture 193d).
Step 5: 1 pick up the transversal string close to the hands and return.
Step 6: Release 2 and extend[34] (pictures 193f and 193g).

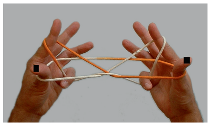
[33] See above Sect. 9.2.1.1 (Variations on Opening M).

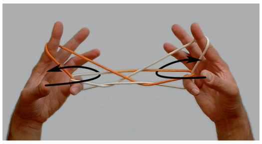
[34] See also this sub-procedure in the accompanying website (*Tukumbu* corpus/Opening N/The *Sanja* subgroup).

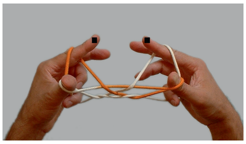

193a

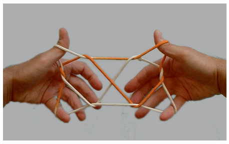

193b


193c

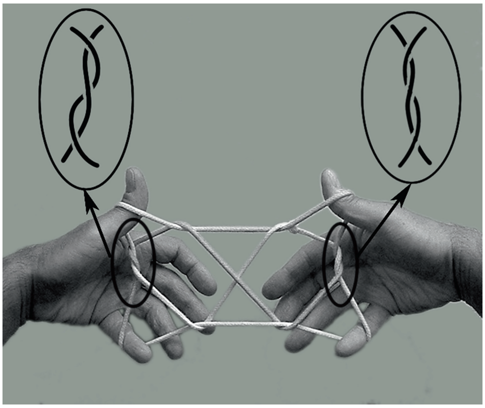

193d


193e


193f


193g

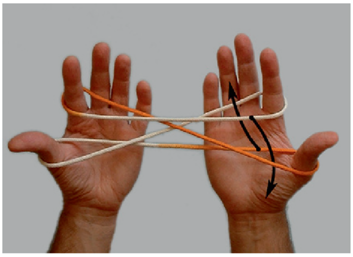
As it is the case in the Trobriands with $SP(\mathit{trob}, 2, \mathit{kuluwawaya})$, passage $SP(chaco, 2, sanja)$ leads to an intermediate figure which has no vernacular name (picture 193g), which indicates that this figure is considered by the practitioners as an intermediate figure only. The effect of sub-procedure $SP(chaco, 2, sanja)$ is mainly to create two symmetrical complex crossings close to the palms, as shown in picture 194.

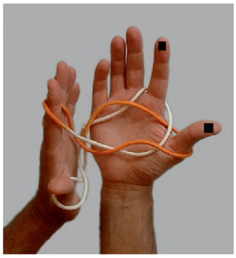

194 – Sanja: second normal position and its complex crossings

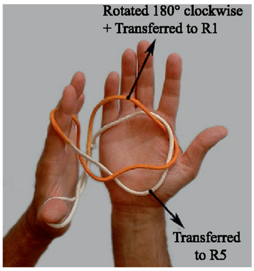
In order to better understand how this complex crossing is made under $SP(chaco, 2, sanja)$, let us determine the heart-sequence of this sub-procedure. Storer analysed the making of the same complex crossing in the Inuit string figure procedure called “The Two Brown Bears”, first collected by Jenness (1924, p. 13). He demonstrated that this crossing results from the simultaneous insertion (or “lacing”) of two loops, one through the other. This led him to introduce a notation that is specific to this complex loop manipulation (Storer 1988, p. 166).

In configuration $\mathit{Conf}(\underline{O}.N)$, there is a loop on the index and thumb of each hand. Let us focus on the movement of these two loops on the right side, caused by Steps 1–6 above. As shown in picture 195a, string $2n$ passes from above into thumb loop

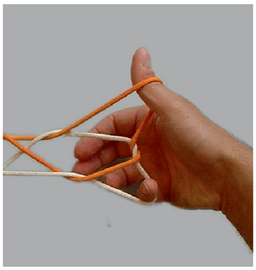
1∞ (orange). This happens under operation “hooking down” in Step 2. Also, string $1f$ passes from below into index loop 2∞ (white). This occurs under operation “picking up” in Step 5. One can see that the release of the index and thumb make a complex crossing appear (pictures 195b and 195c). In fact, in the procedure given above, the indices and thumbs are not released simultaneously, but at Steps 4 and 6 respectively. In order to obtain the final configuration, the former 2∞ (white) is transferred to the little finger and the former 1∞ (orange) is rotated 180° clockwise and returns to the thumb. Similar “lacings” on the left hand lead to the mirror image of the previous complex crossing as shown in picture 194.


195a


195b



195c


195d

Since the latter double insertion (or “lacing”) of the two loops 2∞ and 1∞, one through the other, can be theoretically done simultaneously (even though it is not the case in practice), brackets are used in the notation. These simultaneous passages and transfers is thus noted:

$$\left\{ \begin{array}{l} \overleftarrow{2\infty} \downarrow (1\infty) : \underleftarrow{2\infty} \longrightarrow 5 \\ \underrightarrow{1\infty} \uparrow (2\infty) : < \overrightarrow{1\infty} \longrightarrow 1 \end{array} \right\}^{c} :$$

9.3.2.2 After Opening A

The set of the 14 *tukumbu* which begin by Opening A can be divided into two subgroups.

– **The *Supua* Subgroup**: After Opening A, the four string figures 18.*Porton*, 19.*Supua*, 32.*Re*, and 11.*Paloma Raity* continue by transferring the index loops to the wrists and thus share the same second normal position.[35] Notice that this normal position also occurs within 26.*Vivi* and 41.*Lilu* of the Trobriands corpus.
– **The *Samuù* Subgroup**: 27.*Estrella* (analysed in Chap. 6) and 25.*Samuù* begin in the same way until reaching the third normal position.[36]

9.3.2.3 After Opening P_1: The Pala Subgroup

There are two *tukumbu* that start with Opening P_1: 8.*Guitarra* and 38.*Pala*. These two procedures too have in common sub-procedures $SP(chaco, 2, pala)$ and $SP(chaco, 3, pala)$, leading to the second and the third normal positions. $SP(chaco, 3, pala)$ is of fundamental importance, for comparison purposes between the Trobriands and Chaco corpora. More precisely, the heart-sequence of this sub-procedure is based on loop movements that often occur within the Chaco corpus, whereas these movements are rarely involved within the Trobriands corpus.

9.3.2.3.1 Description of $SP(chaco, 3, pala)$

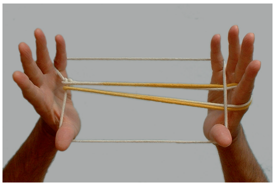
From the second normal position (picture 196a), the three following steps lead to the third normal position[37]:

Step 7: Transfer both $R2$ dorsal loops to $L2$ (pictures 196b and 196c).
Step 8: Distally, insert $R2$ and $R3$ into $L2$ loops, pick up strings $L5n$ and $L1f$ respectively and return to position. Release the left hand (pictures 196d and 196e).
Step 9: Transfer $R2$ and $R3$ loops to $L1$ and $L5$ respectively. Extend (pictures 196f–196h).

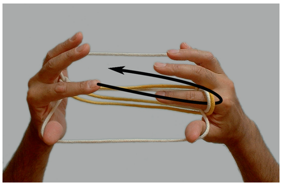
[35] See also this sub-procedure in the accompanying website (*Tukumbu* corpus/Opening A/The *Supua* subgroup).

[36] See these sub-procedures in the accompanying website (*Tukumbu* corpus/Opening A/The *Samuù* subgroup).

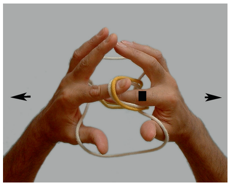
[37] These three steps correspond to Steps 7–9 of procedure 38.*Pala*: see the accompanying website (*Tukumbu* corpus).



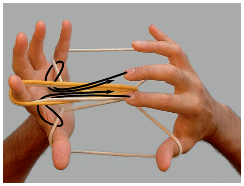
196a – Second normal position



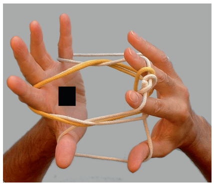
196b



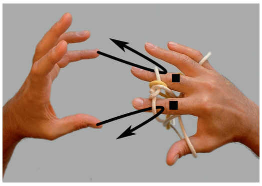
196c



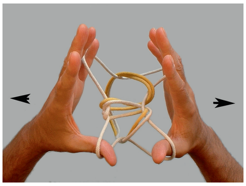
196d



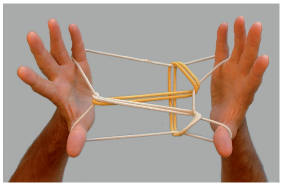
196e



196f



196g



196h – Third normal position

9.3.2.3.2 Heart-Sequence of $SP(chaco, 3, pala)$

To indicate the movement of a loop from one hand to the other, Storer introduced the use of a double arrow (Storer 1988, p. 27). The above Step 7 can thus be encoded: $\overset{\Leftarrow}{R2}\infty \longrightarrow L2$. The double arrow thus indicates the movement of $R2\infty$ from the right to left hand.

Steps 8 and 9 taken together entail the insertion of left little finger loop $L5\infty$ and thumb loop $L1\infty$, from below, through left double index loop $L2\infty$, before returning to their initial positions (pictures 196d and 196e). This can then be coded:

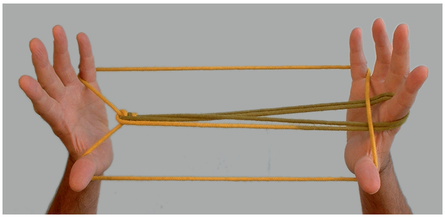
$$\left\{ \begin{array}{l} \underleftarrow{L5\infty} \uparrow (L2\infty) \\ \underrightarrow{L1\infty} \uparrow (L2\infty) \end{array} \right\} .$$

Notice that no transfer is mentioned in the above formula after insertions $\underleftarrow{L5\infty} \uparrow (L2\infty)$ and $\underrightarrow{L1\infty} \uparrow (L2\infty)$. Remember that it means that $L5\infty$ and $L1\infty$ return to their original fingers. The heart-sequence of $SP(chaco, 3, pala)$ is then given by

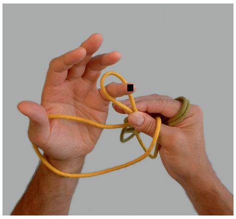
$$\overset{\Leftarrow}{R2}\infty \longrightarrow L2 : \left\{ \begin{array}{l} \underleftarrow{L5\infty} \uparrow (L2\infty) \\ \underrightarrow{L1\infty} \uparrow (L2\infty) \end{array} \right\} .$$

This heart-sequence can be rewritten in deleting transfer $\overset{\Leftarrow}{R2\infty} \longrightarrow L2$ of Step 7. The goal of this transfer is actually to facilitate the insertions of loops $L5\infty$ and $L1\infty$ into original loop $R2\infty$. However, this operation can be done without transferring $R2\infty$ to $L2$ as illustrated in the following. From the second normal position (picture 197a), one can remove $L5\infty$, using the right index and thumb as indicated in pictures 197a and 197b.

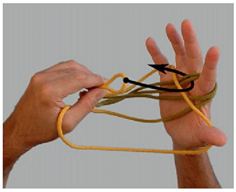
Then, the left index and thumb grab the former loop $L5\infty$, pass it distal to the right palmar string and insert it from above (distally) into $R2\infty$. Finally, the former $L5\infty$ returns to its original finger $L5$ (pictures 197c–197e). This can be encoded: $\overset{\Rightarrow}{L5\infty}(Rp): \overset{\Rightarrow}{L5\infty} \downarrow (R2\infty)$.



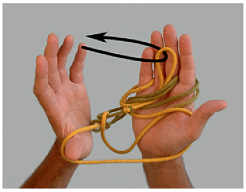
197a



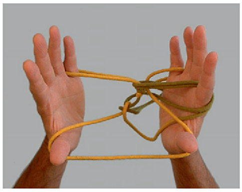
197b



197c

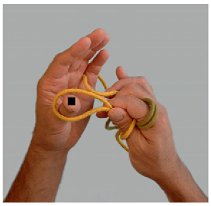


197d

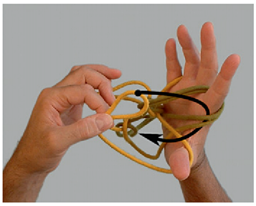


197e

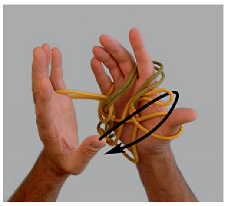
A similar insertion can be done with the loop $L1\infty$ (pictures 197f–197h).



197f

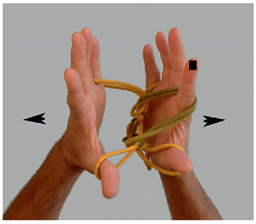


197g

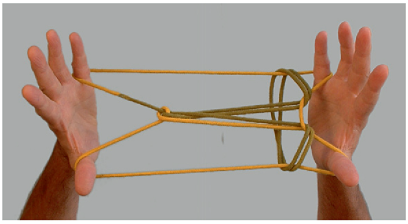


197h

Finally, $R2$ is released and the string extended (pictures 197i and 197j).



197i



197j

The heart-sequence of $SP(chaco, 3, pala)$, written above, is equivalent to the following sequence:

$$\left\{\begin{array}{l} L\overset{\Rightarrow}{5}\infty(Rp) : L\overset{\Rightarrow}{5}\infty \downarrow (R2\infty) \\ L\overset{\Rightarrow}{1}\infty(Rp) : L\overset{\Rightarrow}{1}\infty \downarrow (R2\infty) \end{array}\right\} : \square R2 \mid .$$

$SP(chaco, 3, pala)$ can therefore be seen as a sub-procedure which allows to pass simultaneously two "loops of one hand through a loop of the opposite hand".

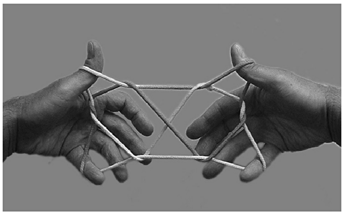
9.3.3 Comparison

The above description and analysis of the passages from the first to the second normal position—and sometimes from the second to the third normal position—applies to 46.5 % of the string figure algorithms I collected in the Trobriand Islands, and 40 % of those I learnt in the Chaco. This brings to light that an important part of the procedures in both corpora seems to be the result of investigations that involved normal positions and passages. For the passages which follow either Opening A in the Trobriands, or Opening N in the Chaco, we have seen that these investigations probably occurred in a systematic manner. These first outcomes has brought to light that certain practitioners have carried out systematic explorations, attempting to saturate a "logical space".

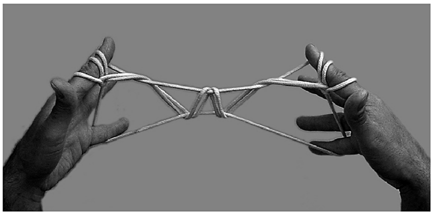
Among the numerous sub-procedures mentioned in the previous sections, only one occurs in both corpora. It is a simple sub-procedure noted $SP(trob, 2, vivi)$ or $SP(chaco, 2, supua)$, which consists in transferring the index loops to the wrists. The various passages from the first to the second normal position (as well as the openings) differentiate the two corpora. Nevertheless, although they differ from one another—i.e. they do not implement the same sequence of elementary operations—the passages which occur immediately after Opening A ($SP(trob, 2, misima)$, $SP(trob, 2, mweya)$, $SP(trob, 2, tubum)$, $SP(trob, 2, vivi)$, $SP(trob, 3, salibu)$ and $SP(chaco, 2, samuù)$, $SP(chaco, 2, supua)$) are based on the same combinatorics of insertions of a loop into another, both loops carried by fingers on the same hand.

The situation is quite different for the passages made after openings M and N ($SP(trob, 2, tobutu\ topola)$, $SP(trob, 2, kuluwawaya)$, $SP(trob, 3, kuluwawaya)$ and $SP(chaco, 2, sanja)$). First, the idea of combining Opening M with Opening

A, as it is done in $SP(trob, 2, tobutu\ topola)$, does not occur in the Chaco corpus. Secondly, although both $SP(trob, 2, kuluwawaya)$ and $SP(chaco, 2, sanja)$ aim to make an intermediate figure (pictures 198a and 198b), their heart-sequences are definitely different. Indeed, each of these two heart-sequences is characterized by a specific manner of "lacing" the loops. $SP(chaco, 2, sanja)$ is based on simultaneous "lacing" of two loops, one through the other,[38] whereas $SP(trob, 2, kuluwawaya)$ results from simple insertions of a loop into another—in this case, however, without fully completing those insertions, and keeping them onto their original finger.[39]



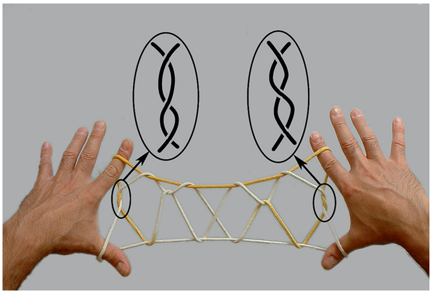
198a – $SP(chaco, 2, sanja)$



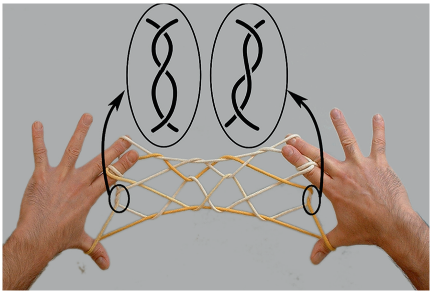
198b – $SP(trob, 2, kuluwawaya)$

9.3.3.1 Complex Crossings

The complex crossing obtained under $SP(chaco, 2, sanja)$ also occurs in the final figure of 1.*Estrellas* and 19.*Supua* of the Chaco corpus (pictures 199a and 199b). It can be seen that, although the sequence of elementary operations involved in *Supua* for the creation of this complex crossing is not the same as in $SP(chaco, 2, sanja)$, it is definitely the same principle of "lacing" two loops, one through the other, which underlies all of these sub-procedures.



199a – Supua



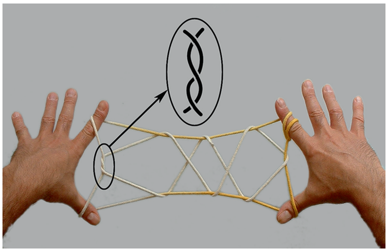
199b – Estrellas

The making of the latter complex crossing rarely occurs in the Trobriands corpus. However, it can be found as part of the final figures of 1.*Meta* and 22.*Kemagu*, implementing once again the same principle. The occurrence of this complex

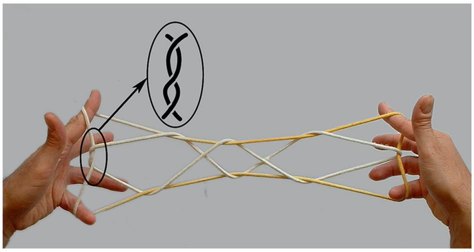
[38] See Sect. 9.3.2.1 (After Opening N: the *Sanja* subgroup).

[39] See the sub-procedure the accompanying website (*Kaninikula* corpus/Opening M/The *Kuluwawaya* subgroup).

crossing thus differentiate the two corpora. Furthermore, we will see later on that the various sub-procedures for implementing it can make difference very clear from one corpus to the other.[40]



200a – Meta



200b – Kemagu

9.3.3.2 Different Viewpoints on String Figure-Making?

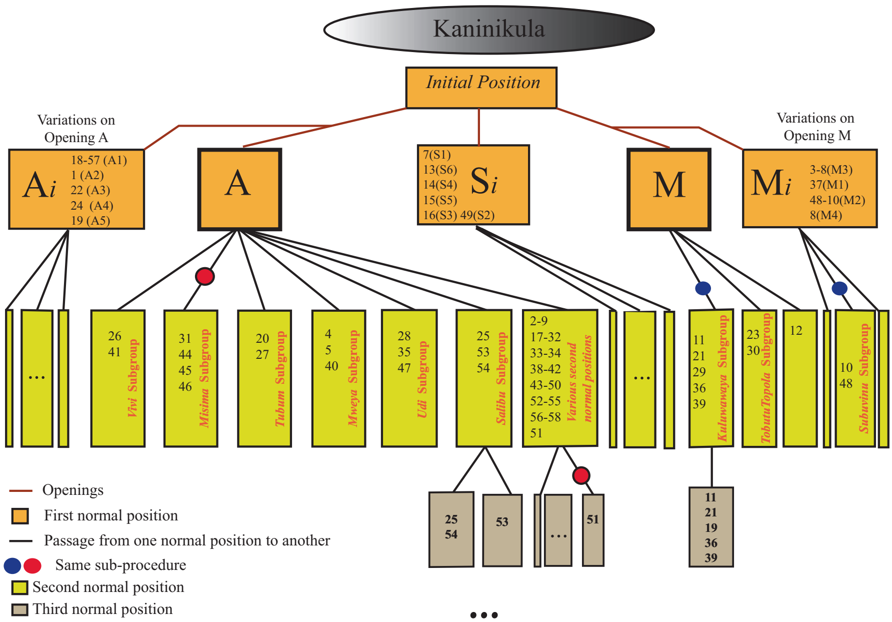
It has been demonstrated that sub-procedure $SP(chaco, 3, pala)$, which occurs just after the Opening P_1 in both procedures 38.*Pala* and 8.*Guitarra* is based on the insertion of a loop created on one hand, through an opposite loop carried by the other hand. This principle is frequent in the Chaco corpus, whereas it has a very low occurrence in the Trobriands, where it is implemented only in the short sub-procedure "Exchanging two loops". The previous analysis of the heart-sequence of $SP(chaco, 3, pala)$ brings to light that the Guarani-Ñandeva practitioners, when creating certain string figure algorithms, probably looked at the configuration of loops in a way that I define as "right to left or left to right" (*Right* $\longleftrightarrow$ *Left*) instead of "towards you—away from you, or away from you—towards you" (*Towards You* $\longleftrightarrow$ *Away From You*). The principle *Towards You* $\longleftrightarrow$ *Away From You* can be found in almost every *kaninikula* of the Trobriand Islands, and also in many *tukumbu* of the Chaco, whereas the principle *Right* $\longleftrightarrow$ *Left*, which occurs frequently in the Chaco but rarely in the Trobriands, draws a clear distinction between the two corpora.

9.3.3.3 Summary: Tree Diagrams

The analysis of the Trobriands and Chaco corpora, through the conceptual tools opening, passage (sub-procedure) and normal position, has allowed us to classify these string figure procedures. This outcome can be summarized in the tree diagrams below (pictures 201a and 201b). The first stage (orange) represents the various configurations (first normal positions) obtained from an initial position under the various openings. The second stage (green) represents the second normal positions. The red and black branches drawn between rectangles represent the

[40] See Sect. 9.4.6 below (Different methods to make the same complex crossing).

openings and the passages respectively. The numbers written in the boxes indicate the corresponding string figure algorithms. These two diagrams give us a quick access to the system of transformation at work in both corpora.

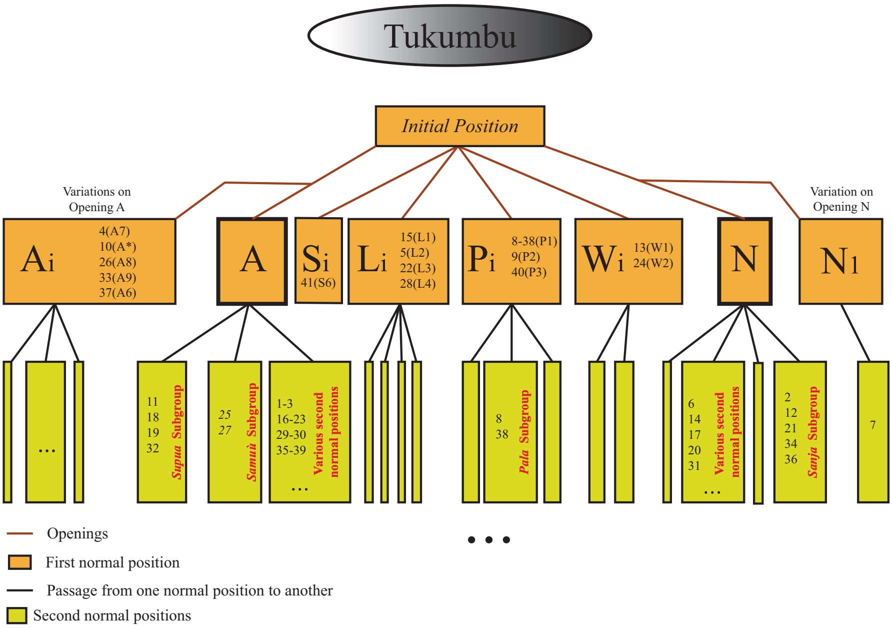


201a – Tree diagram—Trobriands corpus

In the Trobriand Islands, I have enlarged my ethnographical research beyond Oluvilei to other villages in the island of Kiriwina and nearby islets. The first outcomes of this research show that the tree diagram above will grow in a significant way as I learn new procedures, throwing some new light on the creation of Trobriander string figure procedures, and their underlying system of transformation. Throughout the archipelago, I collected 23 string figures that were unknown to my informants in Oluvilei. For the moment, I have learnt a total of 85 procedures in these islands, and there is evidence that there are more,[41] probably many more. Four string figures collected outside Oluvilei suggest that Trobriander practitioners or creators might have worked out continuations of certain *kaninikula*. More precisely, I have collected a continuation of 47.*Udi* and 2.*Tobasi* (at Wawela)—of 3.*Dauta* (at Kaibola)—of 54.*Salibu* (at Vakuta). Therefore, the inclusion of these continuations in the corpus should add several stages to the tree diagram. For instance, procedure 54.*Salibu* can be seen as the result of five passages (including the opening), and then, passing through five normal positions. Therefore, the inclusion into the corpus of

[41] See the example of *Kaukwa* in Sect. 8.5.3.

the continuation of *Salibu*, called *Mwaya tomdawaya*[42] in Vakuta, would add a subgroup of two string figures (*Salibu* and its continuation) at the fifth stage of the tree.



201b – Tree diagram—Chaco corpus

9.3.3.4 Variations on Passages

Until now, may it be in the Trobriand Islands or in the Chaco, I have not found any string figure procedures which, having the initial position and the first and second normal position in common, are connected under "different" passages i.e. passages implemented with different elementary operations and/or with non-equivalent heart-sequences. This is pointed out in the diagrams above by the single branch drawn between two boxes.

In the Trobriands, the case of the *Kuluwawaya* and *Subuvinu* subgroups show that sometimes the same passage can be found between different positions: as indicated in the diagram above, it is the same passage which allows to pass from $Conf(\underline{O}.M)$ to the second normal position of *Kuluwawaya* then from $Conf(\underline{O}.M_2)$ to the second normal position of *Subuvinu*. Moreover, the case of the *Misima* subgroup and procedure 51.*Kapwatala kapwatawaku* ("Various second normal positions" subgroup) shows that the same passage can be found at different stages of the tree:

[42] See procedure 59.*Mwaya tomdawaya* in the accompanying website (*Kaninikula* corpus).

it is the same sub-procedure which is carried out from Opening A to the second normal position of *Misima* and from the second normal position to the third within procedure 51.*Kapwatala kapwatawaku*.

As seen earlier, procedures 24.*Guyau-Bolu-Guyavila* and 54.*Salibu* (or 25.*Sem*) provide two different ways to obtain configuration $Conf(B)$.[43] More precisely, we have seen that Opening A_4 within 24.*Guyau-Bolu-Guyavila* leads to a configuration which differs from $Conf(B)$ in transfer $\overrightarrow{1\infty} \longrightarrow 2$ only. Therefore, Opening A_4 can be seen as a "short-cut" of the sequence *Opening A*:$SP(trob, 2, salibu)$: $SP(trob, 3, salibu)$, to implement an equivalent heart-sequence through a different fingering.

In the Trobriands, I have not found other variations on passages yet. However, the example of 24.*Guyau-Bolu-Guyavila* and 54.*Salibu* leads me to believe that I would certainly find many other variations of this type by enlarging the investigation to nearby areas. I have already noted some interesting variations on passages, comparing Trobriander string figure procedures to those from other Oceanian regions (the Marquesas and Vanuatu). For instance, remember that Marquesan practitioners know a procedure called *Au kape*[44] similar to the Trobriander procedure 54.*Salibu*. These two procedures become identical after reaching the third normal position $Conf(B)$, but they differ before getting to this stage. They both start with Opening A and share the same second normal position, the second passage and the third normal position ($Conf(B)$). However, the third passage is not implemented in the same way.

It can be seen that the aim of passages $SP(trob, 3, salibu)$ and $SP(marquesas, 3, au\ kape)$ is the same in both cases: creating distal loops on the indices by operating on the string $5f$.[45] However, the elementary operations involved are quite different and passage $SP(marquesas, 3, au\ kape)$ can be seen as a "shortcut" of $SP(trob, 3, salibu)$. This example suggests once again that the variations on passages would mostly concern the fingerings rather than the heart-sequences.

The above classification of string figure algorithms has been carried out through the analysis of the various openings, passages and normal positions. There are actually many other ways to detect similarities between string figure procedures. Sometimes, two string figure algorithms have a sub-procedure in common, which is neither an opening nor a passage. Although different, two procedures can lead to the same final figure or they can share one intermediate figure. They can also differ in a few elementary operations. To conclude this book, we will concentrate on such connections, bringing to light some fundamental phenomena that often occur within string figure corpora. Returning to the epistemological issue of determining whether or not the creation of string figures is mathematical, the following analysis will give evidence of the intellectual processes involved in creating these procedures,

[43] See above Sect. 9.2.1.2 (Variations on Opening A—Opening A_4).

[44] See Sect. 6.4.1 (The beginning of *Na Tifai*).

[45] See above Sect. 9.2.1.3.

as they occurred in the Chaco and the Trobriand Islands, such as "iterating" a sub-procedure, "altering" a procedure, or searching different "paths" to obtain similar figures, motifs or complex crossings.

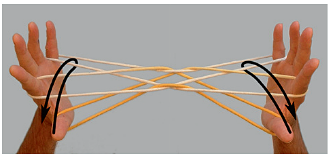
9.4 The Mathematical Activity of Creating String Figures

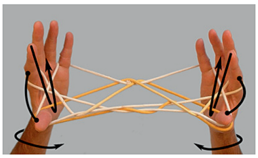
9.4.1 Iterative Sub-procedures

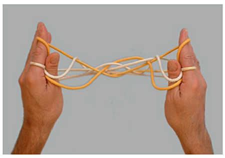
We have given an exhaustive description of openings and sub-procedures which occur as a passage. However, in both corpora, there are many other sub-procedures. Some of them are of fundamental importance since they are based on the principle of "iteration". With the example of Papuan string figure "Family sickness"[46] described in Chap. 3, we have seen that, in certain cases, the effect of an iterative sub-procedure is to iterate the same geometrical pattern.

9.4.1.1 Iteration to Add a Pattern to the Final Configuration

There are many examples of such iterative sub-procedures within the Oluvilei corpus. For instance, this phenomenon can be found within string figure procedures 43.*Ilowosi*, 14.*Dogadoga* and 49.*Toliu*, in which the same sub-procedure is iterated. Let us briefly describe this iteration process within procedure *Ilowosi*. As shown below, the aim of this iteration is to add, at each stage, a pair of lozenges in a row. However, unlike Papuan string figure "Family sickness", the lozenges are not displayed during the process, but only at the end in the final extension. This iterative sub-procedure starts with operation "picking up", immediately followed by the short sub-procedure *kwatuponiniya* (Caroline extension—pictures 202a–202c).

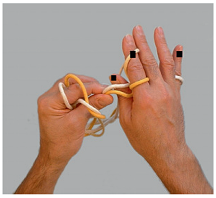

202a – 1 pick up 5*n* and return

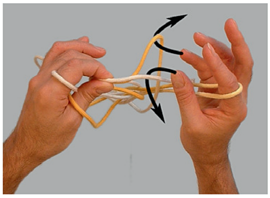

202b – kwatuponiniya

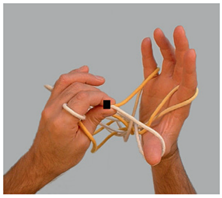

202c

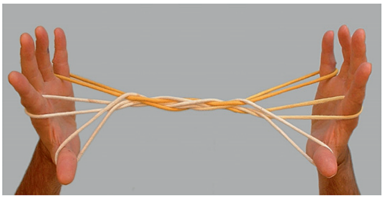
Then, the short sub-procedure *sosewa* is applied on both hands, one after the other (pictures 202d–202f).

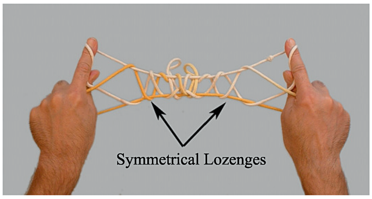
[46] See Sect. 3.4.4 (Transformation through iteration).


202d – sosewa (right hand)


202e


202f – sosewa (done)

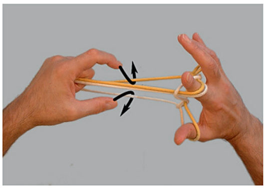

202g

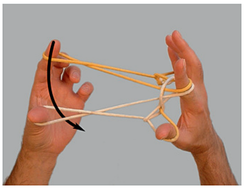


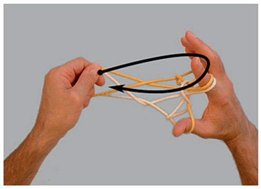
202h – Ilowosi

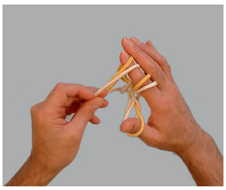
Finally, we obtain the configuration shown in picture 202g, from which the same sub-procedure is iterated twice. This iterative process leads to the figure shown in picture 202h. In this figure, one can see, on both side of a central motif, three symmetrical pairs of “lozenges” resulting from the iteration.

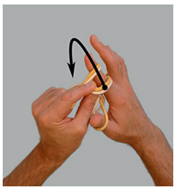
In the Chaco corpus, there is only one string figure algorithm which is based on the iteration of a sub-procedure, aiming to add the same pattern at each stage: procedure 22.*Hueso de iguana*. However, this iterative sub-procedure is quite different from the one that is implemented in *Ilowosi*: the movements of the hands are not symmetrical. It is the left hand which operates, weaving the strings on the right hand side, as shown in pictures 203a–203f.

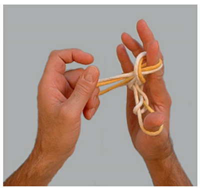

203a


203b

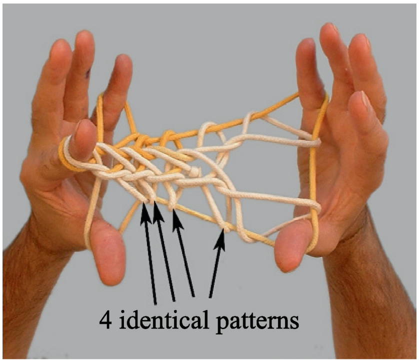

203c


203d


203e – Navaho


203f

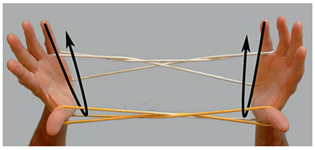
This sub-procedure is iterated about five times. We thus obtain the final figure "Hueso de Iguana"[47] (picture 203g).



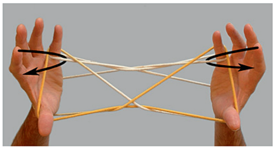
203g – Hueso de iguana

9.4.1.2 Iterating a Sub-procedure a Certain Number of Times

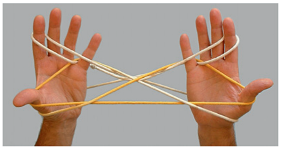
The type of iterative sub-procedures described in the previous section can be theoretically iterated as many times as the length of the string allows it (cf. "Hueso de Iguana" above). However, it is not necessarily always the case. Some iterative sub-procedures must be repeated an exact number of times, otherwise no "interesting" figure can be displayed. For instance, it happens in Trobriander procedure 26.*Vivi*, which starts with Opening A. The loops on the indices are then transferred to the wrists, under the short sub-procedure $SP(trob, 2, vivi)$. From this stage, a sub-procedure, say V, is iterated. V consists in the two elementary operations "picking up" and "hooking up" immediately followed by the short sub-procedure *Sosewa* (pictures 204a–204g).



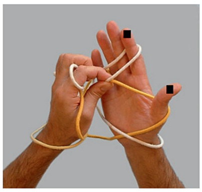
204a – 5 pick up $1f$



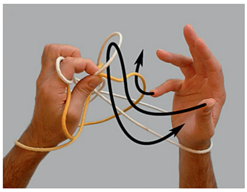
204b – 2 hook up proximal $5n$



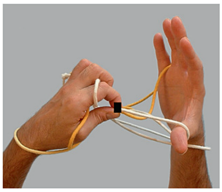
204c



204d – $L1$ and $L2$ grab $R1f$ and $R2n$. Release $R1$ and $R2$

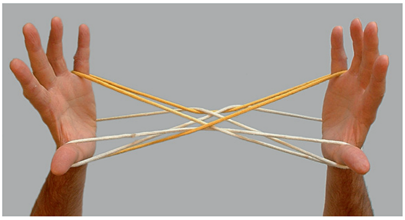


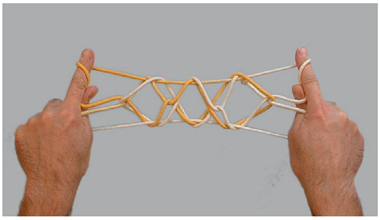
204e – sosewa



204f

[47] See procedure 22.Hueso de Iguana in the accompanying website (*Tukumbu* corpus).


204g – After "sosewa" on both hands


204h – Vivi

Sub-procedure V is repeated exactly three times: two or four times do not bring out a configuration which can be displayed under the "Caroline extension". Three double-sided lozenges result from this iteration, as shown in picture 204h. This phenomenon is frequently found within the Trobriands corpus, whereas I have noticed this kind of iterative sub-procedure only once in the Chaco corpus. It is within procedure 8.*Guitarra* that sub-procedure $SP(chaco, 3, pala)$ (described in Sect. 9.3.2.3) is iterated twice.[48]

22.*Hueso de iguana* and 8.*Guitarra* are the only two procedures of the Chaco corpus in which the principle of iteration is involved, whereas this principle is omnipresent in the Trobriands corpus. We therefore see that the presence, or absence, of iterative sub-procedures is a distinguishing feature between different corpora of string figures. Before returning to this fundamental point, let us study other forms that the principle of iteration can take within the Trobriander string figures corpora.

9.4.1.3 Iterating Twice a Long Process

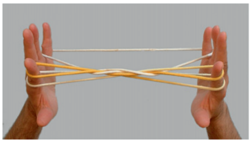
The iteration of a sub-procedure does not necessarily aim to add successively some identical geometrical patterns. We have already seen the example of 54.*Salibu* (as "Ten Men") in Chap. 3. Trobriander string figure procedure 31.*Totuwana kala niya kuliyava* is another very interesting example of this kind.[49] In this case, the iterative sub-procedure is a long process, passing through several intermediate figures. It starts with Opening A. Then, the sub-procedure already described as $SP(trob, 2, misima)$ allows to reach the second normal position. From this position, a long sub-procedure X is applied, leading to a first intermediate figure F_1. Then, a short sub-procedure Y leads to a second intermediate figure F_2 (diagrams below).

Let us note T the sub-procedure obtained in putting $SP(trob, 2, misima)$, X and Y together. It is this long sequence T which is iterated, but this time, starting from a "substratum" a bit different from *Conf*($\underline{O}.A$). To obtain this substratum,

[48] See procedure 8.*Guitarra* in the accompanying website (*Tukumbu* Corpus).

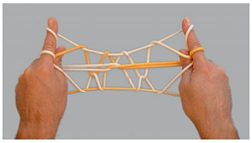
[49] See procedure 31.*Totuwana kala niya kuliyava* in the accompanying website (*Kaninikula* Corpus).

figure F_2 is laid out and grasped by both hands as indicated in pictures 205d–205g. Working in this way, we obtain the configuration *Conf*($\underline{O}.A^*$) which differs from *Conf*($\underline{O}.A$) in a single crossing (picture 205g).

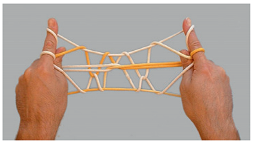


205a – O.A: SP(trob,2,misima)

$\xrightarrow{X}$

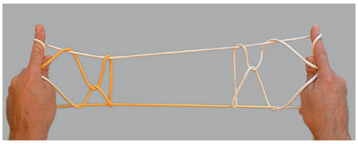


205b – First intermediate figure F_1

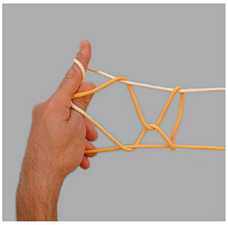


First intermediate figure F_1

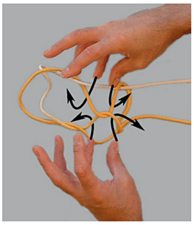
$\xrightarrow{Y}$



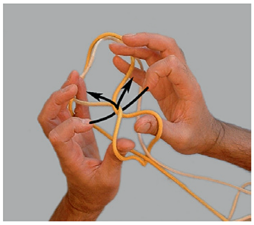
205c – Second intermediate figure F_2



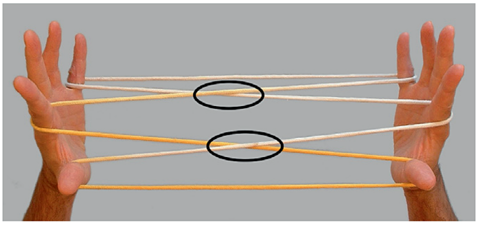
205d



205e

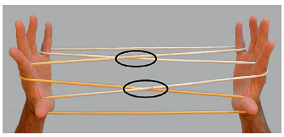


205f



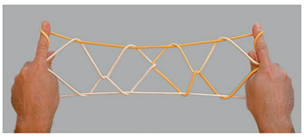
205g – $Conf(\underline{O}.A^*)$

From this stage, the iteration of a sub-procedure T leads to the third intermediate figure F_3 almost identical to F_1. To get the final figure, F_3 is then transformed under the same process than from F_1 to F_2 (diagram below):



$Conf(\underline{O}.A^*)$

$\xrightarrow{T}$

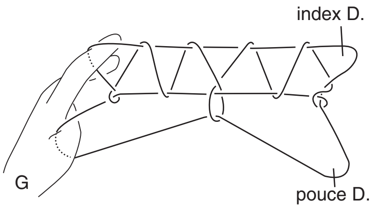


205h – Final figure

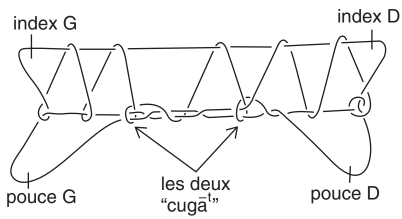
The same principle of iterating a long procedure is applied in the Trobriander procedure 44.*Misima*,[50] whereas it does not occur within the Chaco corpus.

9.4.1.4 Iteration: A Distinguishing Feature Between Corpora of String Figures

Apart from the example given above of procedures 8.*Guitarra* and 22.*Hueso de Iguana*, I have not noticed any other iterative sub-procedures in the Chaco corpus, whereas the iteration of a sub-procedure is omnipresent in the Trobriands corpus. This seems to indicate that the principle of iteration should be an efficient conceptual tool to differentiate string figures corpora. I have often found such iterative sub-procedures in the Oceanian corpora—in PNG (Noble 1979), in Solomon (Maude 1978), etc. but also in the corpora I have personally collected in Vanuatu and in the Marquesas. By contrast, I have often noticed the rareness of iterative sub-procedures in the Arctic corpora. For instance, this kind of sub-procedures occurs only once in the corpus collected by Paul-Emile Victor in Ammassalik, Greenland: an iterative sub-procedure is implemented within procedure *Takritsit tsougarartek martini* (The flames of the lamp oil with two loops—picture 206b).



206a – *Takritsit tsougarartek*
(Victor 1940, p. 125)



206b – *Takritsit tsougarartek martini*
(Victor 1940, p. 138)

The procedure is based on the iteration of a sub-procedure that we also find in string figure *Takritsit tsougarartek* (The flames of the lamp oil with one loops—picture 206a). The effect of this sub-procedure is to create a small loop at the centre of the final figure. When iterating a second time, as in *Takritsit tsougarartek martini*, a second small loop is created (Victor 1940, pp. 115–138).

9.4.2 Variations on a String Figure Algorithm

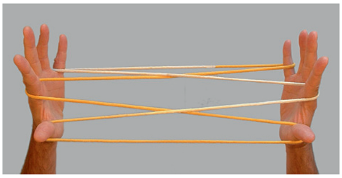
9.4.2.1 Modification of the First Normal Position

String figure algorithms sometimes differ from one another by the addition, after the opening, of a few elementary operations, the effect of which is to modify the first

[50] See the accompanying website (*Kaninikula* Corpus).

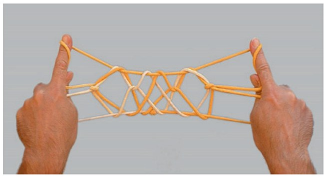
normal position. I found this phenomenon in both corpora. In the Trobriands, for instance, it is the case in 32.*Vivilua*, 33.*Kenabosu* and 34.*Samula kayaula*, which we have already encountered above (Sect. 9.3.1). The procedure 33.*Kenabosu* starts with Opening A. Then, a sub-procedure K is performed until getting the final figure (pictures 207a and 207b).

32.*Vivilua* also starts with Opening A. Then, the indices are twisted once, anticlockwise ($\underline{O}.A : \gg 2\infty$). It is from this new configuration that sub-procedure K is performed (pictures 207c and 207d). Finally, 34.*Samula kayaula* starts with Opening A, and in this case, the indices are twisted twice anticlockwise before performing sub-procedure K (pictures 207e and 207f).

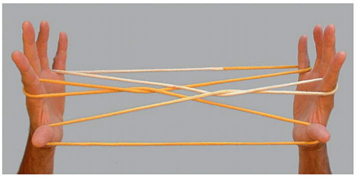


207a – $Conf(\underline{O}.A)$

$\xrightarrow{K}$

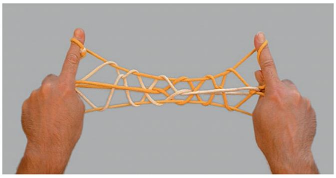


207b – *Kenabosu*

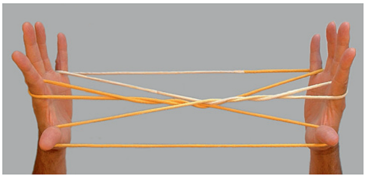


207c – $\underline{O}.A : >> 2\infty)$

$\xrightarrow{K}$

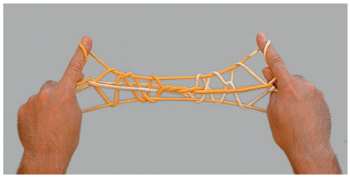


207d – *Vivilua*



207e – $\underline{O}.A : >>>> 2\infty)$

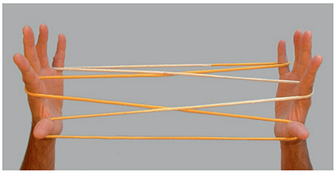
$\xrightarrow{K}$



207f – *Samula kayaula*

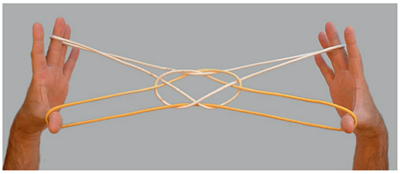
In the Chaco, this phenomenon occurs in procedures 3.*Pata de puma* and 27.*Estrella*. The latter has been already described in Chap. 6, devoted to the comparison of algorithms leading to a double-sided lozenge. It starts with Opening A and continues with a sub-procedure, say H (pictures 208a and 208b). *Pata de puma* also starts with Opening A. Then, the indices are exchanged before applying a sub-procedure H (pictures 208c and 208d).

The same phenomenon can be found in 25.*Samuù* and 26.*Palo Santo*. *Samuù* starts with Opening A, whereas *Palo Santo* starts with the Opening A_8 variation on Opening A. Then, the two procedures end exactly in the same way.[51]

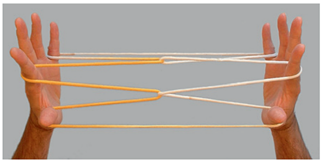


208a – $Conf(\underline{O}.A)$

$\xrightarrow{H}$

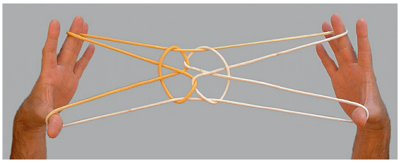


207f – Estrella



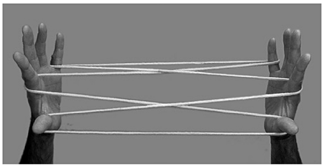
208c – $\underline{O}.A$: Exchange 2 loops

$\xrightarrow{H}$



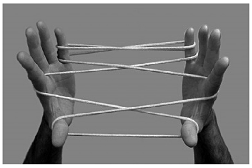
208d – Pata-de-puma

In the Trobriands Corpus, another example of this phenomenon is given by comparing the first part of procedure 31.*Totuwana kala niya kuliyava* (as mentioned in the previous section) with string figure 51.*Kapwatala kapwatawaku*. In the following discussion, I will refer to these procedures simply as *Totuwana* and *Kapwatala*. This example differs slightly from the previous ones. The two procedures do not end in the same manner, however they have a large part of the algorithm in common. Both procedures start with Opening A. In the case of 51.*Kapwatala*, the substratum $Conf(\underline{O}.A)$ is modified (using the teeth[52]), doubling the loops on the little fingers (pictures 209a and 209b).



209a – Opening A

$\longrightarrow$



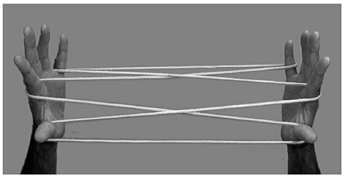
209b – *Kapwatala*—second normal position

Then, the same sub-procedure is performed, starting either from the second normal position in 51.*Kapwatala* or from $Conf(\underline{O}.A)$ in 31.*Totuwana*. This sub-procedure has been already described above and noted $SP(trob, 2, misima)$. It enables to pass from the first to the second normal position in procedure 31.*Totuwana*

[51] See procedures 25.*Samuù* and 26.*Palo santo* in the accompanying website (*Tukumbu* Corpus).

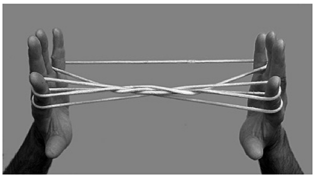
[52] See procedure 51.*Kapwatala kapwatawaku* in the accompanying website (*Kaninikula* Corpus).

(belonging to the *Misima* subgroup), whereas the same sub-procedure is the passage from the second to the third normal position in 51.*Kapwatala*. So formally we have: $SP(trob, 2, totuwana) = SP(trob, 2, misima) = Sp(trob, 3, Kapwatala)$. Let us note X this sub-procedure for the coming description. The passages mentioned above are illustrated in the diagrams below:

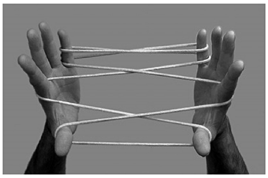


Opening A

$\xrightarrow{X}$

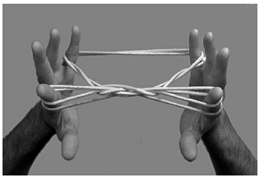


209c – *Totuwana*—second normal position



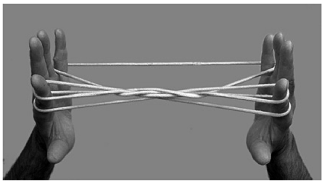
Kapwatala—second normal position

$\xrightarrow{X}$



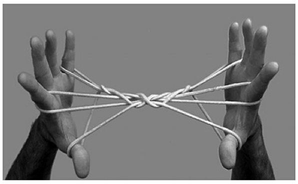
209d – *Kapwatala*—third normal position

From this stage (*Totuwana*—second normal position, *Kapwatala*—third normal position), a common sub-procedure is once again applied to reach the next normal position. Thereafter, the two procedures diverge (see diagrams below).

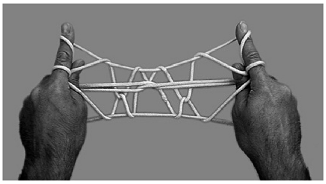


Totuwana—second normal position

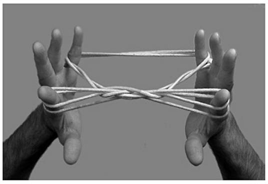
$\xrightarrow{Y}$



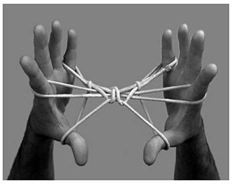
209e – *Totuwana*—third normal position



$\xrightarrow{Z}$ 209f – *Totuwana*—first figure of the series

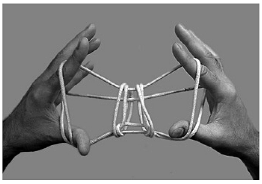


Kapwatala—third normal position $\overset{Y}{\longrightarrow}$



209g – *Kapwatala*—fourth normal position

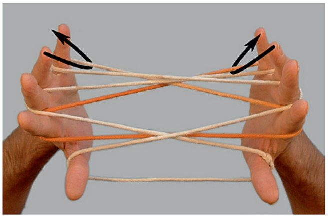
$\overset{Z'}{\longrightarrow}$



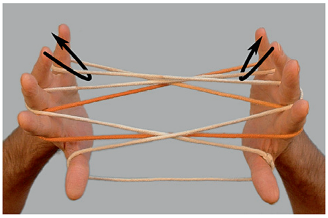
209h – *Kapwatala*—final

9.4.2.2 Modification of a Single Operation Within the Procedure

Sometimes, two string figures differ from one another through one, and only one, elementary operation. This phenomenon occurs several times in the Trobriands corpus. For instance, it is the case in procedures 23.*Tobutu topola* and 30.*Tosalilagelu*. They both start with Opening M. Sub-procedure $SP(trob, 2, tobututopola)$ is then performed, followed by $SP(trob, 3, tobututopola)$. It is on the third normal position that the variation occurs: the transfer of the little finger loops to the middle fingers is made by inserting the middle fingers into the little finger loops 5∞, either from above (*Tobutu topola*) or from below (*Tosalilagelu*) (pictures 210a and 210b).

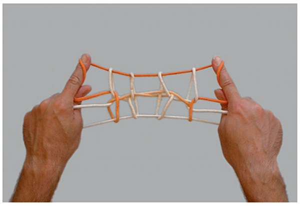


210a – *Tobutu topola*: 3 are inserted, from above, into 5 loops

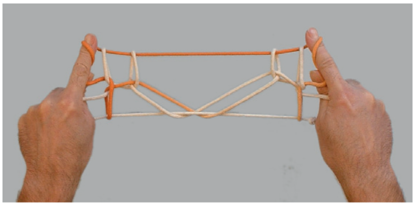


210b – *Tosalilagelu*: 3 are inserted, from below, into 5 loops

In the first case (*Tobutu topola*), the little finger loops are rotated 180° clockwise, and then transferred to the middle fingers ($<5\infty \longrightarrow 3$), whereas in the second case (*Tosalilagelu*), the transfer actually occurs without any rotation ($5\infty \longrightarrow 3$). From this stage, the same sequence is applied. The modification of one elementary operation causes an interesting alteration of the final figure (pictures 210c and 210d).



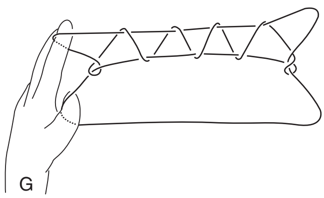
210c – *Tobutu topola*



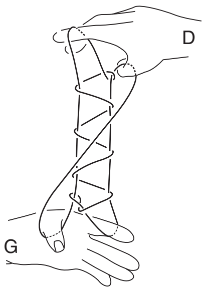
210d – *Tosalilagelu*

In the two cases above—modification of the second normal position and modification of a single elementary operation—the concept of transformation comes into play at two different levels. On one hand, there is a transformation of the procedure, on the other hand, a transformation of the final figure occurs. Of course, these two types of transformation are intimately connected: the alteration of one stage of the procedure entails the transformation of the final figure. Is this alteration the result of a conscious exploration of the procedures? Or is it the result of an inadvertent error which would have been memorized by the practitioners, since it was causing a noticeable transformation of the final figure? At this stage, it is hard to tell. Nevertheless, even though we do not know how this alteration occurred, the fact remains that the phenomenon has been noticed and memorized by practitioners.

I have not found such alteration of a single operation in the Chaco corpus. By contrast, I have found it very often in the ethnographical literature about the Arctic string figures. For instance, such is the case of string figures *takritsit* (the flames of the oil lamp) (Victor 1940, pp. 105–114) and *takritsit tsougarartek* (the twisted flames of the oil lamp) (Victor 1940, pp. 148–158), described by P. E. Victor.



211a – *Takritsit* (Victor 1940, p. 114)



211b – *Takritsit tsougarartek* (Victor 1940, p. 158)

Procedure *takritsit* is described in a few other studies of string figure-making in the Arctic,[53] whereas, to my knowledge, there is no trace of figure *takritsit tsougarartek* elsewhere than in East Greenland. We may therefore think that this figure has been created in this region through the transformation of procedure

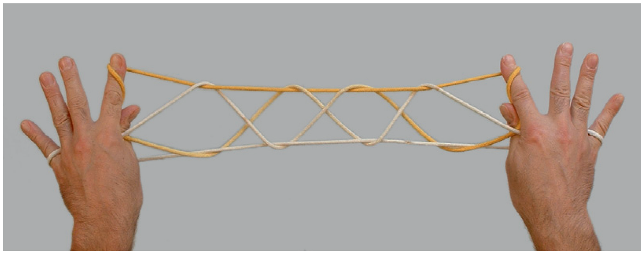
[53] Jenness (1924), Mary-Rousseliere (1969) and Paterson (1949).

takritsit.[54] The alteration of one and only one elementary operation entails the twist of the former final figure (pictures 211a and 211b). Furthermore, the name given to the resulting procedure certainly reflects the intention of transforming the figure *takritsit*, or, at least, the memorization of the fact that a noticeable modification of this string figure occurs under this alteration.

9.4.3 Different Paths to Get the Same Pattern

9.4.3.1 Obtaining Exactly the Same Final Figure

Although the sequence of elementary operations involved within Trobriander procedures 47.*Udi* and 42.*Nebogi* are significantly different from one another, both these procedures conclude with exactly the same final figure (crossings included). Moreover, it is obvious that their heart-sequences too are definitely different.



212 – Final figure of *Udi* and *Nebogi*

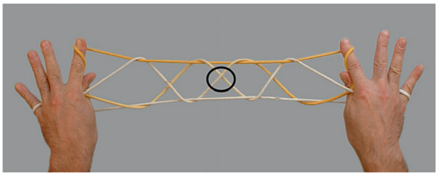
To my knowledge, this phenomenon is quite rare in the various Oceanian corpora. Moreover, there is nothing as such in the Chaco corpus. By contrast, the idea of creating different "paths" to reach the same final figure appears quite frequently in the Arctic corpora. An interesting example is given in the Ammassalik corpus documented by Victor. Each of the final figures of procedures *natsit* (cache sexe), *kattizit* (unknown meaning), and *nikkèt* (the loops) (Victor 1940, pp. 72–87, 88–104, 56–71), can be obtained through two different procedures. Moreover, the words *piaginni* (the shorter) and *piadinni* (the longer) are used to point out that one of the two procedures is longer than the other. For instance, the figure named *nikkèt* (loops) is the common final figure of both procedures *nikkèt piaginni* and *nikkèt piadinni* (Victor 1940, pp. 56–61, 62–71).[55]

[54] See the accompanying website (Arctic).

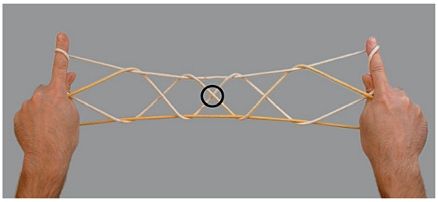
[55] See the accompanying website (Arctic).

9.4.4 Getting the Same "Motif"

The four lozenges in a row displayed through both procedures 47.*Udi* and 42.*Nebogi* is also the "motif" of 8.*Kalatu gebi navalulu*'s final figure. However, the final figures differ in one, and only one, simple crossing (pictures 213a and 213b).

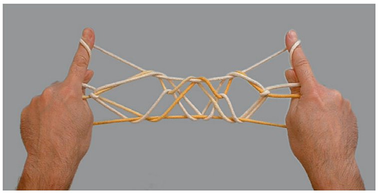


213a – *Udi*

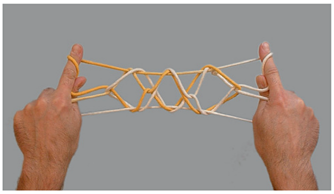


213b – *Kalatu gebi navalulu*

This observation led me to hypothesize that Trobriander practitioners might have imagined several procedures to reach the same "motif", without necessarily seeking to obtain exactly the same final figures. This phenomenon can also be observed in the final figures of 36.*Vivi* and 33.*Kenabosu*. These procedures end on a final figure which shows "three double sided lozenges in a row". However, the two final figures differ in many crossings (pictures 213c and 213d).



213c – *Kenabosu*



213d – *Vivi*

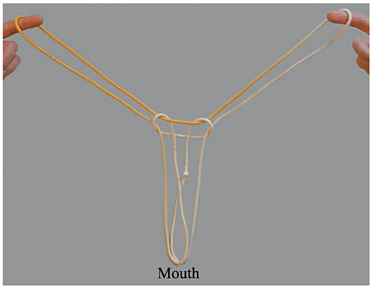
The same phenomenon appears only once in the Chaco corpus. Procedures 16.*Jasytata* and 27.*Estrella* both lead to a double-sided lozenge "motif".[56] Once again, the procedures are definitely different, but the "motif" is the same—although the final figures are not exactly the same (crossings included).

The idea of determining different paths to reach the same or similar figures can be found in many corpora of string figures. However, the intention does not always seem to be the same. In Ammassalik, practitioners clearly tried to get exactly the same final figure by two distinct paths, whereas in the Trobriands and in the Chaco, it appears to be the "motif" more than the exact final figure which was taken into account. This crucial observation allows us to hypothesize that the "geometry" of final figures might not be perceived in the same way among all societies.

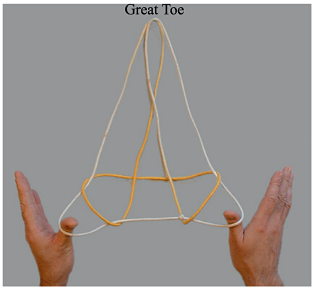
[56] See Sect. 6.2.

9.4.5 Obtaining Same Intermediate Figures

Sometimes, it is one intermediate figure (or normal position) which is reached through distinct paths. There are only two examples of such procedures in the Trobriands corpus: 40.*Mweya* and 50.*Tadoyai* have a same third normal position in common (pictures 214a and 214b). However the passages from the opening (Opening A in both cases) to the third normal position are definitely different.[57]

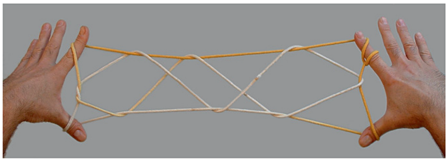


214a – Third normal position of *Mweya*

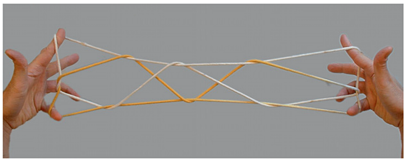


214b – Third normal position of *Tadoyai*

The "motif" (three lozenges in a row) of 1.*Meta*'s final figure is also reached, as an intermediate figure called *Esuma*, in procedure 22.*Kemagu* (pictures 214c and 214d). More precisely, *Esuma* can be obtained by reversing the mirror image of the final figure of *Meta*: formally, $S \circ R_1(Meta) = Esuma$.



214c – Final figure of *Meta*



214d – *Esuma*: First intermediate figure of *Kemagu*

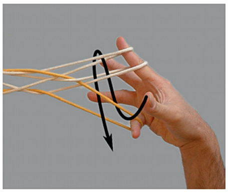
9.4.6 Different Methods to Make the Same Complex Crossing

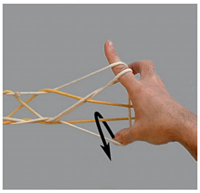
As mentioned earlier in this chapter, $SP(chaco, 2, sanja)$, 1.*Estrellas*, 19.*Supua* of the Chaco corpus and 1.*Meta*, 22.*Kemagu* in the Trobriands corpus all implement the same principle—i.e. simultaneous "lacing" of two loops, one through the other—by different sequences of elementary operations. This phenomenon can be analysed as similar heart-sequences implemented with various different fingerings.

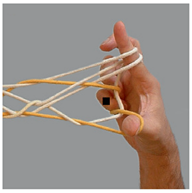
– As seen above, in sub-procedure $SP(chaco, 2, sanja)$, it is the sequence "Hooking down - Picking up - Releasing" which entails the complex-crossing in question (see above, Sect. 9.3.2, pictures 193a–193g).

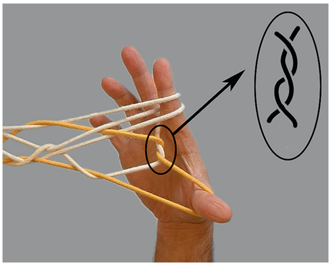
[57] See procedures 40.*Mweya* and 50.*Tadoyai* in the accompanying website (*Kaninikula* Corpus).

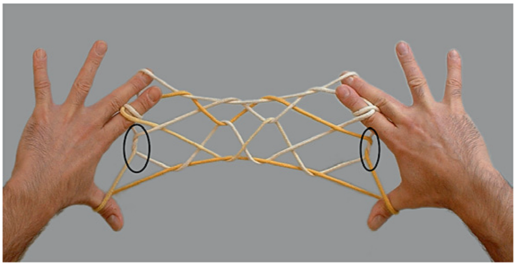
– In 1.*Estrellas* it is under the sequence "Inserting - Hooking down - Picking up - Releasing" that this complex-crossings appear (pictures 215a–215e).


215a – Inserting—Hooking down

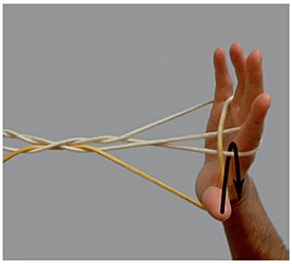

215b – Picking up

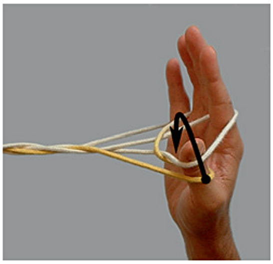

215c – Releasing

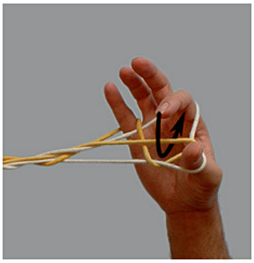

215d – Complex crossing

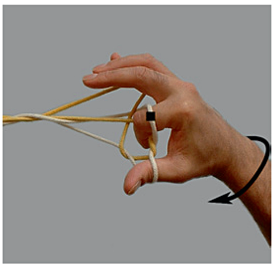

215e – Estrellas

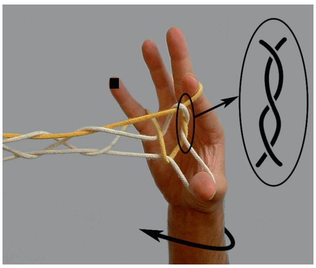
– In 19.*Supua*, it is the sequence "Picking up - Navaho - Hooking up - Releasing" which creates the complex crossing (pictures 216a–216f).

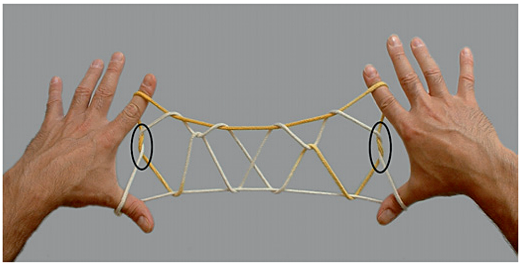

216a – Picking up


216b – Navaho


216c – Hooking up

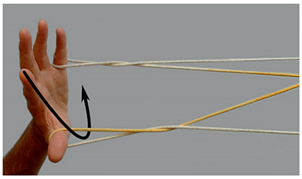

216d – Releasing


216e – Complex crossing

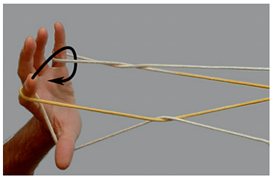


216f – *Supua*

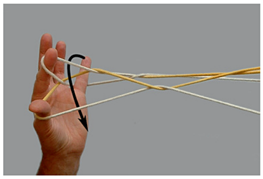
In 22.*Kemagu* in the Trobriands, it is in the sequence "Hooking up (2 times)-Hooking down - Releasing" that the crossing appears on the left side (pictures 217a–217e):



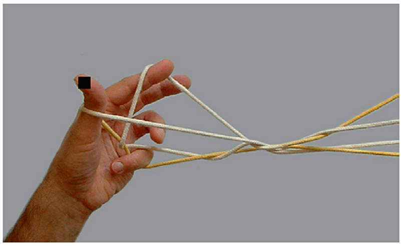
217a – Hooking up



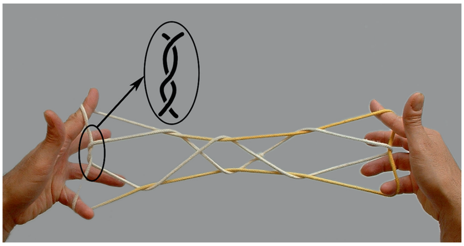
217b – Hooking up



217c – Hooking down

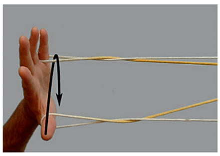


217d – Releasing

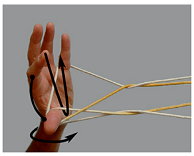


217e – Complex crossing in *Kemagu*

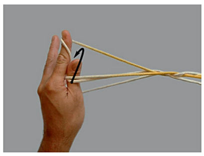
Finally, in 1.*Meta*, it is the sequence "Picking up - Caroline extension - Navaho" that creates the crossing (pictures 218a–218e). I was able to identify four different ways (two in each corpus) to implement this simultaneous "lacing" of two loops i.e. four sub-procedures to implement equivalent heart-sequences, leading to the same complex crossing. This seems to confirm one of the outcomes of the double-sided lozenge string figures comparison (Chap. 6): the different ways by which equivalent movements of loops in space have been implemented by the actors from different societies appear as one of the distinguishing features between the various corpora of string figures.



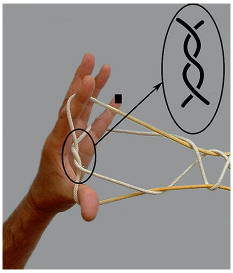
218a – Picking up



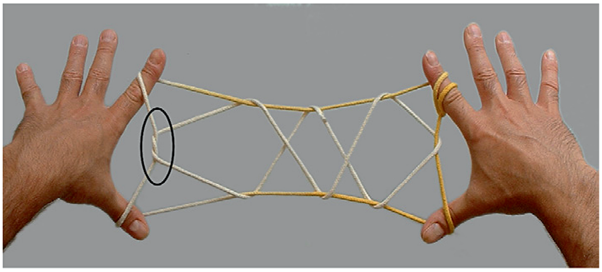
218b – Caroline extension



218c – Navaho



218d – Complex crossing



218e – *Meta*

To my knowledge, the making of the above complex crossing occurs in every corpora of string figures. However, as demonstrated by the comparison between the Trobriands and the Chaco, its occurrence may vary significantly from one corpus to another. Storer showed that many such complex crossings can be identified throughout the corpora of string figures and defined as the entanglement of two, three, four or even more strands (Storer 1988). He has initiated a classification of these complex crossings—a "dictionary of complex crossings", as he called it. It would be certainly fruitful to follow this track. A comparative analysis of the complex crossings in use in different corpora of string figures—comparing their occurrences and the various ways in which they have been implemented—would certainly lead to fundamental results in the future.

9.4.7 Similar String Figures

The Trobriands and Chaco corpora have one, and only one, procedure in common: 41.*Angirà* (Chaco) and 13.*Sopi* (Trobriands). This simple algorithm seems to be widespread all over the planet. It is also the case for 4.*Pata de avestruz* (Chaco): even though I have not found it in the Trobriands, it has been observed in many other societies. In particular, P. E. Victor collected it in Ammassalik as "birds harpoon", and Haddon found it as "fish spear" in the Torres Straits (Chap. 3).

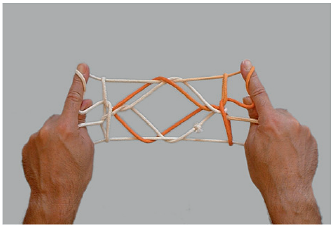
Although much more complicated than 41.*Angirà*, 19.*Supua* (Chaco) too is a string figure described in many published collections. It has been collected in Africa (Cunnington 1906, p. 123) and in many places in the Americas (Jayne 1962, p. 24), from the Arctic to the southern regions of the continent.[58] I have personally recorded it in Ua Pou, Marquesas Islands, where it is known as *Kivi* (white bird). Nowadays, many Americans still know this procedure, which is usually called "Jacob's ladder". I have not found this string figure in Melanesia so far, neither in the field nor in ethnographical papers. Although 19.*Supua* ends with exactly the same final figure

[58]It has been recorded under the name *Trarilonko* (men's headband) by the Argentine ethnologist Ana Guevara, among the "Mapuche" in Patagonia, Argentina (Guevara 2011).

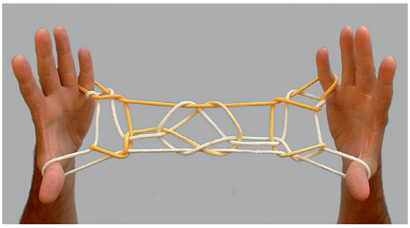
as the "Jacob's ladder" procedure does, the first half of the algorithm differs from the method usually given in the ethnographical or recreational literature.[59]

Similarities between Trobriands and Chaco string figure procedures can be observed by comparing the final figures, the sequences of elementary operations (sub-procedures) and the heart-sequences. We have already compared 16.*Jasytata* and 6.*Kapiwa*. They both lead to the motif "double-sided lozenge" through similar heart-sequences belonging to what I have called Group I (Chap. 6). The procedures 25.*Samuù* (Chaco) and 24.*Guyau-Bolu-Guyavila* (Trobriands) also lead to very similar final figures in which a double-sided lozenge is displayed at the centre of the figure. The comparison of these procedures through their heart-sequences reveals the reason for this great similarity.

9.4.7.1 *Samuù* and *Guyau-Bolu-Guyavila*



219a – *Guyau-bolu-guyavila*



219b – *Samuù*

Both procedures start with Opening A, then the rest of the procedures can be "factorized" in two sub-procedures, say X_1 and Y_1 for 25.*Samuù*, and X_2 and Y_2 for 24.*Guyau-Bolu-Guyavila*: Formally, $Samuù \equiv \underline{O}.A : X_1 : Y_1$ and $Guyau - Bolu - Guyavila \equiv \underline{O}.A : X_2 : Y_2$. The goal of sub-procedures Y_i is to make the symmetrical "motifs" that lie on both sides of the double-sided lozenge. Obviously, Y_1 and Y_2 are very different.

Sub-procedures X_1 and X_2 prepare the extension of the double-sided lozenges. It can be demonstrated that both sequences $\underline{O}.A : X_1$ and $\underline{O}.A : X_2$ are based on the same principle shared by the double-sided lozenge procedures previously classified in Group II (Chap. 6). In the Chaco, the two principles underlying the making of a double-sided lozenge (Group I/Group II) occur within procedure 27.*Estrella*—which is actually the beginning of 25.*Samuù*—and within 16.*Jasytata*.[60] We had not yet encountered the second principle (Group II) at work in the Trobriands corpus, and yet we now see that it is somehow active in procedure 24.*Guyau-Bolu-Guyavila*.

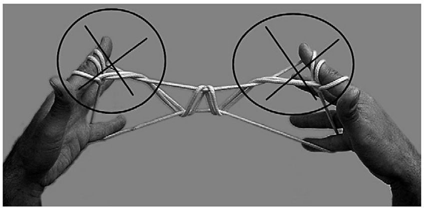
[59] See procedure 19.*Supua* in the accompanying website (*Tukumbu* Corpus). For "Jacob's ladder", see the figure "Osage diamonds" in Jayne (1962, pp. 24–27).

[60] See Sect. 6.2.

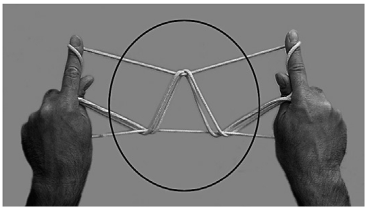
We have already noticed the great similarity between Opening M (Trobriands) and Opening N (Chaco). The comparison between procedures 29.*Kuluwawaya* (Trobriands) and 6.*Vivora* (Chaco) will show that this similarity probably entailed kindred investigations, leading the Trobriander and Guarani-Ñandeva practitioners in the same direction, thus creating two very similar string figures.

9.4.7.2 *Vivora* and *Kuluwawaya*

The first figures of the series 29.*Kuluwawaya* (Trobriands) and 6.*Vivora* (Chaco) are very similar. 29.*Kuluwawaya* starts with Opening M.[61] Then, two intermediate figures (the second and third normal positions) are reached successively. Let us call them *Kuluwawaya*(1) and *Kuluwawaya*(2). *Kuluwawaya*(2) is obtained from *Kuluwawaya*(1) by untying the "entanglements" on both sides, near the indices (pictures 220a and 220b).



220a – Kuluwawaya(1): first intermediate figure of *Kuluwawaya*

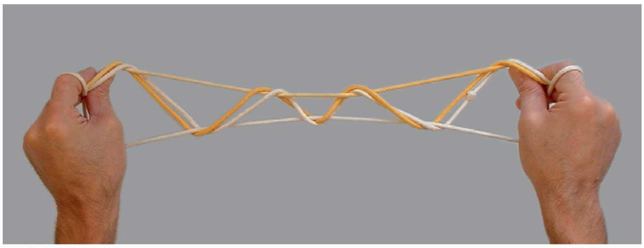


220b – Kuluwawaya(2): second intermediate figure of *Kuluwawaya*

6.*Vivora* starts with Opening N. Remember that Openings M and N are very similar and lead to the same string configuration *modulo* three transfers of loops, according to the following equivalence:

$$\underline{O}.M \Leftrightarrow \underline{O}.N : \overrightarrow{2\infty} \longrightarrow 5 : > \overrightarrow{1\infty} \longrightarrow 2 : \overleftarrow{5\infty} \longrightarrow 2 \mid$$

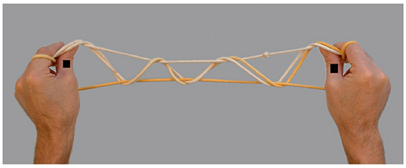
After $Conf(\underline{O}.N)$, the first intermediate figure of the series 6.*Vivora* is reached. Let us call it *Vivora*(1).



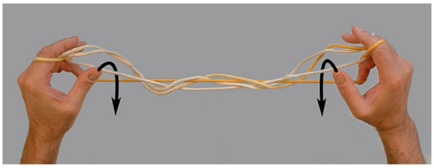
220c – Vivora(1): first intermediate figure of *Vivora*

[61] See procedure 29.*Kuluwawaya* in the accompanying website (*Kaninikula* Corpus).

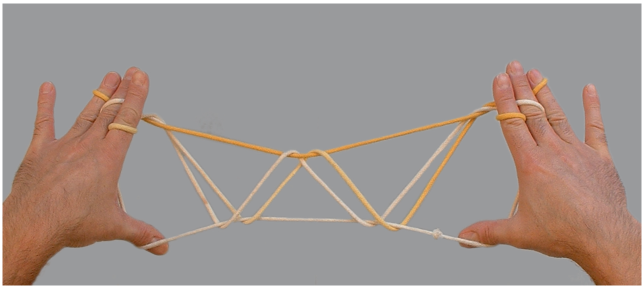
Vivora(1) is actually identical to the first intermediate figure of *Kuluwawaya*. This clearly appears by releasing the thumbs, and hooking down the strings $3f$ with the thumbs (pictures 220d–220f).



220d – Release 1



220e – 1 hook down $3f$

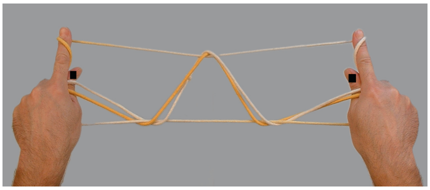


220f – Done

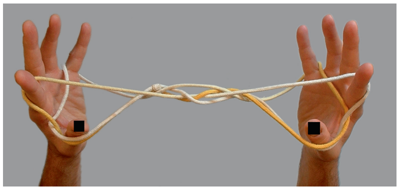
Furthermore, it can be demonstrated that although the sequences of elementary operations are different, the heart-sequences of sub-procedures $SP(\textit{chaco}, 2, \textit{vivora})$ and $SP(\textit{trob}, 2, \textit{kuluwawaya})$, both enabling to reach the series' first intermediate figure, are the same *modulo* some transfers of loops. As in the passage from *Kuluwawaya*(1) to *Kuluwawaya*(2), the first intermediate figure *Vivora*(1) is deconstructed. The deconstruction occurs as soon as the ring fingers and thumbs are released. This allows to get a configuration, say Z (picture 220g). Formally, we have $Z \equiv \textit{Vivora}(1) : \square 1 : \square 4$.

220g – Configuration Z of *Vivora*

Kuluwawaya(2) can be readily transformed into the configuration Z through a few operations on loops. More precisely, we have $Kuluwawaya(2) : \square 1 :< 2\infty : \overleftarrow{5\infty} \longrightarrow 3 \equiv Z$ (pictures 220h–220k). In the configuration *Kuluwawaya*(2) the thumbs share their loops with the little fingers and indices (pictures 220h and 220i). Therefore, the release of thumb loops ($\square$1) does not cause a significant modification of the configuration. In particular, there is conservation of the total number of loops.

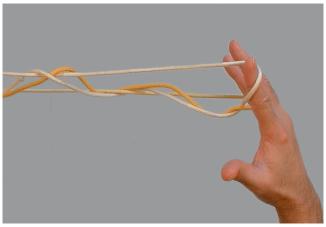


220h – Release 1

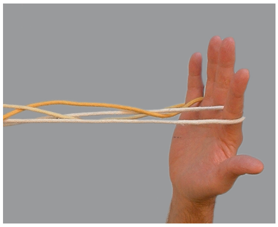


220i – $Kuluwawaya(2) : \square 1$

Moreover, the rotation and transfer $<2\infty : \overleftarrow{5\infty} \longrightarrow 3$ do not modify the configuration in a significant manner, and allow to reach a configuration Z (pictures 220j–220l).



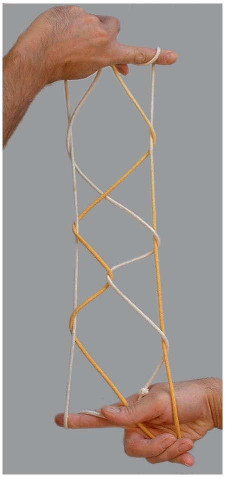
220j – Rotate 2∞ clockwise



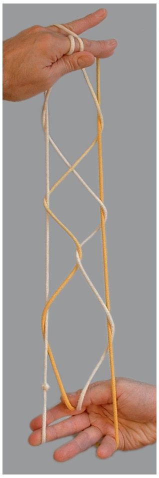
220k – Done

220l – Transfer 5 loops to 3 -> Configuration Z

In *Vivora*, a configuration Z allows to obtain the first intermediate figure, say X. In *Kuluwawaya*, the second intermediate figure *Kuluwawaya*(2) is transformed into the third intermediate figure which is identical to X. This figure is composed of three lozenges in a vertical row (pictures 220m and 220n). It can be shown that the sequence "from Z to X" within *Vivora* and the sequence from "*Kuluwawaya*(2) to X" within *Kuluwawaya* have the same heart-sequence *modulo* some transfers of loops.



220m – $Kuluwawaya(3) = X$

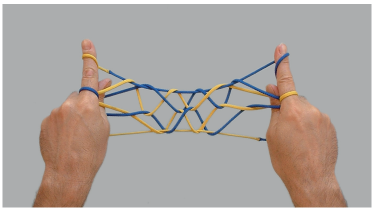


220n – $Vivora(2) = X$

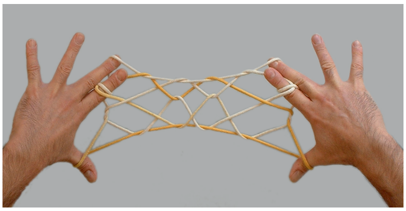
In both previous examples, the similarity of the final figures is due to either the equivalence of the heart-sequences (29.*Kuluwawaya* and 6.*Vivora*) or a part of it (24.*Guyau-Bolu-Guyavila* and 25.*Samuù*). In the next example, the situation is slightly different: the procedures begin in the same way, and this entails a similarity in the final figures or, rather, part of them.

9.4.7.3 *Estrellas* and *Misima*

The beginning of procedures 1.*Estrellas* and 44.*Misima* are absolutely identical.[62] Formally, these two procedures begin by the sequence $\underline{O}.A : SP(trob, 2, misima)$. Then, the rest of the procedures and of the heart-sequences differs, leading to similar (at the center) but different figures (as a whole).



221a – First intermediate figure of *Misima*



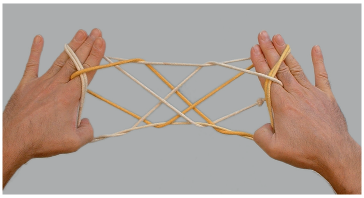
221b – Estrellas

The final figures of the next two string figure procedures are also very similar, even though no similarity can be found in either procedures or heart-sequences.

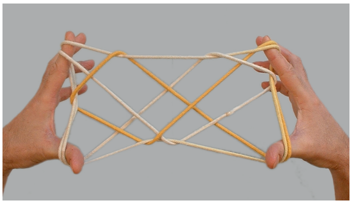
[62] See the accompanying website (*Kaninikula* corpus and *Tukumbu* Corpus).

9.4.7.4 *El re* and *Tubum*

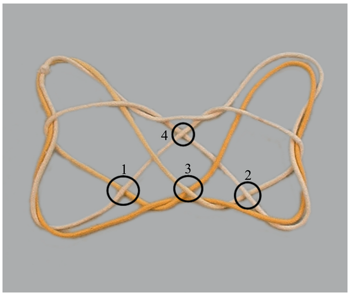
The final figures of 39.*El re* (Chaco) and 27.*Tubum* (Trobriands)[63] are very similar (pictures 222a and 222b).



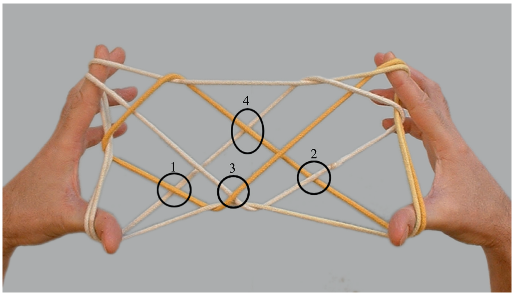
222a – El re



222b – *Tubum*



222c – “El re”: crossings comparison



222d – “*Tubum*”: crossings comparison

More precisely, laying out both final figures while taking a closer look at the simple crossings, one can see that these two final figures differ in four crossings only. This is due to significant differences within their heart-sequences. Moreover, the difference in the crossings numbered 1 and 2 (pictures 222c and 222d) implies that no simple transformation (such as mirror symmetry, rotation, or reversal) allows to pass from one another.

References

Cunnington WA (1906) String figures and tricks from Central Africa. J R Anthropol Inst G B Irel 36:121–131

Guevara A (2011) De madre a hija: juegos de hilo y memoria del paisaje mapuche. Corpus 1(1). http://ppct.caicyt.gov.ar/index.php/corpus/article/view/285

[63] See the accompanying website (*Kaninikula* Corpus and *Tukumbu* Corpus).

Jayne CF (1962) String figures and how to make them: a study of Cat's Cradle in many lands. Dover, New York. A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York

Jenness D (1920) Papuan Cat's Cradles. J R Anthropol Inst 50:299–326

Jenness D (1924) Eskimo string figures. Report of the Canadian Arctic Expedition 1913–1918, vol XIII, part B. F.A. Acland, Ottawa

Mary-Rousseliere G (1969) Les jeux de ficelles des Arviligjuarmiut. Bulletin, vol 233. Musées nationaux du Canada, Ottawa

Maude H (1978) Solomon Island string figures. Homa Press, Canberra

Noble PD (1979) String figures of Papua New Guinea. Institute of Papua New Guinea Studies, Boroko

Paterson TT (1949) Eskimo string figures and their origin. Acta arctica, fasc. 3. E. Munksgaard, København

Storer T (1988) String figures. Bull String Fig Assoc 16 (Special Issue):1–212

Victor P-E (1940) Jeux d'enfants et jeux d'adultes chez les Eskimo d'Angmassalik: Les jeux de ficelle. Meddelelser om Gronland 125(7):1–212. Copenhagen

Chapter 10
Conclusion

10.1 Mathematical Aspects of String Figure-Making

10.1.1 A Mathematical Practice

In this book, I have argued that the creation of string figures can be seen as mathematical. They could not exist without precisely worked out "elementary operations" and "procedures". I have therefore proposed to consider and study the making of string figures as genuine algorithms. As put forward in Part I and confirmed throughout this book, the creation of these algorithms is based on the identification of ordered sets of elementary operations—sub-procedures—either iterated within a given procedure or repeated identically within several different string figure algorithms of the same corpus. Sometimes these sub-procedures can be found as passages between two stable positions, called "normal positions" by José Braunstein. We have seen that, in certain cases, these passages and normal positions might have been investigated by the actors in a systematic way as a basis for creating new procedures. Also, in certain cases, the impact of a sub-procedure on a given "substratum" (configuration of the strings) can be clearly identified as the making of a "prefix" which enables a particular "motif" to be displayed at the end of the procedure, as part of the final figure. So the string figure algorithms provide evidence of mathematical practice. The latter is of a "topological" nature in that it is based on the "study" of continuous transformation of complex spatial configurations. Elementary operations and sub-procedures were most probably efficient tools which enabled the practitioners to investigate these complex objects in space through the concepts of transformation and iteration.

Within the corpora of string figures, the concept of transformation is active at different levels. Firstly, this concept is omnipresent because a string figure is the result of a continuous transformation of a loop of string. Secondly, we have seen that the practitioners worked out how to transform a given final figure (a) into another figure (b). Sometimes, such a transformation begins by a deconstruction of final

E. Vandendriessche, *String Figures as Mathematics?*, Studies in History and Philosophy of Science 36, DOI 10.1007/978-3-319-11994-6_10

figure (a). The aim of this deconstruction is to go backwards within the algorithm in order to reach either a configuration from which a simple extension allows figure (b) to be displayed, or a "connection point" within another procedure of the same corpus. In this case, the latter procedure can be performed from this point to obtain figure (b). This suggests that string figure algorithms were viewed by the actors as procedures connected to one another. Finally, the concept of transformation can be found in the alteration of the algorithms themselves. In some cases, the creators modified only the first normal position or a single elementary operation within the process, and were able to observe the consequences of such alterations on the final figure.

The concept of iteration is involved in the "iterative sub-procedures" i.e. sub-procedures which are repeated several times within a given string figure algorithm. Sometimes, the creators of string figures worked out these singular sub-procedures to display a particular pattern—such as a "lozenge" or a "double-sided lozenge"—as part of the final figure and as many times as the number of iterations. Presumably the creators of string figures perceived whether an iterative sub-procedure can be performed an unlimited number of times (if the length of the string allows it) or "works" only for a certain number of iterations. In certain cases, the iteration's aim is more difficult to perceive and can be found in the creation of simple or complex crossings which become the framework of the final figure.

Our analysis of such phenomena (transformation and iteration) has brought to light the high level of understanding that the creators of string figure algorithms had of these procedures in time and space. The different paths used to display the same patterns or the various methods for obtaining a given complex crossing—as figured out by the Trobriand practitioners—confirm this.

10.1.2 Formalization of "String Figure Algorithms"

We have seen that Cambridge mathematician W. W. Rouse Ball, a practitioner well acquainted with string figures, perceived the mathematical nature of this activity and attempted to demonstrate it in a chapter of his book *Mathematical Recreations and Essays* (1911). In the 1980s, mathematician Thomas Storer did not tackle the subject in the same way. His aim was not so much to discuss the mathematical aspects of string figure-making as to create modelling tools enabling a formal description of how these figures were made. Storer thus introduced the concept of Heart-sequence that we have developed in this book. This approach to string figure algorithms has allowed us to analyse and compare them in an "algorithmic" and "topological" way, focusing on the movement of loops in space during the process. By doing so, we have reached a better understanding of phenomena which often occur in string figure algorithms, such as procedures leading to lookalike figures, transformation of a figure into another, and combinations of various motifs used in the making of several different final figures. I have suggested that a string figure algorithm can be regarded as a heart-sequence, which is interpreted through a precise fingering.

"Dynamically" equivalent heart-sequences (i.e. related to one another under plane or mirror symmetries) can be found in areas that are culturally and geographically distant. However, these heart-sequences are most often implemented through very different fingerings (Chap. 6—"double-sided lozenge" string figure procedures).

The symbolic notation introduced by Storer in order to write down a heart-sequence has a major flaw that I have attempted to correct by illustrating each formula with a series of pictures showing the motion of coloured loops. Since the notation of a loop is related to the finger (numbered from 1 up to 5) carrying it, the symbolic name of a given loop changes under every transfer of this loop from one finger to another. There is therefore a trace of the fingering within the notation of the heart-sequence, which sometimes make it difficult to follow the movement of a given loop that changes identity at each transfer. Colouring the loops in the illustrations helps to visualize their movement during the string figure procedure, giving the loops an identity that they keep throughout the process. In the future, it will be of fundamental importance to improve the symbolic heart-sequence's notation, in order to make it better reflect the independence between heart-sequences and fingerings. It would also be fruitful to create a computer program designed to instantly display the result of a given heart-sequence on a video screen. Such a tool would be extremely useful when investigating string figure corpora. It is also likely that such a program would enable an improvement of Storer's notation of heart-sequences.

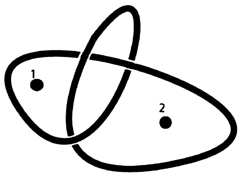
With the concept of heart-sequence and its formalization, we have seen that analysing string figures corpora through an accurate mathematical observer's tool helps to raise hypotheses about how the actors created string figure algorithms. These algorithms are mathematically difficult both to describe and to characterize. Further research will be necessary to get a fully satisfactory formalization. Storer introduced other formal approaches that would be worth developing: the regular projections and linear-sequences, in particular. The latter approaches were inspired by Knot Theory (Murasugi 1996; Livingston 1993). In mathematics, a "knot" is defined as a closed curve (without crossing-points) in 3-dimensional space. And indeed, at first glance, a knot does seem to be a mathematical object with a close relation to string figures. For more than a century, mathematicians have tried to find mathematical tools to characterize "knots". The point is to search what they have called "invariants" (polynomials, matrices, . . .), that can be calculated for each knot, aiming to differentiate them—i.e. to be able to determine whether or not two given knots can be obtained from one another by continuous deformation of the curve (isotopic knots). No ideal invariant of knots has been found so far, and this issue remains open.[1]

Leaving the fingers out, each step of a string figure algorithm shows a knot which is isotopic to a circle in space that mathematicians call the "trivial knot". Therefore, at first glance, Knot Theory does not seem suitable for a mathematical

[1]For further discussion on the history of knot theory see Sossinsky (1999), Epple (1999), and Kauffman (1988).

characterization of string figures. However, mathematicians Jim Hoste and Josef H. Przytycki introduced an object called "punctured diagram", which involves prohibiting certain deformations of the regular projection of a knot by specifying—in the diagram—a "dot" (puncture) that the "string" cannot pass over.

Hoste and Przytycki published a paper which demonstrates that the polynomial invariant discovered by Vaughan Jones[2] can be adapted to characterize "punctured diagrams" (Hoste and Przytycki 1989). As mentioned earlier, a Japanese-Malaysian computer scientist team (formed by Yamada Masashi, Burdiato Rahmat, Itoh Hidenori and Seki Hirohisa) showed that Hoste and Przytycki's polynomial can provide a tool to algebraically and chronologically follow the operations that are carried out throughout a string figure process. They showed that it is possible to associate a series of polynomials to a string figure algorithm by identifying the regular projection of some stages (roughly, the normal positions) to an extended "punctured diagram" with several "dots" representing the fingers (picture 223).



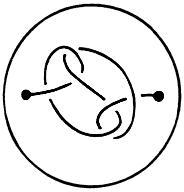
223 – Extended "punctured diagram" with two dots

The first polynomial of the series characterizes the initial position. The Japanese-Malaysian team proved that if a stage B is obtained from a previous stage A under the elementary operation "Releasing" (a loop) we can easily deduce the polynomial determined at stage B from the one calculated at stage A (Yamada et al. 1997). I have continued this work by extending it to other elementary operations. I have succeeded for some of them. However, the problem remains open for most elementary operations.

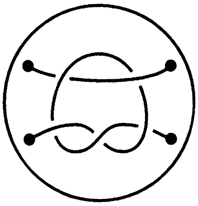
An $(n, n) - tangle$ is another mathematical object stemming from the field of Knot Theory which could be connected to the search for a mathematical characterization of string figure processes, provided that one concentrates on the string without taking the fingers' position into account. An $(n, n) - tangle$ is defined by Japanese mathematician Kunio Murasugi as follows: on a sphere B of 3-dimensional space, place $2n$ points. An $(n, n) - tangle$ is formed by attaching to these points, within the sphere B, n curves, none of which should intersect each other as shown in the Diagrams below.[3]

[2]In 1990, V. Jones received the Fields Medal, in particular for this discovery. About Jones' Polynomial see Jones (1985) and Kauffman (1987).

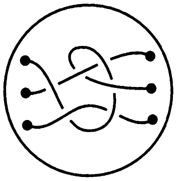
[3]Definition and diagrams adapted from Murasugi (1996, p. 172).



224a – (1,1)-Tangle

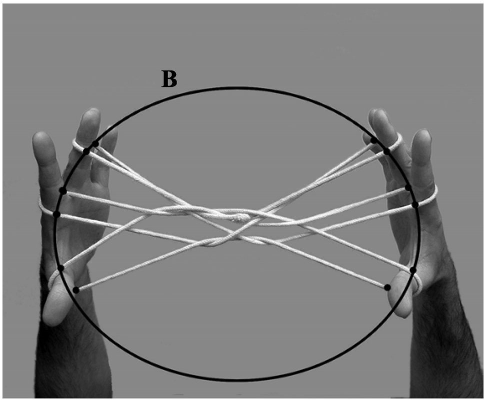


224b – (2,2)-Tangle



224c – (3,3)-Tangle

At each stage of a string figure process, the two hands can be seen to form sphere B, and the strings between the two hands form a mathematical Tangle (picture 225). Although certain cases have been explored successfully,[4] the characterization of Tangles remains an open issue. Investigation of string figure algorithms through the prism of mathematical studies of Tangles may help to achieve simultaneous progress in both these fields of research.



225 – String figure *versus* Tangle

10.2 Comparison Trobriands/Chaco: Main Outcomes

The previous comparative study of the string figure corpora from the Chaco and the Trobriands has brought to light some invariant and distinguishing features in the way string figure-making is embedded within these two societies. In both of them, I did

[4]Certain types of (2,2)-Tangles, named Rational Tangles, have been classified. This classification was of fundamental importance in the study of DNA recombination (Kauffman and Lambropoulou 2002, 2004). Also, David N. Yetter demonstrated that significant progress could be made by connecting Knot Theory and Theory of Categories (Yetter 2001).

not meet anyone that was creating new string figures. However, I was able to meet practitioners with a high level of competence, to whom I have referred as "experts". I was able to notice several differences in the social aspects of string figure making: in the Trobriand Islands, it is during the rainy season that string figures are practiced the most. However, some elders claim that in the past string figure-making was connected to the period of the *Milamala* i.e. festivities, which are organized at the end of the yam harvest (July and August). By contrast, I was not told anything of this nature in the Chaco.

In the Trobriands, string figure-making is mainly practised by women and children. Although I did meet a few male practitioners in Oluvilei, the more skilful individuals are female. Moreover, women seem to be the main actors in the transmission of this knowledge. In the Chaco, I did not notice such a difference, and I was able to meet both male and female "experts". The involvement of Trobriander women in string figure-making led me to study the Trobriand Islanders' kinship system, which results in a continuous circulation of women from an area to another. I sought a possible link between this circulation and the diffusion of string figures throughout the archipelago. I soon realized that the circulation of women due to the kinship system was quite difficult to describe precisely. However, knowing that the Trobriand Islands are divided into districts which can be considered as cultural and linguistic areas, I have found that such circulation rarely occurs from one district to another. Therefore, these districts could constitute a relevant framework for a comparative study of string figures throughout the archipelago.

In the Trobriands, the making of string figures is often accompanied by oral texts and appears in everyday life as theatrical entertainment. Besides, their role could be, on certain occasions, to remind people of social rules (prohibition/prescription). This does not seem to be the case in the Chaco, where most Guarani-Ñandeva simply consider string figures as a difficult activity requiring concentration, memory and dexterity.

In both regions, it is presumable that children know a corpus of string figures that adults do not necessarily remember. The transmission of this corpus occurs mostly among children. In the Trobriands, I obtained enough data to make a statistical analysis of a set of string figures known by most of the children in Oluvilei. The comparison of these string figures with those known by my adult informants showed some differences in the fingering by which the elementary operations are performed, as well as in the low occurrence of some short sub-procedures or in the length of the procedures—as if the learning of string figures were a gradual process.

Since most of the time I spent with practitioners was used to learn and record how to make these figures, these outcomes are to be seen as first steps which, I hope, will pave the way towards further anthropological studies on that subject.

Apart from a few exceptions, we have identified the same elementary operations and short sub-procedures (successions of a few elementary operations) in the Trobriands and in the Chaco corpus. The statistical comparative analysis of elementary operations' occurrences has shown a great similarity from one corpus to another. By contrast, we have noticed significant differences between the Trobriands and the Chaco in the way these operations are performed with different fingerings.

Furthermore, the calculation of the "parameter of length"—i.e. the mean number of elementary operations at work in a corpus per procedure—has brought to light that Trobriand string figure procedures involve a greater number of elementary operations, on average, than the ones from the Chaco. Finally, all the short sub-procedures that I found in Santa Teresita are also known in Oluvilei. However, there is a clear difference in their respective occurrence within each corpus. Furthermore, the high occurrence in the Trobriands corpus of the two short sub-procedures *Kwatuponiniya* and *Sosewa*—which are absent from the Chaco corpus—has clearly a significant impact on the form of Trobrianders' string figure algorithms. The latter statistical analysis of elementary operations and short sub-procedures occurrences has provided some elements to differentiate the Trobriands corpus from the Chaco corpus. It would certainly be fruitful to apply the same methodology to many other corpora. It is a huge task, but we can expect fundamental outcomes to emerge from it, and it will help to better characterize a given corpus of string figures in the future.

We have seen that Opening A has a high occurrence rate in both the Trobriands and Chaco corpora, as it does in many other. I have argued that the reason for this phenomenon could be the great fecundity of this opening—as a starting point for creating many procedures, but also as a basis for creating new openings as variations on it. However, listing the openings from Oluvilei and Santa Teresita has shown, in each corpus, a real specificity in the way the procedures begin. Except for two (A and S_6), openings in the two corpora lead generally to different configurations, even though there are some exceptions where an opening from the Trobriands and one from the Chaco both lead to identical or equivalent configurations—i.e. identical *modulo* a few transfers or rotations of loops. In these cases, however, these equivalent configurations have been worked out by practitioners through different fingerings in each corpus.

Focussing on the passages from the first to the second normal position, and sometimes also from the second to the third normal position, we have seen that these passages differ a lot from one corpus to another. Furthermore, among the numerous passages only one occurs in both corpora ($SP(trob, 2, vivi) \equiv SP(chaco, 2, supua)$). This seems to indicate that the explorations of passages generally took place locally. However, the analysis of both corpora through the concept of Openings and Passages has allowed us to see both corpora as tree diagrams that give a global view of these procedures and throw some new light on their structures and—to a certain extent—on their history. Moreover, the analysis of the heart-sequences of the various passages that we find in Oluvilei, from $Conf(\underline{O}.A)$ to the second normal position, led us to an encouraging outcome. As shown in Chap. 9, these passages can be analysed as the result of a systematic exploration of the possible movements of the six loops in configuration $Conf(\underline{O}.A)$, as if the practitioners from the Trobriands had carried out a systematic combinatoric research in an attempt to find out all the possibilities. Finally, the comparative analysis of certain passages—through their heart-sequences—suggests that Guarani-Ñandeva and Trobriander practitioners certainly considered the configuration of loops in different ways. In the Chaco, the insertion of a loop into another is often based on the insertion of a loop created on one hand through an opposite loop carried by the other hand. This phenomenon is quite rare in the Trobriands corpus, where the insertions mostly involve the loops carried by the same hand.

In Chap. 9, the last section confirms what was put forward at the end of Part I: in many places all over the world, the creation of string figures was guided by concepts such as “iteration”, “transformation” or “alteration”. Moreover, these concepts have appeared to be efficient tools to compare and differentiate string figure corpora. The concept of “transformation” is obviously an invariant since a string figure algorithm can be seen as a continuous transformation; but we also find it, in both Trobriands and Chaco corpora, as transformation of one figure into another. The “alteration” of the first normal position of a procedure also occurs in both corpora, whereas the “alteration” of a single elementary operation in the procedure is frequent in the Trobriands but cannot be found in the Chaco corpus. The “iteration” of a sub-procedure has a high occurrence in the Trobriander corpus and was found only twice in the Chaco corpus. In the future, we shall question the experts to know whether they are aware of these phenomena, and how they express and explain them.

We have seen that sometimes the exploration of string figure algorithms was certainly motivated by a search of different paths towards the same pattern. However, the comparison of different corpora showed that the intention could differ from a cultural area to another. In some cases, it is the exact final figure (crossings included) that the practitioners tried to obtain through different procedures (different heart-sequences or different fingerings, or both), as it is often the case in the Arctic. But, it can be a particular “drawing” (same final figure, without taking the exact crossings into account) that is reached under different procedures. Until now, it has been difficult to clarify what motivated the practitioners to do so. However, some accounts led me to hypothesize that these various procedures leading to the same patterns may sometimes result from intellectual challenges. Remember that Santa Teresita resident Victor Rolom learnt string figures from his grand-father, who often showed him only the final figure, hiding the making of it and asking him to figure out a procedure to display this figure. We may reasonably think that such a way of transmission was appropriate to generate new procedures. In the summer of 2005, I recorded similar testimony in the Marquesas Islands. In the valley of Hakatao (Ua Pou Island) I was told by Taiea Epetahui, a man in his 60s, of the presence in each village, until the mid-twentieth century, of a man considered by the other inhabitants of the valley to be a specialist of knots. Taiea informed me that such specialists (one per valley) used to invent new string figures, but also other types of knots (knots for making the framework of traditional houses, knots for sailing boats…). These experts were often asked to show and to teach the other villagers their string pattern creations. Moreover, during meetings between villagers of the various valleys, these new string patterns gave rise to intellectual tournaments: communities challenged each other to find a procedure leading to a new design. Such testimony shows that circulation of these procedures within a small area might have sometimes stimulated the creation of variations on a given string figure algorithm. We may think that in these tournaments, some practitioner, representing a given community, figured out variations in terms of his own skills—that he probably shared with other members of the group—and in terms of local or personal preoccupations.

10.3 The Question of the Wide Circulation of String Figures

We have seen in Chap. 2 that, throughout the first half of the twentieth century, diffusionism constituted the intellectual context of the ethnographical papers on string figures which followed the 1902 article by Haddon and Rivers. In several papers about string figures collected in the Pacific Islands, authors undertook to compare their collection to other publications of related interest. They drew comparative charts in which some string figures they had collected were matched to others that had appeared in published collections of string figures recorded elsewhere in Oceania or, occasionally, on other continents. The matching procedures were often defined by the authors as “same or very similar procedures”.

In these tables, we see that some string figures were known with slight variations throughout Oceania, at different moment over the twentieth century.[5] However, although these charts give evidence of circulation of a few string figures throughout the whole Pacific, they are generally not easy to interpret. It is difficult to exhibit from these tables cultural or geographical areas in which some string figures might have circulated. Information are often widespread in time and space, and the similarities between string figures are not analysed in sufficient detail to measure the closeness of the procedures that are pointed out as “similar”. It is probably for that reason that the authors often drew these comparative charts at the end of the text without any commentary. But some exceptions can be found.

Anthropologist James Hornell asserted, in the article “String figures from Fiji and Western Polynesia” (Hornell 1927), that a table designed “to exhibit the geographical distribution of the figures described from Fiji” reveals notable Melanesian influence:

> Table 1 [Distribution of Fijian string figures] amply demonstrates the predominance of Melanesian influence in Fiji. Of the 30 solitary or independent figures and series of figures which I have recorded from Fiji, the large total of 12 has been recorded also from New Caledonia, Loyalty Islands, Torres Straits, D’Entrecasteaux Archipelago, and the Fly river district of Papua New Guinea (Hornell 1927, p. 6).

In the article “String Figures from Hawaii” (1928), anthropologist Lyle A. Dickey also relied on such a distribution table to show that recent immigration did not seem to have imported string figures in Hawaii:

> Though anciently Hawaii was perhaps the most isolated of lands, for more than a century it has been the cross roads of the Pacific. Hawaiians have gone as sailors to every land touched by sailing vessels; laborers have been imported from Europe, China, Japan, and the South Pacific. It might be expected that the string figures of Hawaii are mainly those already published. The opposite is true - immigration seems not to have brought string figures. Gilbert Island and New Hebrides laborers were imported into Hawaii in 1878. The nine New Hebrides and the two Gilbert island string figures described illustrate the small

[5] As mentioned earlier in Sect. 6.4.1, the Trobriand string figure 54.*Salibu* can be found in almost every collection of string figures from Oceania. I found this procedure 16 times in ethnographical papers. And I have personally recorded it in the Marquesas, Vanuatu and Papua New Guinea. The slight variations from one to another lie mainly in the way $Conf(A)$ or $Conf(B)$ is reached from Opening A. See Annex III.

> influence of late immigration on Hawaii string figures for, though simple figures consisting of two, three, or four diamonds in a row, are among the easiest to make and are the most popular figures with Hawaiian school children, yet neither New Hebrides nor Gilbert Islands methods are found in the schools (Dickey 1928, p. 1).

About 10 years after this article by Dickey, Daniel S. Davidson wrote a long paper on Aboriginal Australian string figures (Davidson 1941). In comparing his collection to other corpora published at that time, Davidson favours the probable Melanesian derivation of a great number of Australian string figures, which would have spread to other regions of Australia afterwards:

> The principal reason for considering northern Queensland the area of greatest antiquity is found in a comparison of Australian and Oceanic figures, for on this basis there can be no doubt that string figures first came from Melanesia (Davidson 1941, p. 783).

We may think that more information about the string figures that are known all over the planet would allow us to explore further this comparative approach. However, the number of published collections still seems too low nowadays to make capital out of these comparative charts. Nevertheless, as far as I know, there is an outcome given by these tables which has not been pointed out yet. As we shall see, instead of focussing on the possible circulation of some procedures, all of these tables actually seem to indicate that a large number of string figure algorithm do not circulate. The papers about Oceanian string figures in which a comparative chart is drawn are grouped chronologically in the table below. For each of these papers, the number of string figures matched by the authors is given in comparison to the total number of string figures described in each article. The last column gives the corresponding frequencies.

Reference	Number of string figures matched	Total number of string figures	Percentage
New Caledonia (Compton 1919, pp. 207–208)	16	25	64
Fiji & Western Polynesia (Hornell 1927, p. 7)	18	49	36.7
Hawaii (Dickey 1928, pp.6–7)	24	126	19
Australia (Davidson 1941, pp. 890–899)	46	74	62.1
Gilbert Islands (Maude and Maude 1958, pp. 157–160)	31	127	24.4
Tikopia (Maude and Firth 1970, p. 64)	21	54	38.8
Solomon Islands (Maude 1978, pp. 172–173)	36	114	31.6
Tuamotus (Maude and Emory 1979, pp. 146–147)	33	82	40.2

In a noteworthy way, authors that sought to highlight similarities between their collection and others known at that time seldom succeeded to match more than half of the procedures. As for string figures from Australia and New Caledonia, the high proportion of similarity is certainly due to the "Melanesian derivation of Australian string figures" I mentioned above. However, no such similarity was found in most string figures included in these compared corpora. This seems to indicate that a significant number of string figures within each corpus did not spread widely to other areas, and it would be worth studying why. To my knowledge, only a few testimonies reported in ethnographical literature give evidence that string figures were not originally known and practiced throughout large areas of the planet and were imported from elsewhere. In 1941, Davidson argued that string figures were of recent introduction in a large part of Australia.

> For most of the remainder of Western Australia, which occupies roughly one third of the continent, we have evidence to show that string figures are of recent introduction from areas to the east.
>
> In the extreme northwest the relatively recent westward movement is well affirmed by native testimony. Old Ingarda natives in the Carbarvon area claim they first learned string figures in their childhood, about the beginning of the twentieth century, from their northern neighbours, the Baiong. The latter, in turn, state that string figures were unknown to them until about that time when they acquired them from their neighbors to the north, the Talainji. The general accuracy of this testimony is substantiated by old white inhabitants who recall the marked enthusiasm, about 1900 or shortly thereafter, which accompanied the initial introduction (Davidson 1941, p. 777).

Davidson continues by quoting several testimonies that mention significant traces of string figures spreading to geographical areas where this activity was apparently not practiced (Davidson 1941, pp. 777–778). This led him to assume that northern Queensland could be the region from which string figures were transmitted to other regions of Australia.

> The antiquity of string figures elsewhere in Australia is not demonstrated by direct evidence, but several considerations point to northern Queensland as the area whence they diffused to other parts of the continent (Davidson 1941, p. 780).

According to him, a great number of the Australian string figures he collected might have come from Melanesia, in particular from Papua New Guinea, where string figure-making has been attested as early as 1888 by Haddon. Davidson not only found and studied identical procedures in various areas, but he also identified similar technical "usages", which led him to believe that certain zones of circulation could emerge as cultural areas in terms of string figure making.

> Not only do we find in Melanesia identical procedures for a number of the more complex Australian patterns but, equally significant, also the presence of distinctive string figures usages, manipulations and extensions not reported for other parts of the world. As stated above it is difficult to define at the moment many of these peculiarities but the evidence as a whole seems sufficient to indicate that Australia, Melanesia, Micronesia and Polynesia comprise a major string figure area (Davidson 1941, p. 783).

Although he did not himself explore this avenue, Davidson suggests a methodology to identify "string figure areas" all over the planet. In referring to "usages, manipulations, and extensions", Davidson is not so far from the concept of elementary operation or sub-procedure—conceptual tools which allowed us, in this book, to define some characterization elements common to the string figure corpora of two distant areas. Davidson gives the example of the "usage" of the "Caroline extension", also called "Pindiki" by Kathleen Haddon, who borrowed the term from a native terminology (Haddon 1930, p. 156). He pointed out that, according to the publications made at that time, the "Caroline extension" was commonly attested in the Western part of the Pacific, whereas it was lacking in the Eastern part.

> A most trait in Oceania and Australia is the Pindiki movements, otherwise known as the Caroline Islands Extension. [. . .]
>
> In addition to its apparent universal use in Australia it is found in New Caledonia, the Loyalty Islands, Fiji, New Zealand (not common), the Ellice, Tokelau, Gilbert and Caroline Islands, in Nauru. It seems to be lacking in Tonga, the Marquesas and Society Islands, Tahiti, Hawaii, and in North and South America, Asia, Africa and Europe. (Davidson 1941, p. 785)

From 1940 onwards, publications on the subject of string figures, in particular those by Maude (1971, 1978), Maude and Emory (1979), Maude and Firth (1970), and Maude and Maude (1958), confirm Davidson's viewpoint. Like anthropologist Willowdean C. Handy, I did not personally find this short sub-procedure in the Marquesas Islands (Handy 1925). And like Braunstein, I found no trace of the "Caroline extension" in the Chaco (Braunstein 1992). However, it is commonly used in the Trobriand Islands (called *Kwatuponiniya*) and in Northern Ambrym, Vanuatu, where it is called *Wehe* by practitioners. We may hope that further fieldwork, using the methodology developed in this book, will throw some new light on the modes of wide circulation of string figure algorithms. However, a huge task will have to be carried out before one can expect to get a comprehensive view of the phenomenon.

At the same time, it would be certainly fruitful to study the circulation of string figures on a more local scale. As mentioned earlier, the way string figure procedures and their accompanying recitatives have circulated can sometimes be brought to light and analysed by focussing on limited geographical area. The example of *Kuluwawaya*—and its variations in particular (see Chap. 8)—invites us to carry out an in-depth study of string figure circulation throughout the Trobriand archipelago and the nearby islands of Milne Bay province. Long and patient fieldwork will be necessary to undertake such a project. It should begin by assembling a complete collection of string figure procedures and their accompanying oral texts (*vinavina*), gathered in the context of the cultural and linguistic areas (districts) of the Trobriand archipelago, as well as in the context of the *Kula* Ring in Milne Bay Province. The analysis of the string figure procedures, through the various conceptual tools introduced in this book, should be carried out in parallel to an in-depth ethnolinguistic study of the related oral texts, and in the light of anthropological literature that deals with *Kula* ring societies. Significant progress could be made through this interdisciplinary approach. On the one hand, we should gain a better understanding of the links between the *vinavina* and the string figure procedures, that this book has begun to underline. On the other hand, this approach should highlight the simultaneous transformations of text and procedure when they pass "ethnic frontiers", circulating from one cultural group to another.

Such a research program should be undertaken in the Chaco too. As pointed out by Braunstein, many indigenous communities, such as the Guarani-Ñandeva, still practice string figures in this area (Braunstein 1996). Furthermore, some of these societies can be differentiated from each other by the fact that certain string figures are practiced or not. String figures would thus be used by the natives to mark cultural identities, and thus define ethnic boundaries.[6] For the moment, I have not found any trace of oral texts accompanying string figure procedures among the Guarani-Ñandeva, nor have I found such indication in the ethnographical papers on string figures of this region. Yet, it does not mean that such texts never existed. It is not improbable that they fell into oblivion. This could be due to the fact that these peoples have been constantly persecuted over the past 150 years. Conducting long-term fieldwork in the Chaco will help to highlight this point.

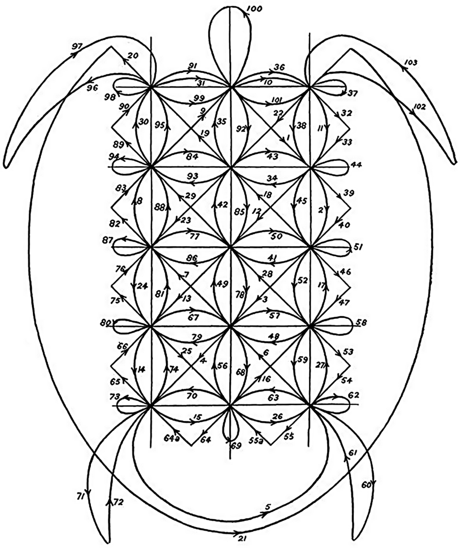
To conclude I will propose another promising direction of research for further studies of the cognitive acts at work in the activity of string figure-making, and thus for further investigation in its mathematical nature. It would be of interest to look for connections, within the same society, between the making of these figures and other technical practices that can be seen as mathematical. In the Trobriands, such connections with string figures could be explored, for instance, as regards the making of mats or baskets, which could certainly be analysed in an algorithmic way. In the Chaco, string figures should be connected to a long tradition of textile production there.[7]

226 – Nivacle's string bag, Chaco boreal, Paraguay (2005)

[6]J. Braunstein, personal communication, 2012.

[7]See Métraux (1946, pp. 270–288). For further discussion on "the idea that artefacts such as string bags may play an altered role" in the ethnography of the Gran Chaco, see Alvarsson (1992).

In Vanuatu, it would certainly be fruitful to carry out a comparative analysis of string figure-making and the practice of sand-drawing, which consists in drawing a continuous line with the finger, either in the sand or on dusty ground. Like string figure-making, sand-drawing has been observed in Vanuatu since the early twentieth century (Dickey 1928; Deacon and Wedgwood 1934) and is still practised in many places throughout the archipelago.



227a – *Hi* (The turtle) recorded by Deacon in Ambrym

227b – Bongrowo from Magam, Nothern Ambrym

Ethnomathematician Ascher has demonstrated that the making of some of these patterns—collected by Deacon[8] in Ambrym and in the nearby island of Malekula—also consists in an ordered succession of operations which can be seen as geometrical algorithms. In Northern Ambrymese society—in which I carried out fieldwork in 2006—string figures and sand drawings seem strongly connected to one another since both of which are locally termed "*tu*" (lit. "to write").

[8]I obtained evidence that Deacon focused on both string figures and sand drawings: an editorial footnote in Deacon's monograph on Malekula (Deacon 1934) indicates that Haddon and Wedgwood had hoped to publish his research on string figures (alongside his records of sand drawing) in a separate volume. Unfortunately, while the sand drawing records were published shortly afterward (Deacon and Wedgwood 1934), the string figures have never appeared. The worst of it is that Deacon's field notes on string figures have never been found. In December 2005, I tried in vain to find them in Haddon's collection at the Cambridge Library and in Wedgwood's collection at the Royal Anthropological Institute of London. Although I have no evidence, the document may have been kept at the University of Sydney, where she worked from 1934 until her death.

Comparing, at a formal level, string figure-making and bag-weaving in the Paraguayan Chaco, mat-making in the Trobriand Islands, or sand drawings in Vanuatu, should bring a new light on these practices involving mathematical ideas. To my knowledge, no ethnomathematical in-depth analysis of bag-weaving and mat-making—unlike sand-drawings—has been undertaken yet. There are many artefacts that would be worth investigating in that perspective. Such study should be at the heart of new projects that are urgent to set up, since these indigenous mathematical knowledge are often endangered. It is my earnest hope that this book will be an impulse for further ethnomathematical studies on artefacts that can be regarded as mathematical. All of these will contribute to a better understanding of the nature of mathematics, and also, more generally, of rationality. Ethnomathematics, by applying interdisciplinary methods, should help to better understand the cognitive acts involved in mathematical practice. The universality of mathematics could thus be reinvestigated.

References

Alvarsson J-A (1992) Artefacts in ethnographic description: some ideas on an analysis of three string bags from Mataco Indians of Bolovia. Antropol Stud AS 49:2–25

Braunstein J (1992) Figuras juegos de hilo de los Indios Maka. Hacia una Nueva Carta Etnica del Gran Chaco III:24–81

Braunstein J (1996) Langages de ficelle: Au fil d'une enquête dans le Chaco Argentin. Techn et Cult 27:137–151

Compton RH (1919) String figures from New Caledonia and Loyalty Islands. J R Anthropol Inst G B Irel 49:204–236

Davidson D (1941) Aboriginal Australian string figures. Proc Am Philos Soc 84:763–901

Deacon AB (1934) Malekula, a vanishing people in the New Hebrides. G. Routledge, London. Edited by Camilla H. Wedgwood; with a preface by A. C. Haddon

Deacon AB, Wedgwood C (1934) Geometrical drawings from Malekula and other islands of New Hebrides. J R Anthropol Inst 64:129–175

Dickey LA (1928) String figures from Hawaii, including some from New Hebrides and Gilberts Islands. Bishop Museum, bulletin, vol 54. The Museum, Honolulu. (Reprint edition 1985, Germantown, New York edition)

Epple M (1999) Geometrical aspect in the development of knot theory in "History of Topology". Elsevier, Amsterdam

Handy WC (1925) String figures from the Marquesas and Society Islands. Bishop Museum, bulletin, vol 18. The Museum, Honolulu

Hornell J (1927) String figures from Fiji and Western Polynesia. Bishop Museum, bulletin, vol 39. The Museum, Honolulu. (Reprint edition 1971, Germantown, New York: Periodicals Service Co)

Hoste J, Przytycki JH (1989) An invariant of dichromatic links. Proc Am Math Soc 105(4):1003–1007

Jones VFR (1985) A polynomial invariant for knots via von Neumann algebras. Bull Am Math Soc 12(1):103–111

Kauffman LH (1987) State models and the Jones polynomial. Topology 26(3):395–407

Kauffman LH (1988) New invariant in the theory of knots. Am Math Mon 95(3):195–242

Kauffman LH, Lambropoulou S (2002) Classifying and applying rational knots and rational tangles. Am Math Soc Contemp Math Ser 304:223–259

Kauffman LH, Lambropoulou S (2004) On the classification of rational tangles. Adv Appl Math 33(2):199–237

Livingston C (1993) Knot theory. The Carus mathematical monographs, vol 24. The Mathematical Association of America, Washington, DC

Maude H (1971) The string figures of Nauru Island. Libraries board of South Australia occasional papers in Asian and Pacific Studies, vol 2. Libraries Board of South Australia, Adelaide

Maude H (1978) Solomon Island string figures. Homa Press, Canberra

Maude H, Emory K (1979) String figures of the Tuamotus. Homa Press, Canberra

Maude H, Firth R (1970) Tikopia string figures. Royal anthropological institute of Great Britain and Ireland, occasional paper, vol 29. Royal Anthropological Institute, London, 63p

Maude H, Maude HE (1958) String figures from the Gilbert Islands. J Polyn Soc Mem 13:161

Métraux A (1946) Ethnography of the Chaco. In: Bulletin 143, Hand book of South American Indians. Smithsonian Institution, Bureau of American Ethnology, vol 1, pp 197–380. US Govt. Print Off., Washington, DC

Murasugi K (1996) Knot theory and its applications. Birkhäuser, Boston. Translated from the 1993 Japanese original by Bohdan Kurpita

Ball WWR (1911) Mathematical recreations and essays, 5th edn. Macmillan, London

Sossinsky A (1999) Noeuds: Genèse d'une théorie mathématique. Editions du Seuil

Yamada M, Burdiato R, Itoh H, Seki H (1997) Topology of Cat's Cradle diagrams and its characterization using knots polynomials. Trans Inf Process Soc Jpn 38(8):1573–1582

Yetter DN (2001) Functioral knot theory: catergories of tangles, coherence, categorial deformations, and topological invariant. Series on knots and everything, vol 26. World Scientific, Singapore/River Edge

Annexes

Annex I: Classification of Double-Sided Lozenge String Figures

The names of string figures marked * indicate the string figure algorithms that can be found in the accompanying website (Double-sided lozenge family).

Oceania

Names	From	Group	Comments about the procedure
Kapiwa*	Trobriand Islands	I	Collected by Eric Vandendriessche
Niu* (Star)	Solomon Islands	II	(Maude 1978, p. 1–2)
Nepe (Moon)	Solomon Islands	I	Close to Kapiwa (different beginning) (Maude 1978, p. 1)
Pu kava* (Big shell)	Marquesas	I	Collected by Eric Vandendriessche
"Butterfly"	New Caledonia	I	Identical to Kapiwa (Compton 1919, p. 214–215)
"Nameless"	Loyalty Islands	II	(Compton 1919, p. 222)
Taai'i (Sun)	Gilbert Islands	I	Close to Kapiwa (different beginning) (Maude and Maude 1958, p. 27)
Na Tifai I (Turtles)	Tuamotus, French Polynesia	II	Close to Niu (tiny difference at the end) (Maude and Emory 1979, p. 1–2)
Na Tifai II	Tuamotus	I	Identical to Pu Kava (Maude and Emory 1979, p. 2)
Na Tifai III*	Tuamotus	II	Identical to "Nameless" from New Caledonia, (Maude and Emory 1979, p. 3–4)

(continued)

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Names	From	Group	Comments about the procedure
Foi nupu Pu Taumako	Tikopia Island	II	Close to Niu (different beginning) (Maude and Firth 1970, p. 18)
Wahine (Butterfly)	New-Zealand	I	Identical to Pu kava (Andersen 1927, p. 242)
Ekwan II (Sun)	Nauru Island	I	(Maude 1971, p. 62–63)
Ekwan III (Sun)	Nauru Island	I	Identical to Pu kava (with a Caroline Extension at the end) (Maude 1971, p. 63–64)
Eongatubabo	Nauru Island	II	(Maude 1971, p. 77) Steps 1–5 identical to Niu, then continuation by iteration.
Paa (Crab)	Samoa	II	Identical to Niu (Hornell 1927, p. 73–74)
Sasa (White Cockatoo)	Numba Village, Managalas and Musa, PNG	I	Identical to Nepe (Noble 1979, p. 35–36)
"Star variation"	Umbovore, Itokana, PNG	I	Identical to Kapiwa (Noble 1979, p. 111–112)

Double-Sided Lozenge String Figures from Other Geographical Areas

Names	From	Group	Comments about the procedure
Jasytata* (Star)	Chaco, Paraguay	I	Collected by Eric Vandendriessche
Estrella* (Star)	Chaco, Paraguay	II	Collected by Eric Vandendriessche
Mwezi (Moon)	Murungu, West Tanganika, Central Africa	I	Mirror moves of Pu Kava (Cunnington 1906, p. 129)
Kumba ma De (Male and Female)	Zande People, Central Africa	I	(Evans-Pritchard 1972, p. 230–231)
Bagli no khoto (The nest of the crane)	Gujarat, India	I	(Hornell 1932, p. 156–157)

Annex II: Classification of the Names of String Figures

Trobriands Corpus

Each *kaninikula* from Oluvilei carries a name in Kilivila. The following 62 names of *kaninikula* can be divided into four subsets: objects (18), animals (17), plants (7), people or human actions (14), adding to 5 *kaninikula* whose meanings are forgotten in Oluvilei.

Objects (19)
1.Meta (trap?)
4.Togesi (basket)
8.Kalatu gebi navalulu (linen for young mother)
13.Sopi (water, sea)
14.Doga doga (Grass-skirt)
15.Bwala (house)
31.Totuwana Kala Niya Kuliyava (bones of fish and dolphin)
33.Kenabosu (lime stick made with the bone of the fish Bosu)
34.Samulakayaula (river coming from the sea to kayaula (name of a place))
37.Waga (canoe)
41.Lilu (sun)
42.Nebogi (getting dark, night)
44.Misima (Island)
45.Solava (necklaces)
46.Dakuna (stones)
53.Budi Budi (name of an Island)
54.Salibu(mirror)
Sowa (saw)- 2 players

Animals (17)
3.Dauta (write bird)
5.Beba (butterfly)
6.Kapiwa (bee)
7.Kakanukwa (small crab)
10.Kweviviya (bird)
11.Posisikwa (little bird)
17.Sakausasa (bird)
18.Sakaupauli (2birds which usually fight early in the morning in coconut trees)
22.Kemagu (crab)
25.Sem (shoal of fishes)
28.Uligova (alligator)
29.Kuluwawaya (red ant)
35.Kaukwa (dog)
36.Bunukwa (pig)
48.Subuvinu (black ant)
52.Kwadoya (possum)
57.Metalibu (stoup)
Takwau (shark) (2 players)

Plants (7)
20.Samuam Leya (ginger)
21.Butia (flower)
26.Vivi (nut)
39.Seda (nut)
40.Mweya (kind of long bean eaten with buwa)
47.Udi (banana)
51.Kapwatala kapwatawaku (kapwatawaku = name of a big tree)

People or action (14)
2.Tobasi (to spear)
9.Gwadi (child)
12.Nekura Mada (group of people)
16.Mina Kaibola (Man from Kaibola)
23.Tobutu topola (Tobutu = fisherman chasing the fish- topola = fisherman with net)
24.Guyau-bolu-guyavila (chief-cup- wife of the chief)
30.Tosalilagelu (person cutting a canoe)
32.Vivilua (name of a person)
38.Kalamolu Nageta (Nageta is hungry)
43.Ilowosi (traditional circular dances)
49.Toliu (name of a person – stick in the nose?)
50.Tadoyai (to peep? putting the head out of something)
55.Tokwelasi (adultery)
Tapwawa (child?) – 2 players

Meaning forgotten (5)	Tricks
19.Tokopokutu 27.Tubum 56.Sileu 58.Mbanekua Tagegila – 2 players	Tutulobasi (Meaning forgotten) Tokwemtuya (Meaning forgotten) Daweku (Meaning forgotten) Mistakam-mistamun (Meaning forgotten) Im (Pandanus roots) – trick Boku (to cough)-trick

Chaco Corpus

The names in bold are written in the language of the Guarani-Ñandeva. Otherwise they are given in Spanish.

Objects (15)	
1. Estrellas (Stars) 8. La guitarra (Guitar) 10. Trampa (Trap) 12. Casita (Little house) 15: Series II – 3rd figure: Hamaca (Hammock) 16. **Jasytata** (Star) 18. Porton (Gate) 27. Estrella (Star)	31. **Uyrapa** (Arc) 38. Series IV (1st figure): Pala (Shovel) 37. Red (Net) 41. **Ajo** (Bag) 39. **Re** (2) (Net) 40. Hamaka (Hammock) 41. **Angirà** (Chair)

Animals: objects made by animals (23)	
3. La pata de puma (The leg of the puma) 4.Pata de avestruz (The leg of the Ostrich) 5. Murcièrlago (Flying fox) 6. Series I: Vibora (Snake) 7. Piel de Vibora (Skin of the snake) 11. **Paloma raity** (The nest of the bird Paloma) 13. **Mukune** (Small animal) 14. El nido (The nest) 15. Series II (1st figure): Huella de Vaca (Trail of the Cow) 15. Series II (2nd figure): Huella de avestruz (Trail of the ostrich) 21. **Kaurei** (Little Owl)	22. Hueso de Iguana (Bone of the Iguana) 23. Nido de Lorito (Nest of the bird “Lorito”) 24. Avestruz (Ostrich) 28. **Mbopi** (Flying fox) 29. **Jagua** (Dog) 30. **Tapiti** (Rabbit) 33. **Tukatuka** (Mole) 34.**Tatoui** (Small “Tatu” = small animal) 36. **Karumbe** (Turtle) 37. Series III (2nd figure): **Tatu** (small animal) 38. Series IV (2nd figure): Huella de “**Wanako**” (trail of the “Wanako”) 38. Series IV (3nd figure): **Ovecha ija** (trail of the Goat?)

Plants (8)	People (2)
2. **Sanja** (Small Watermelon) 9. **Sapalio** (A Fruit) 19. **Supua** (A Fruit) 20. Najanra (Orange) 25. **Samuù** (Big Tree) 26**. Palo Santo** (Big Tree) 37. Series III (1st figure): **Sapalio** 37. Series III (3rd figure): **Tronco (?)**	17. **Timaka** (Knee) 37. Series III (1st figure): Hombre (Man)

Annex III: The Procedure *Salibu* Throughout Oceania

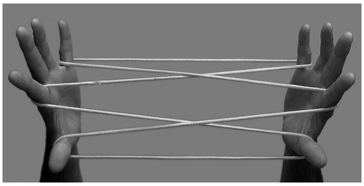
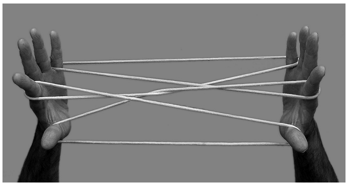
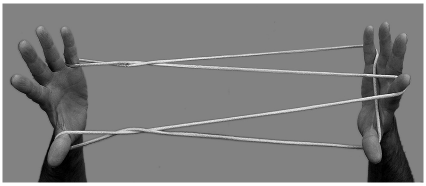
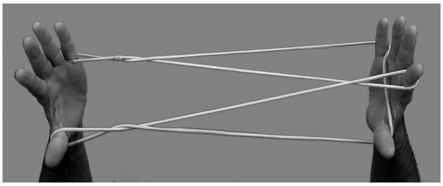
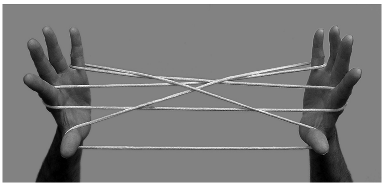
The string figure called *Salibu* in the Trobriand Islands is decribed in almost every collection from Oceania. I found this procedure 16 times in ethnographical papers. I have personally recorded it in the Marquesas, Vanuatu and Papua New Guinea. The slight variations of one of these procedures to another lie mainly in the way $Conf(A)$ or $Conf(B)$ is reached from $Opening A$.

Name	Location	Reference	Sub-procedure to reach Con(B) or Conf(A)
Salibu (mirror)	Trobriand Is.	Personal finding	Opening A. Release 1 Teeth seize 5f (see Sect. 9.2.1.3) Towards Conf(B)
Wayu (a variety of yams)	Northern Ambrym I. Vanuatu	Personal finding	Same as “Au kape” below
Au kape (taro leaf)	Ua Pou Marquesas Is.	Personal finding	Opening A. Release 1 R1 hooks down 2n & 2f & 5 R2 hooks up 5f ...(see Sect. 6.4.1) Towards Conf(B)
Koukape	Marquesas Is.	Handy (1925, p.29)	Same as “Au kape” without hooking down 2n & 2f & 5
Nab’a (number?)	D’Entrecasteaux Is. PNG	Jenness (1920, p.306)	Same as “Salibu”
Nuvo (net)	Fenualoa Solomon Is.	Maude (1978, p.192)	Opening A Making of a small loop with 5f ... Towards Conf(B)
Rau kape	Tikopia	Maude and Firth (1970)	Same as “Salibu” however L2 (instead of R2) picks up right Teeth string Towards Conf(A)
Crocodile	North Queensland Australia	Davidson (1941, p. 844–45)	Same as “Au kape” “ however “Release 2” done after “R2 hooks up 5f”
Beira	Buna District PNG	Rosser and Hornell (1932)	Same as “Salibu”. Towards Conf(B)

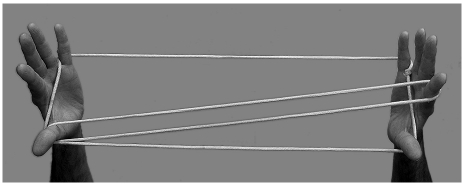
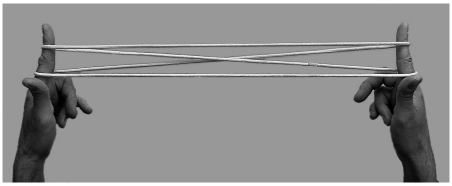
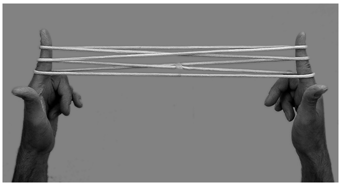
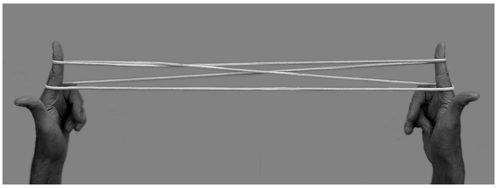
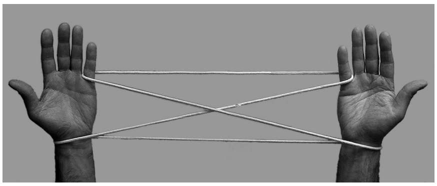
Loukape Kabe leaf	Vavau I., Tonga Western Polynesia	Hornell (1927, p. 67)	Same as “Salibu”. Towards Conf(B) (At the end, 3 operate before the Navaho)
Imbi (The mat)	Ovalau I. Fidji	Hornell (1927, p. 45–46)	Same as “Au kape” L2 & L1 operate (instead of R1&R2) Towards Conf(A). “Lou kape” ending
Nameless	New Caledonia	Compton (1919, p. 218)	Same as “Imbi” Without hooking down 2n & 2f & 5 Towards Conf(A)
Gomakian (A kind of taro)	Saibai I. Torres Strait	Maude (1987, p.16–17)	Same as “Au kape”
Mother	Mont Hagen, Highland PNG	Shishido and Noguchi (1987, p. 45–46) Noble (1979, p. 150–151)	Same as “Salibu”. But Teeth string picked up by the thumbs Towards Conf(B)
Ten men	Natik Carolines Is.	Jayne (1962, p. 150–151)	Same as Salibu But “Release 1” occurs after picking up teeth strings with 2 (right side by L2 first) Towards Conf(A)
Tonga Raurepe	New Zealand	Andersen (1927, p. 142–143)	Same as “Ten men”
Mageogeo	Tuamutus	Maude and Emory (1979, p. 7–8)	Same as the “nameless” from New Caledonia (above)
Ba ni mai (Leaves of Breadfruit)	Onotao Gilbert Is.	Maude and Maude (1958, p. 102–103)	Same as “Salibu” But L2 operates first. Towards Conf(A)
The ten men	Nauru	Maude (1971, p. 5–6)	Same as “Salibu”

Annex IV: Classification of the Openings

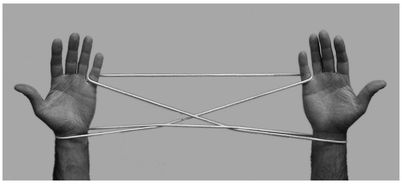
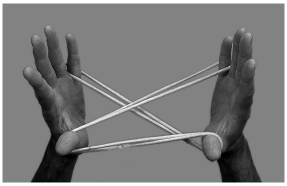
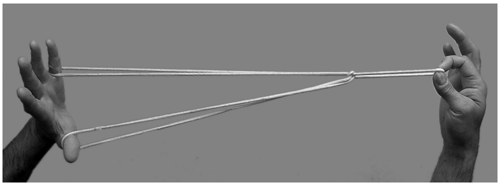
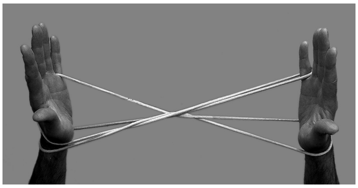
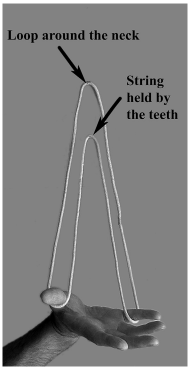
Trobriands Corpus

Openings A_i	*Kaninikula*	*Occurrence*
 Opening A	2-4-5-6-9-17-20-25-26-27-28-31-32-33-34-35-38-40-41-42-43-44-45-46-47-50-51-52-53-54-55-56-58	33
 Opening A_1	18 - 57	2
 Opening A_2	1	1
 Opening A_3	22	1
 Opening A_4	24	1

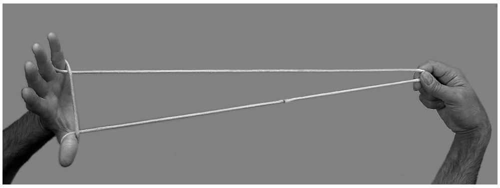
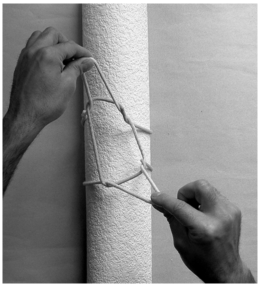
(continued)

Openings A_i	*Kaninikula*	*Occurrence*
 Opening A_5	19	1
Openings M_i	*Kaninikula*	*Occurrence*
 Opening M	11 - 12 - 21 - 23 - 29 - 30 - 36 -39	8
 Opening M_1	37	1
 Opening M_2	48-10	2
 Opening M_3	3	1

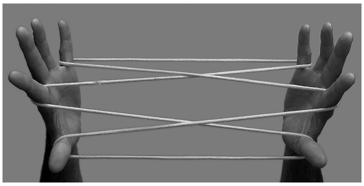
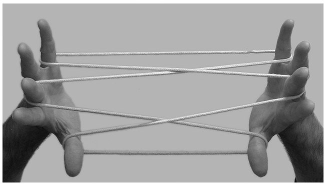
(continued)

Openings M_i	*Kaninikula*	*Occurrence*
 Opening M_4	8	1
Openings S_i	*Kaninikula*	*Occurrence*
 Opening S_1	7	1
 Opening S_2	49	1
 Opening S_3	16	1
 Opening S_4	14	1

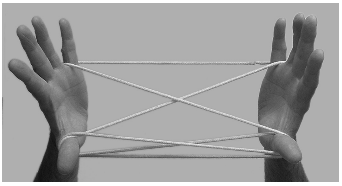
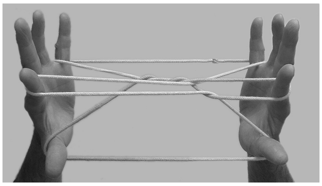
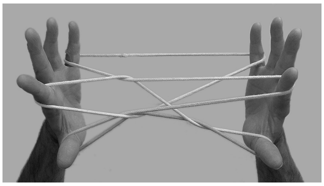
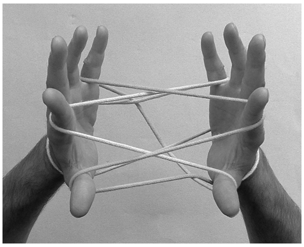
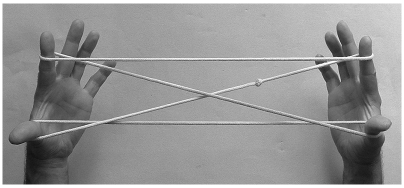
(continued)

Openings S_i	*Kaninikula*	*Occurrence*
 Opening S_5	15	1
 Opening S_6	13	1

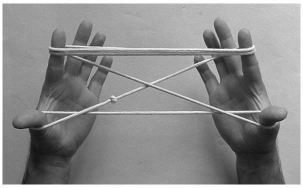
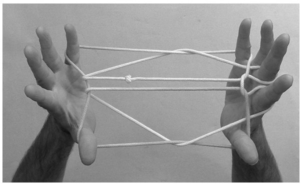
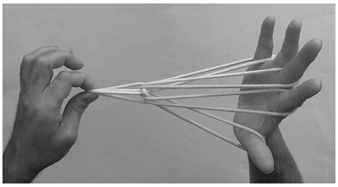
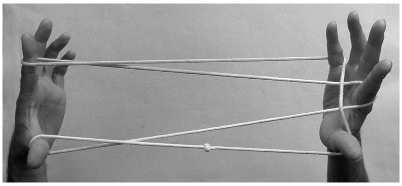
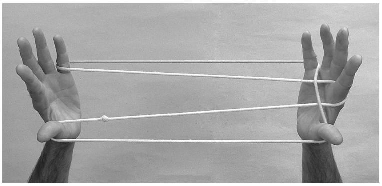
Chaco Corpus

Openings A, A_m and A_*	*String figures*	*Occurrence*
 Opening A or Opening A_m	1-3-11-16-18-19-23-25-27-29-30-32-35-39	14
 Opening A_*	10	1

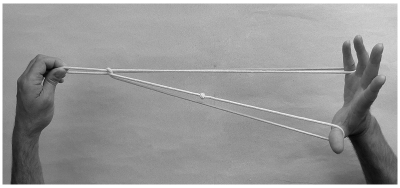
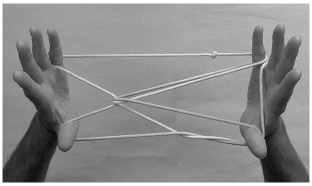
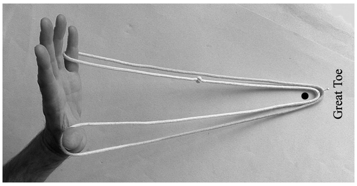
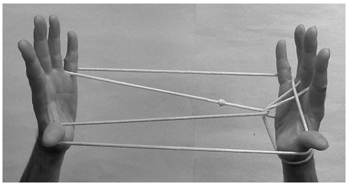
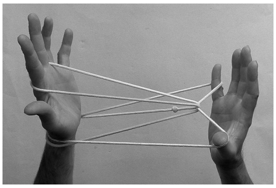
(continued)

Openings A_i	*String figures*	*Occurrence*
 Opening A_6	37	1
 Opening A_7	4	1
 Opening A_8	26	1
 Opening A_9	33	1
Openings N and N_1	*String figures*	*Occurrence*
 Opening N	2-6-12-14-17-20-21-31-34-36	10

(continued)

Openings N and N_1	*String figures*	*Occurrence*
 Opening N_1	7	1
Openings L_i	*String figures*	*Occurrence*
 Opening L_1	15	1
 Opening L'_1	5	1
 Opening L_2	22	1
 Opening L'_2	28	1

(continued)

Openings P_i and Openings W_i	*String figures*	*Occurrence*
 Opening P_1	8-38	2
 Opening P_2	9	1
 Opening P_3	40	1
 Opening W_1	13	1
 Opening W_2	24	1

The tables above refer to 40 *tukumbu*. The missing one is the string figure 41.*Angirà* (chair) which is the simple 3 dimensional figure also made by the Trobrianders (13.*Sopi*—See Opening S_6 in the classification of the Openings of the Trobriander string figures).

Terminology: Summary Tables

Haddon & Rivers' Nomenclature

Adjectives	Part of the hand
Radial	Towards the thumb
Ulnar ("Ulnaire" in French)	Towards the little-finger
Palmar ("Palmaire" in French)	Across the palm
Dorsal	Across the back of the hand
Distal	Near the tip of finger
Proximal	Near the wrist

Storer's Systemology

Functors	
Symbols	*Definition*
1	Thumb
2	Index
3	Middle finger
4	Ring finger
5	Little finger
Ri	i th finger of the right hand
Li	i th finger of the left hand
R, L, B	Right Hand, Left Hand, Both Hands
M	Mouth
T	Great toe
W	Wrist

Objects	
Loops	
∞	Loop
$Li\infty$	Loop carried by ith finger of the left hand
$Ri\infty$	Loop carried by ith finger of the right hand
$i\infty$	Both $Li\infty$ and $Ri\infty$
$W\infty$	Loop on the wrist
Strings	
Lif	Far (or ulnar) string of the loop carried by the finger Li
Rin	Near (or radial) string of the loop carried by the finger Ri
if	Entire string encompassing the connected Lif and Rif
in	Entire string encompassing the connected Lin and Rin

Openings – Sub-procedure – Extension			
Openings		*Sub-procedure*	
$\underline{O}$	*Opening*	N	Navaho(ing)
$\underline{O}.A$	*Opening A*	$N(1)$	Navaho the thumbs
$\underline{O}.M$	*Murray Opening*	$\ldots$	
$\underline{O}.N$	*Navaho Opening*	*Extension*	
$\ldots$		$\vert$	Extend the string, palms facing each other

Operations on loops	
Releasing	$\square Ri, \square Li, \square Ri\infty, \square i\infty, \ldots$
$\square$	Releasing a finger or a loop
$\square R2\infty$	Release $R2\infty$
$\square 2\infty$ *or* $\square 2$	Release both 2∞
$\ldots$	
Passing (over/under)	$\overrightarrow{F\infty}\ (F'\infty),\ \overleftarrow{F\infty}\ (F'\infty),\ \underrightarrow{F\infty}\ (F'\infty), \ldots$
$\overrightarrow{1\infty}\ (3\infty)$	1∞ move away from the practitioner over 3∞ (and over all intermediate strings, if any)
$\underleftarrow{5\infty}\ (2\infty)$	5∞ move towards the practitioner under 2∞ (and under all intermediate strings, if any)
$\ldots$	
Transferring	$\underrightarrow{i\infty} \rightarrow j,\ \ \overleftarrow{i\infty} \rightarrow j, \ldots$
$\rightarrow$	"to transfer"
$\overrightarrow{1\infty} \rightarrow 3$	1∞ move away from the practitioner and over all intermediate strings (if any), then 1∞ is transferred to 3

(continued)

Operations on loops	
$\underleftarrow{5\infty} \rightarrow 1$	5∞ move towards the practitioner and under all intermediate strings (if any), then 5∞ is transferred to 1
...	
Rotations	$< Ri\infty,\ > i\infty,\ >> i\infty,\ << i\infty, \ldots$
$>$	Rotating a loop 180° clockwise (for an observer located to the left side of the practitioner)
$<$	Rotating a loop 180° anticlockwise (for an observer located to the left side of the practitioner)
...	
Inserting	$\overrightarrow{F\infty} \downarrow (F'\infty)\,,\ \overleftarrow{F\infty} \uparrow (F'\infty)\,,\ \underrightarrow{F\infty} \downarrow (F'\infty)\,, \ldots$
$\overrightarrow{1\infty} \downarrow (5\infty)$	1∞ move away from the practitioner and over all intermediate strings (if any), then 1∞ pass from above through 5∞
$\underleftarrow{5\infty} \uparrow (2\infty)$	5∞ move towards the practitioner and under all intermediate strings (if any), then 5∞ pass from below through 2∞

References

Andersen J (1927) Maori string figures. Board of Maori Ethnological Research, Memoirs, vol 2. Board of Maori Ethnological Research, Wellington. (Reprint edition 1979, AMS Press, New York)

Compton RH (1919) String figures from New Caledonia and Loyalty Islands. J R Anthropol Inst G B Irel 49:204–236

Cunnington WA (1906) String figures and tricks from Central Africa. J R Anthropol Inst G B Irel 36:121–131

Davidson D (1941) Aboriginal Australian string figures. Proc Am Philos Soc 84:763–901

Evans-Pritchard EE (1972) Zande string figures. Folklore (London) 83:225–239

Handy WC (1925) String figures from the Marquesas and Society Islands. Bishop Museum, bulletin, vol 18. The Museum, Honolulu

Hornell J (1927) String figures from Fiji and Western Polynesia. Bishop Museum, bulletin, vol 39. The Museum, Honolulu. (Reprint edition 1971, Germantown, New York: Periodicals Service Co)

Hornell J (1932) String figures from Gujarat and Kathiawar. Mem Asiat Soc Bengal 11(4):147–164

Jayne CF (1962) String figures and how to make them: a study of Cat's cradle in many lands. Dover, New York (A reprint of the 1906 edition entitled "String Figures", published by Charles Scribner's Sons, New York)

Jenness D (1920) Papuan cat's cradles. J R Anthropol Inst 50:299–326

Maude H (1971) The string figures of Nauru Island. Libraries board of South Australia occasional papers in Asian and Pacific studies, vol 2. Libraries Board of South Australia, Adelaide

Maude H (1978) Solomon Island string figures. Homa, Canberra

Maude H (1987) String figures from Torres Straits. Bull Intern String Fig Assoc 14:1–35

Maude H, Emory K (1979) String figures of the Tuamotus. Homa, Canberra

Maude H, Firth R (1970) Tikopia string figures. Royal Anthropological Instutute of Great Britain and Ireland, occasional paper, vol 29. Royal Anthropological Institute, London, 63 p.

Maude H, Maude HE (1958) String figures from the Gilbert Islands. J Polyn Soc, Memoir 13:161
Noble PD (1979) String figures of Papua New Guinea. Institute of Papua New Guinea Studies, Boroko
Rosser WE, Hornell J (1932) String figures from British Guinea. J R Anthropol Inst 62:39–50
Shishido Y, Noguchi H (1987) Some string figures of Highland people in Papua New Guinea. Bull Intern String Fig Assoc 14:38–69

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