

Spaces of Thinking

Flavia Santoianni

Ease of recognition may be strongly affected by what information is explicit in a representation, and what is only implicit.

Larkin and Simon 1987

It is especially important to determine how the symbol systems of maps and diagrams interact with pre-attentive psychological processes... A person cannot therefore willfully influence them.

Winn 1991

The pre-attentive visual processes draw from cognitive resources that do not interfere with those required for attentional processing.

Nesbit and Adesope 2006

Abstract Spatial representations have been considered for their high didactical efficacy, as *concept maps* and *mind maps*. Graphical and spatial representations may be seen as key elements of knowledge management and may contribute to enhancing spatial knowledge. Even if isomorphisms between the physical and the mental dimension can be controversial in the field of spatial knowledge, it is nevertheless interesting to study the role of spatial interpretation in knowledge management processes. In science education, spatial skills are actually highly required due to the development of new technologies and their highly demanding spatial tasks they often work intertwined with other abilities, such as logical reasoning and verbal skills. Despite spatial knowledge being significative in the overall field of learning management, there is instead little research that shows its complex role in the comprehension of concepts in the humanistic fields, e.g. in philosophical conceptual reasoning. The *Elementary Logic Theory*—which underlies the philosophical maps of this Atlas—identifies at the basis of complex thinking prototypical knowledge units that may be activated in the possible collaboration between explicit and implicit thinking. In *EL Theory*, spatiality is considered the most suitable transition format for the hypothesized collaboration between implicit and explicit processing because it shares common aspects with both of them. The focus of *EL Theory* is to research particularly the role of the implicit in knowledge comprehension through spatial representations. In this Atlas, the role of *Elementary*

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Logic Theory is highlighted in shaping philosophical knowledge and comprehension of philosophical concepts and their intertwining.

Scientific areas of research usually refer to graphical representations to deepen the understanding of scientific phenomena (Larkin and Simon 1987; Miller 1996; Mohler 2008); in particular, attention has been focused on graphs (Roth et al. 1999). Spatial representations have also been considered for their high didactical efficacy, as *concept maps* (Novak 1998; Novak and Gowin 1984) and *mind maps* (Buzan and Buzan 2000). The graphical representation of knowledge through maps has been described as a way to express meanings inherent in the material to be learned according to its property of explicitly expressing relations between ideas, theories, and concepts.

Graphical and spatial representations may be seen as key elements of knowledge management and may contribute to enhancing spatial knowledge, which in its most elemental type may be considered the knowledge of the identities and appearances of objects or environmental features (McNamara et al. 2008). In this last sense, *landmark knowledge* is recognized as the first building block of other spatial knowledge (Siegel and White 1975). Sequences of landmarks are represented by *route knowledge*, which consists of discrete chunks of information representing sequential locations (Hirtle and Hudson 1991) allowing one to get from one point to another (Taylor and Tversky 1992). Procedural descriptions are in fact related to the sequential records of the space involved.

Survey knowledge may instead give an overall picture of a context as an aid in orientation, resembling a ‘map in the head’ (Kuipers 1982) which locates objects in a general frame of reference (Hirtle and Hudson 1991). It gives a *configural*¹ holistic representation about the location of objects (Taylor and Tversky 1992). The overall configuration of an environment and its definition within a common reference system is regulated by survey knowledge, the most sophisticated type of spatial knowledge, which is also referred to as a cognitive map (Tolman 1948). Even if isomorphisms between the physical and the mental dimensions can be controversial in the field of spatial knowledge (McNamara et al. 2008), it is nevertheless interesting to study the role of spatial interpretation in knowledge management processes. Just as a geographical map is used to orient oneself in a territory, a concept/mind map may be considered a tool to interpret and process knowledge, displaying links between concepts and developing paths of reasoning (Gineprini and Guastavigna 2002).

In science education, spatial skills—the capacity to understand and remember the spatial relations among objects—are enhanced to construct, from verbal descriptions in textbooks, mental models of objects which may sustain the mastering of the subject matter. More in general, spatial skills are actually highly required due to the development of new technologies and their highly demanding

¹The terms featural and configural may be used, respectively, to refer to procedural/route-like and holistic/map-like representations.

spatial tasks; they often work intertwined with other abilities, such as logical reasoning and verbal skills.

Despite spatial knowledge being significant in the overall field of learning management and the fact that it is deeply studied in its several aspects in relation to scientific areas and STEM fields (Metz et al. 2012), there is instead little research that shows its complex role in the comprehension of concepts in the humanistic fields, apart from its general didactical sense—e.g. in philosophical conceptual reasoning (Santoian 2014a). Moreover, the improvement of spatial knowledge is related to environmental factors, the manipulation of which through educational experience may increase learning performances. This aspect implies an educational interest towards this research topic and makes it attractive for experimental research in the human sciences.

A key related point concerns the relationships between spatial knowledge and language; for instance, while graphs are mainly considered as topological, verbal linguistic representations may be seen as typological (Bastide 1990), due to their categorizing character. The graphical and spatial representations that combine topological and typological features should be more effective, as they represent multimodal expressions—as in Paivio's *Dual Coding Theory* (Paivio 1986)—even if the phenomenon known as *verbal overshadowing*² has to be considered (Fiore and Schooler 2002).

In concept/mind maps—which can be seen as an example of topological spatial representations—graphical representation of concepts are connected by lines that make explicit the internal relationship between these concepts within a geometric shape, through linking words that may express relations of sequentiality (and comparison), and inference. In the field of spatial knowledge, scholars have recently focused on environmental shape and its role in learning processes. Learners are indeed sensitive to contextual geometry in new environments (Shelton and McNamara 2001) which is an aid to orient oneself in them (Schmidt and Lee 2006; Hartley et al. 2004; Hermer and Spelke 1994).

Instead, in the *Elementary Logic Theory* (Santoian 2011, 2014b)—which underlies the philosophical maps of this Atlas—the foreseen relations between concepts are more than the ones envisaged by conceptual and mind maps. *EL Theory* model concerns the *spaces of thinking* represented by elementary logics, to be understood as the knowledge prototypes that express the logical relationships underlying the organization of concepts in language and mathematics, and probably in other fields of knowledge, both theoretical and practical.

According to *EL Theory*, explicit knowledge is developed in relation to implicit functions of thinking, which may be interpreted as cognitive antecedents constantly active in cognitive processing, both in the early stages of conceptual development and as primitive forms of cognitive organization. Implicit knowledge may operate as a default level to be activated on demand regarding cognitive tasks in an individual's lifespan.

²This overshadowing is caused by verbalization and is evident in various forms of cognition; it consists of an impairment of *configural* processes in favour of *featural* representations.

Table 1 Elementary logics

ADD	Integration	Putting together two or more conceptual elements or addition of a conceptual element to a set of pre-existing elements
CHAIN	Sequentiality	Concatenation of two or more conceptual elements that are correlated under the relationship of the consequential links between them
EACH	Individuation	Focusing on one or more conceptual elements within a set of elements, distinguishing it/them from others
COMPARE	Comparison	Comparing two or more conceptual elements and the recognition of the possible similarities and differences between them
FOCUS	Inference	Deductive and inductive process according to which a conceptual element can be in a derivative relation with others
LINK	Correlation	Non-systematic identification of possible links between more conceptual elements related by connection points with a specific bridge function

Implicit functions play the role of prototypes of the possible models of explicit knowledge and are involved in the continuous cognitive collaboration with it through dynamic patterns as modes of connection between the two levels. Logical functions that may regulate these dynamic patterns are represented by elementary logics of thinking and by their spatial representations. Elementary logics underlie linguistic and mathematical thinking and may be expressed by spatial representations. In *EL Theory*, elementary logics are systematized in three classes—*union*, *separation*, and *correlation*—each subdivided in two functions: *integration* and *sequentiality* (union), *individuation* and *comparison* (separation), *inference* and *correlation* (correlation). Everyone learns through a combination of elementary logics (Table 1).

Indeed *EL Theory* identifies at the basis of complex thinking prototypical knowledge units that may be activated in the possible collaboration³ between explicit and implicit thinking. Linking words and word tags—characteristic of the spatial structure of maps in traditional literature (see Sorrentino in this volume)—are substituted by logical and mathematical symbols (Table 2). The significance of graphical representations in the spatial comprehension of knowledge concepts is here studied mainly in its implicit dimension, without necessarily referring to its possible explicit expression.

In *EL Theory*, spatiality is considered the most suitable transition format for the hypothesized collaboration between implicit and explicit processings because it

³EL Theory proposes the hypothesis that the function performed by implicit learning may be integrative with regard to the explicit, thus overcoming the *polarity fallacy* (Reber 1993)—this is a crucial node of discussion in literature (Santoianni 2014a, b). In this case it could be *on demand*, to be activated at the request of the explicit in respect to the specificity of any cognitive task or to environmental requirements. Its presence in the cognitive system would be justified by its functional role of adaptive nature in philogenesis as in ontogenesis.

Table 2 Elementary logics symbols

ADD	<i>Integration</i>			
CHAIN	<i>Sequentiality</i>			
EACH	<i>Individuation</i>			
COMPARE	<i>Comparison</i>			
FOCUS	<i>Inference</i>			
LINK	<i>Correlation</i>			

shares common aspects with both of them (Lleras and Von Mühlenen 2004; Haun et al. 2005) (Table 3).

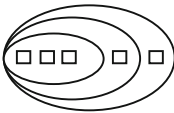
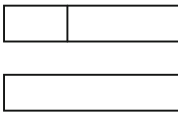
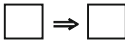
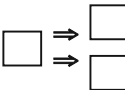
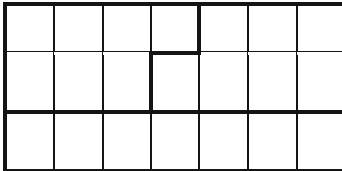
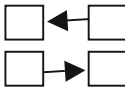
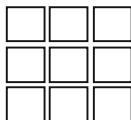
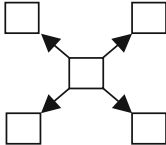
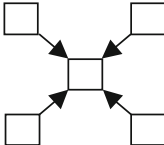
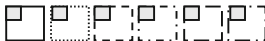
Even if both implicit and explicit may contribute to the cognitive activity processes, the focus of *EL Theory* is to research particularly the role of the implicit in knowledge comprehension through spatial representations.

However, spatiality of visual processing can be explicit or implicit. At the phylogenetic level, knowledge prototypes may have been characterized by only partially aware functions of recognition and identification (Ramachandran 2004) and by implicit spatial maps with an adaptive role which have anticipated the explicit linguistic thinking (Siegler et al. 1996). At the ontogenetic level, brain regions involved in visuospatial tasks seem to be correlated to automatic modes of thinking, while brain regions close to language centres appear to regulate the explicit expression of thinking, more related to the verbal sphere (Smith and DeCoster 2000). The relationship between visual processing and implicit processing is thus a characteristic of visuospatial representations (Chun and Jiang 1998). In the cognitive field, the nexus of the spatial representations of the schematic type (diagrams) with explicit processing has been recognized.

Visual processing appears to be one of the most significant aspects in spatial thinking development, which implies engendering internal non-linguistic mental images (Gardner 1983). Both explicit and implicit learning can be configured in internal images with a peculiar structure and definition in space (Entwistle and Smith 2002; Hollands and Spence 2001), and in mental models (Morra 2001) which can be stored in specifically spatial representational formats (Robinson et al. 1999).

Spatial representations have been traditionally distinguished from textual representations because the latter may contain implicit information about the logical

Table 3 Elementary logics and spatial representations

IMPLICIT ELEMENTARY LOGICS				IMPLICIT AND EXPLICIT SPATIAL REPRESENTATIONS		
PARALLELISM	SEQUENCE	UNION	ADD	<i>Integration</i>		
			CHAIN	<i>Sequentiality</i>		
		SEPARATION	EACH	<i>Individuation</i>		
	COMPARE		<i>Comparison</i>			
	CORRELATION		FOCUS	<i>Inference</i>		
		LINK	<i>Correlation</i>			

relationships between the parts of a text, while the spatial arrangement of textual information implies the idea that these relationships can be made explicit. As Larkin and Simon wrote in their famous article of 1987, diagrammatic representations are distinguishable from sentential representations because they can make explicit the implicit relationships possibly hidden between the different parts of a text (Larkin and Simon 1987). Spatial diagrammatic representations have been defined as *visual*

organizers of thinking patterns which reflect the structure of knowledge contents (Clarke 1991) and play a significant role in learning management. The effectiveness of schematic representations (*graphic organizers*) lies therefore in the learner's possibility to explicitly identify the logical relations between parts of a text, in a more or less direct connection with the subsequent linguistic traceability characteristic of explicit learning (Santoian 2006).

Graphical and spatial representations may be a learning facilitator (Nesbit and Adesope 2006). However, in some cases—such as the interpretation of unfamiliar graphs by scientists—the understanding of the meaning of a graph may be not self-evident as occurs with familiar graphs. It would instead be the result of a complex inferential process (Roth and Bowen 2003). The lack of familiarity with a specific representation, its contextual signs and inherent conventions, may be then an impediment to spatial encoding processes. So the cognitive system must make a verbal effort to elaborate and explain graphical representations.

According to this view, familiarity with a graphical representation may be due to its adaptive use and, in this sense, it can imply the involvement of the implicit processing. Following an evolutive model of implicit learning, implicit processing could originate from phylogenesis as the oldest form of learning—a process 'at the root' of the behavioural adaptive repertoire of every complex organism—appearing prior to the human race's explicit linguistic manner of communication (Reber 1992, 1993). Implicit learning could be a form of prototypical⁴ cognitive processing (Santoian 2011), linked to spatiality (Huttenlocher et al. 1991; Crawford et al. 2000), which can be used adaptively even in ontogenesis to represent the structure of the environment to solve problems and to produce basic—that can also be abstract—knowledge (Reber 1989).

In adaptive learning environments (Santoian 2007), there may be predefined maps to provide adaptive learning guidance for learners (Shian-Shyong et al. 2007). To be effective, these maps should be built according to scientific models, to simplify and clarify abstract concepts, and to explain and understand theories (Dori and Barak 2001). Models can contribute to visualizing complex ideas, processes and systems. But what kind of scientific model could be used to organize maps in the humanities?

In this Atlas, the role of *Elementary Logic Theory* (Santoian 2011, 2014b) is highlighted in shaping philosophical knowledge and comprehension of philosophical concepts and their intertwining. The use of graphical and spatial representations in the humanities—a field domain strictly dominated by linguistic expression—may be justified precisely by the role that adaptive processes play in any learning situation (Santoian 2007). And, if the familiarity with a graphical representation is enough for a cognitive system to read it without the aid of linking or tag words, the continuative use of graphical and spatial representations in a humanistic field, like philosophy, may enhance philosophical and spatial mastery through implicitly linked map-like representations, such as *EL maps*.

⁴See *knowledge prototypes* (Lambiotte et al. 1989; O'Donnell et al. 2002).

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