# Clark Lecture in 1968 "Processes of Cognitive Growth: Infancy"

**Jerome S. Bruner**

## Introduction

Distinguished colleagues, ladies and gentlemen. I am deeply honored and personally moved to be the Heinz Werner Lecturer. For Heinz Werner was a man whose stature and purpose give dignity and substance to the study of development. He was a daring man who combined the insights of anthropology, biology, and psychology in his studies of the nature of development, one of those rare psychologists who took it as a working tenet that man had a mind but also a body that mattered, and lived in a society that mattered. Heinz Werner delighted to teach and to discuss. Although I was, so to speak, never duly enrolled, I was often the beneficiary of his teaching and his discussion. He was a quarter century my senior. He made us all feel like comrades of the quest. I am honored to be at Clark again, helping to keep lively the memory of this great and generous man.

Let me say a word at the outset concerning the plan of these two lectures. Originally, I had hoped to give over the first lecture to human infancy—roughly the period from birth to the appearance of rule-bound grammatical discourse at about two years of age. In the second lecture, we were to turn to the nature of cognitive development in childhood, rather arbitrarily setting the upper limit at the age of puberty. I am, at this juncture, actively involved in research on infancy. You will forgive me if my original resolve failed me. Both lectures will deal with infancy and what kind of prolegomenon to human life it is.

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J.S. Bruner (✉)
Director of the Center for Cognitive Studies, Harvard University, Harvard Graduate School of Education, 13 Appian Way, Cambridge, MA, USA
e-mail: jerome.bruner@nyu.edu



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Like Heinz Werner, I take it as a working premise that growth cannot be understood without reference to human culture and to primate evolution. Human beings, uniquely among species, grow in a fashion that permits them to participate in human culture, to use its language, its kinship system, its technological way of organizing work. As Lévi-Strauss (1963) has pointed out, the base structure of culture involves three forms of exchange: of symbols through language, of mates through human kinship, and of artificial goods and services through economy—all species-specific to *Homo sapiens.* I believe all three of them are supported by powerful biological predispositions, shaped in the course of primate evolution. Plainly, there is an important innate component in language acquisition (e.g., Lenneberg 1967; McNeill 1966) quite unlike anything to be observed in the primate series (compare the closely studied communication system of the *macaque,* Rowell and Hinde 1962). There may be a beginning among the great apes of a mutuality and exchange that presages human kinship. But in humans, the pattern reaches its classificatory form supported by language and reinforced further by such new and stable patterns of mother-infant interaction as eye-to-eye contact and mutual smiling (cf. Robson 1967 and Freedman et al. 1967). Finally, there appears to be as well an innate capacity for tool-using and tool-making that is the fruit of a long and detailed set of evolutionary changes such as increasing bipedalism, differentiation of power and precision grip, more ductile phalanges, increased and less mediated neural representation for the hands and fingers. Man's biological endowment and his position in primate evolution surely predispose him to the use of culture. His growth from infancy to adulthood reflects that predisposition.

This is not a proposal for a new teleology. I know that the danger of concerning oneself with the terminus of growth or evolution is that we assert covertly that the terminus *causes* growth to go in the direction it does. That would be an unpardonable teleology. Let me plead for a pardonable and heuristic one that asserts, simply and for convenience, that it helps to understand a course of growth if one knows where it is leading. Interestingly enough, such a teleology-of-convenience, the kind of workaday tacit assumption of most biologists, withers away as one gets a better sense of the mechanisms and processes involved in growth.

Let it he clear, however, that there are detailed consequences that ensue from an emphasis upon the terminus of growth. One, which we shall meet again in discussing the ontogenesis of the intelligent use of the hands, has to do with certain pre-adaptive structures that must he present in the child's behavioral repertory in order for his development to go in the direction it finally takes. However much experience is necessary for growth, the experience writes on a slate that is plainly predisposed to accept some messages more readily than others, the predispositions reflecting a long evolutionary history.

The existence of species-specific human behavior, moreover, should not obscure the fact that human intelligence and perception, while characteristically human, represent continuities of primate evolution from prosimians through the early hominids from which *Homo sapiens* emerged. Professor LeGros Clark (1963) is very compelling in his analysis of this continuity. There is a long trend toward increased dependence upon distance receptors, with specialization of the brain for processing information from these receptors that is crucial to an understanding of man's ways of mapping an enlarged environment. Similarly, the emergence of a sharply defined distinction between power grip and precision grip and of the functional-anatomical asymmetry of the hands has a long primate history, itself strongly influenced by the slow emergence of bipedalism. Man's capacity as a tool-user as we have noted, is hard to imagine without that history. Indeed, my colleague Trevarthen (1968) would urge upon us that the strong differentiation of a two-aspect visual system, the one focal, refined and identity-sensitive, the other ambient and sensitive to location and movement, is itself a resultant of primate evolution.

So in considering the early life of a member of our own species, it helps to bear in mind not only what the infant and child are developing *towards*, but also what they have developed *from.* But just as one must caution against future-state teleology, so one properly guards lest the evolutionary past lead one to a causal historical determinism. One cannot "explain" the development of human manipulatory behavior either by reference to its terminus in tool-using or by reference to the undisputed fact that it reflects patterns observed earlier in the primate series. Yet both forms of reference provide a working perspective. Without either of them, a developmental theory risks being sterile.

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The research upon which we shall focus in these lectures is designed to elucidate four great issues in human infancy. It is research very much in progress, and there are few definitive answers to he given. It is nonetheless better, I think, to explore these issues in the context of this incomplete research so that they may be operationally tangible. The four great issues are these.

1. Through what processes does voluntary control of behavior develop? Obviously, voluntary control implies several highly specific forms of mastery. For one thing, it implies anticipation of a goal or an outcome and the choice of a means for achieving that goal. It implies, moreover, a certain freedom from immediate sensory control of behavior. Voluntary control also implies a capacity to sustain a direction of behavior longer than a single response, and the issue of sequential organization of responses must be faced. Finally, voluntary behavior implies skill: the ability to mobilize the intended response. In the very young infant, one finds none or critically few of these; there is imperfect anticipation, reflex response rather than choice of means, domination by stimuli, short-term acts to such a degree that it is difficult in a practical sense to know when longer acts begin or end. Finally, there is an absence of virtually all skills save in the oculomotor apparatus and in nutritional activity, principally sucking, of which more later. How, then, does the child grow in the course of a year from this helpless state to one in which he has such an effective capacity for voluntary control?
2. Through what means does the child gain control of his own attention? Put in another way: How does the child learn to orient in a way that reflects the needs of search and problem-solving rather than the mere tracking of sensory change? Inevitably, this must involve the infant's ability to represent his environment, to form a record of where things are and what uses they may serve. Such early representation—particularly the child's use in representation

of equivalence and identity rules—is a matter of some difference between Cambridge and Geneva, as those of you know who heard Professor Piaget's (1968), brilliant lectures here last year.

3. Through what form of learning does the infant progress from being a "one-track" enterprise, capable seemingly of one activity at a time, to a capacity for carrying out several lines of activity jointly or synergically? By the end of a year, there is little question that the infant is capable of doing things that are "parentheses within parentheses." How is this essential hierarchical embedding achieved?
4. Finally, how does the infant manage to begin a career of reciprocation and exchange that prepares him in such a degree for culture using in general and language using in particular?

We have been sampling, in our research, four activities better to understand the growth of voluntary control, the internalization of attention, the intercalation of several enterprises, and the mastering of reciprocity rules. All are crucial to the child's existence; all go through cataclysmic changes during the first year. They are feeding (notably sucking), looking, manipulating, and interacting with an adult.

Before we turn to these matters concretely, consider first the possible functions of infancy in the life cycle of the human being. Let me suggest three. One striking thing about human infancy is that the infant sensory apparatus yields information far beyond the capacity of the motor apparatus to use it. Before the child is able even to hold up bis head, his eye movements can be shown to be highly discriminating (e.g., Kessen 1967). The bases for size constancy seem well developed at six weeks though the infant can neither reach out nor locomote (Bower 1966). Does the damped down motor system make it possible for sensory scanning to occur without the establishment of precocious habit? Closely related to this asymmetry of motor and sensory systems is a second fact: that the motor system, notably the part given to manipulation, is designed with far more degrees of freedom for movement than the infant can control for years. Early manipulation thus requires strategies for controlling these excess degrees of freedom. Later, tools again add more degrees of freedom to manipulation. But in an interesting way, they may represent a continuity with the way we master our own manipulatory behavior using only our own limbs. Finally, there is an extraordinary degree of dependency upon parental aid in the human infant in comparison with other primates. The hair-grasping reflexes (and the hair!) are gone, or virtually so. Given this dependence, there is a surprisingly primitive communications system with very little built into it at the outset. Communication, then, must be learned and must depend upon a reciprocal code that precedes language proper.

The net result of all this is, first, a prolonged period of scanning the environment without early motor commitment, so that the structure of space can be elaborated autonomously of action. I realize that it is not freely independent of action and that action helps shape it. Rather, I am speaking relatively. There is, second, a very slow process of motor mastery so that, after the dissolution of the first reflexive patterns discussed by Twitchell (1965), McGraw (1943), and others, there is required a succession of strategies for coping with excess degrees of freedom. This is the origin of human infantile clumsiness, and I shall argue that it serves an important role in the growth of uniquely human, tool-assisted skill. Finally, there is in human infancy a prolonged dependence upon adult tutelage and shaping, based on exchange of reciprocal signaling and interaction. In a word, human infancy appears to be a guarantor against the achievement of precocities of development, a period in which very general rules of skill, of perceptual organization, and of interaction are learned in preparation for later, species-specific forms of human achievement in action, perception, and communication. In this sense, infancy can be conceived almost as a shield against premature specialization.

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## The Integration of Multiple Activities

Consider first the growth of feeding and sucking. What light can they shed on the critical issues with which we began our discussion? Let me begin by recalling some of the facts of sucking and the role of the mouth in early infancy.

Sucking serves several functions. It can be observed as early as the third gestational month (Peiper 1963). Though it is instinctive, it requires some priming to get started in the neonate, as we know from the work of Gunther (1961), and if not early exercised, may become difficult to evoke. At birth the infant may have certain difficulties beginning to suck, grinding jaws back and forth, missing the pressure, etc. Once he has "connected," so to speak, and I have observed as many as four five-second periods of trying before he does, the sucking is immediately highly expert. Sucking in very early infancy is with corners of the mouth shut, eyes usually shut, and with uniform pressure throughout the buccal cavity.

In addition to its role in feeding, sucking occurs non-nutritively, and the studies of Jensen (1932) and Wolff and Simmons (1967) indicate that this may serve either an antidistractant or analgesic function or both. Pin pricks and tickling of the face by a feather increase the sucking rate or lead to initiation of sucking. Indeed, it is now standard practice in some hospitals to carry out circumcision while the child is sucking on a favored pacifier. While relieving distress, sucking also inhibits the newborn infant's level of general activity (Kessen and Leutzendorff 1963), with effective suckers showing the greatest quietening (Kessen 1967). A variety of studies indicate that infants suck non-nutritively at about a con stant individual rate of 48–80/min whether hungry or not (Balint 1948; Bridger 1962). But at the same time, non-nutritive sucking has been shown to vary in rate as a function of the nature of the object provided for sucking—a nipple producing a better output than a polyethylene tube of comparable gauge (Lipsitt and Kaye 1964). The third function of the mouth is for exploration, and its importance in the organization of behavior will concern us shortly.

The mouth, from the start, is embedded functionally in several systems. For one thing, it is the aiming point in the head-turning system. A touch to the edge of the jaw or the side of the cheek will produce a rooting reflex with mouth moved toward the touch. It is also mapped into the arm-and-trunk system, as indicated by the Babkin and the palmomental reflexes; pressing the palm will produce mouth movements in the newborn, as will pressure on the ball at the base of the thumb produce contractions in the mentalis muscle of the jaw.

Now consider a few observations. The first has to do with the nature of the flexibility and voluntary control that gradually permeates this originally quite reflexive system of sucking. While, at the outset, sucking has a very compulsive property, closer examination of it shows in what measure it is, even in the first day of life, quite sensitive to changes in the environment that relate to it. A word about how one records sucking. Figure 1 provides a diagrammatic sketch of the system. It provides a means of measuring suctioning pressure on a polygraph, as well as the positive pressure of mouthing and pressing the nipple with the gums and tongue. At the same time we are enabled to deliver milk directly through the nipple to the baby in response either to positive or negative sucking or to some combination, and with what-ever contingency we choose. For not only does a record of the baby's sucking register on a polygraph, but also on a programming device that can be set to activate a milk-pulsing system each time the baby sucks in a specified way, every other time, etc. or at specified intervals of time after the baby has sucked. The device builds upon similar devices that have been used in recent years by kron et al. (1963) and by Sameroff (1965). Complicated though the instrument may seem in the context of infancy as lived, it is quite indistinguishable from an ordinary nursing bottle to the infant and mother, as Fig. 2 indicates.

Nutritional sucking is surprisingly flexible. Sameroff (1965) has shown in the neonate that when milk is delivered exclusively for mouthing, the negative

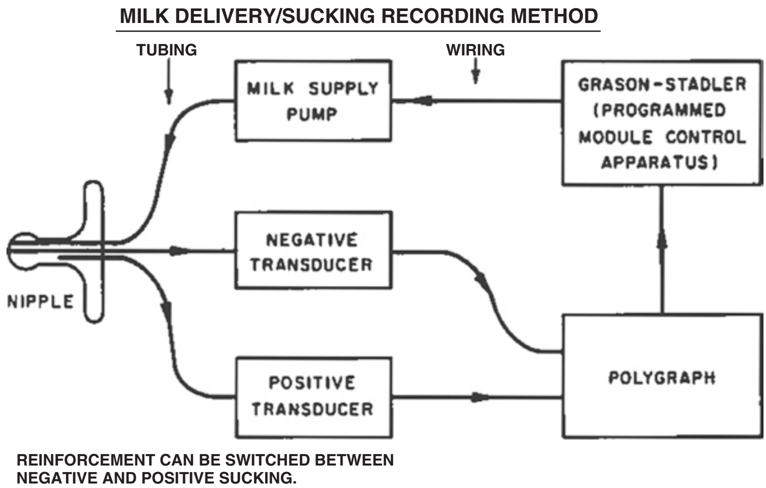


**Fig. 1** Diagram of sucking apparatus

**Fig. 2** Mother and infant with bottle part of sucking apparatus

or suctioning component will diminish. Indeed, if one establishes a certain level of required mouthing pressure to get milk, the infant within a minute or two will adapt to that level. But the adaptation will not carry over to the next feeding. The infant will begin anew at his own “natural” or signature level of pressure (or with mouthing and suctioning at original level). In our own laboratory, working with children a month of age or older, Hillman finds that over a session of fifteen minutes, suctioning will virtually drop out if mouthing alone produces milk. In subsequent sessions, though the infant begins with no sign of adaptation, he may more quickly adapt to the demands for mouthing rather than suctioning.

In another part of Hillman's experiment the child receives a pulse of his own formula milk at the end of a second if there has been any sucking during that second, or at the end of every two seconds if sucking has occurred in the two-second period. The learning that ensues is very interesting indeed, being much more akin to strategy-learning than to specific response acquisition. When a pulse of milk is delivered each second or every two seconds in which a suck has occurred, the effect on some babies is to shorten their sucking bursts. As you know, non-nutritive sucking and then nutritive sucking develop a burst-and-pause pattern, and usually by a month, there is a typical pattern of a burst of from eight to fifteen sucks followed by a pause that would correspond to some four or five sucks as illustrated in Fig. 3. In response to fixed-interval milk delivery, some twelve-week-olds will shorten their bursts of sucks and increase their pauses (Fig. 4). This abortive attempt at solution indicates a sensitivity to a changed feature of the environment with a highly general "response" or adaptation. The child appears to be learning some such rule as increasing the number of starts and stops—that starting anew may produce results. If the situation reaches limits that the infant clearly cannot cope with—as often happens with a two-second interval before milk delivery—then the subtle modulation of the infant's behavior may be disrupted by crying or, seemingly in frustration, he will shift back to his usual pattern of bursts and pauses. Such strategic adaptation seems to occur only with moderate deviations from expected environmental states. When the environment exceeds acceptable limits, the behavior goes back to a highly developed preadaptive pattern.

Another way of approaching the "voluntarization" and adaptability of sucking is to observe the extent to which it can be integrated with other higher-order activities. "Normal" sucking, we know from observations by Kessen (1967) and Wolff (1968), can he observed in brain stem infants. What does it take to intercalate this primitive activity with such a higher order information processing system as visual scanning? Let me report some of our own observations, again with the proviso that it is a report of work in progress. Kalnins and I have noted the following sequence.

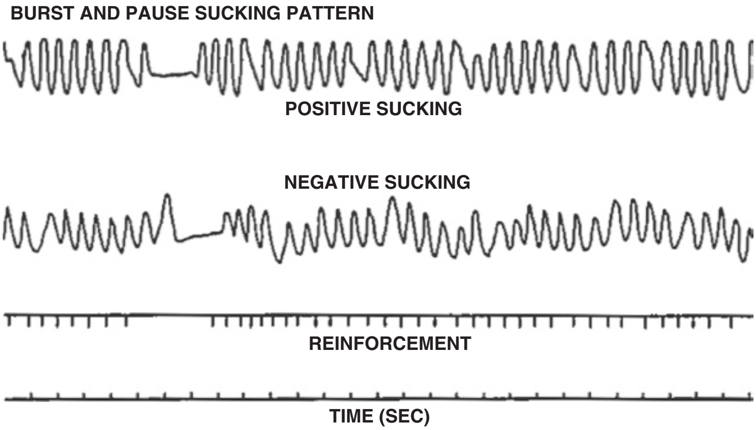


**Fig. 3** Burst-and-pause sucking pattern at thirteen weeks

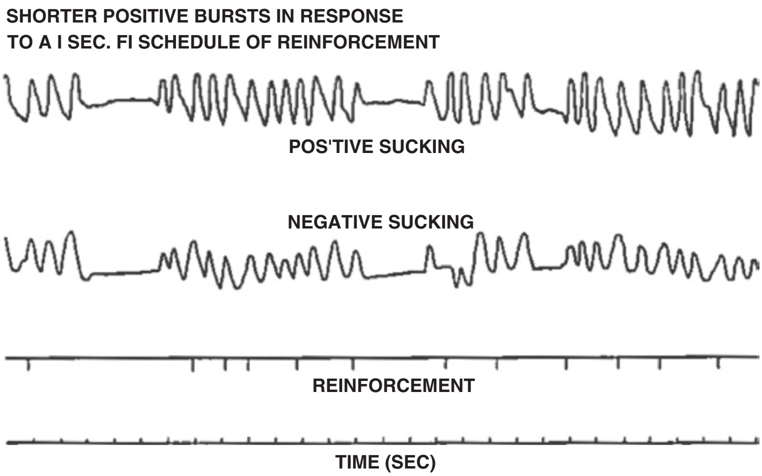


**Fig. 4** Shorter bursts and longer pauses in a fixed-interval delivery of milk at thirteen weeks

At birth, and for some days after, the infant sucks with eyes tight shut. If the infant looks, tracks, or listens, sucking is disrupted—indeed, the disruption has been used as a measure of attending, as in the classic study by Bronshtein and Petrova (1967). With the three- to five-week-old baby, the eyes may be open while sucking, but there is a high likelihood that when fixation or tracking occurs, sucking stops. It may well be that, in Trevarthen’s terms (1968), if the focal rather than the ambient visual system is brought into play, sucking stops.

There is a new pattern by nine or thirteen weeks at the latest. And note that these timetable figures may be a little parochial, for they deal in the main with infants of middle-class parents interested enough in child rearing to come to our laboratory. The child now sucks in bursts, and looks during pauses. He may remain generally oriented toward the source of stimulation while sucking, but not fixated and never showing the “caught” or locked-on gaze while sucking. Around this age, three months, a stimulus change occurring during a sucking burst will disrupt the burst or bring it to an end sooner. But if the stimulus is presented during a pause, it will have no effect on subsequent bursts (compare Figs. 5 and 6). It appears that the pauses are being used to process information, a matter that we shall wish to investigate much more thoroughly before letting it rest at that.

Finally, usually before four months and often as early as two months, the baby appears to be able to suck and look at once. But when one examines the sucking record, it turns out not to be the case. For now, the act of looking inhibits negative sucking or suctioning, while mouthing or positive sucking goes right on through, though with reduced amplitude (Fig. 7). It is this phenomenon, at first so puzzling to us, that first made us suspect what we think to he a form of externalized enterprise maintenance that for the moment we refer to as *place holding.* By maintaining some feature of an ongoing act in operation while carrying out some other act in parentheses, one is reminded that the original act is to be resumed. We shall meet it again later.

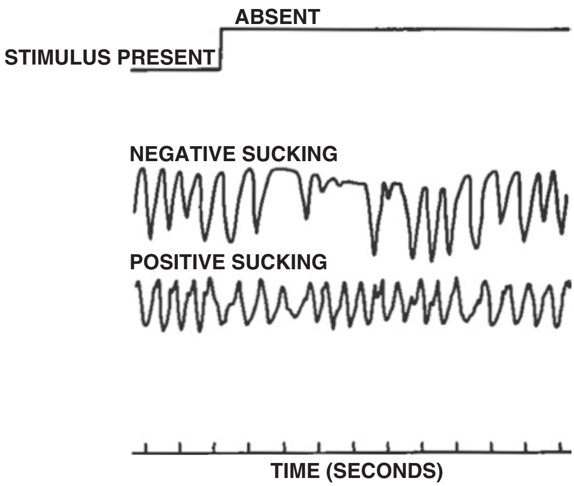


**Fig. 5** Disruption of negative sucking with stimulus change during sucking burst

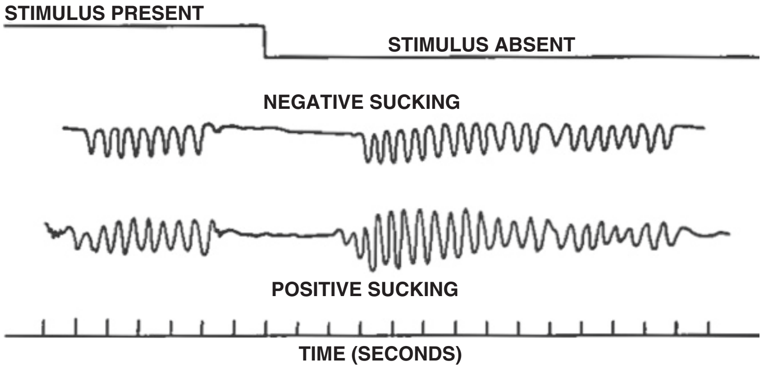


**Fig. 6** Absence of any disruption of sucking in an eight-week-old infant when stimulus disappears during a pause

One can summarize the relation between sucking and looking by noting that it goes through three phases in its growth. The first is *suppression* of one by the other—and mostly it is looking that suppresses sucking. The second phase is simple succession of sucking and looking, organization by alternation. The third phase is *place holding,* in which the two acts can go on, with one in reduced form that is sufficient for easy resumption, while the other goes into full operation.

One suspects, on the basis of these observations—and a stronger conclusion is not yet warranted—that this decreasing preemption by the act of sucking is part of a broader pattern involving a general decrease in one-trackedness of behavior. In considering the decreased preemptiveness of sucking, bear in mind that the mouth is also involved in what is properly called the epistemic function—exploring. To the degree that it is linked to nutrition and distress reduction, it is not available for

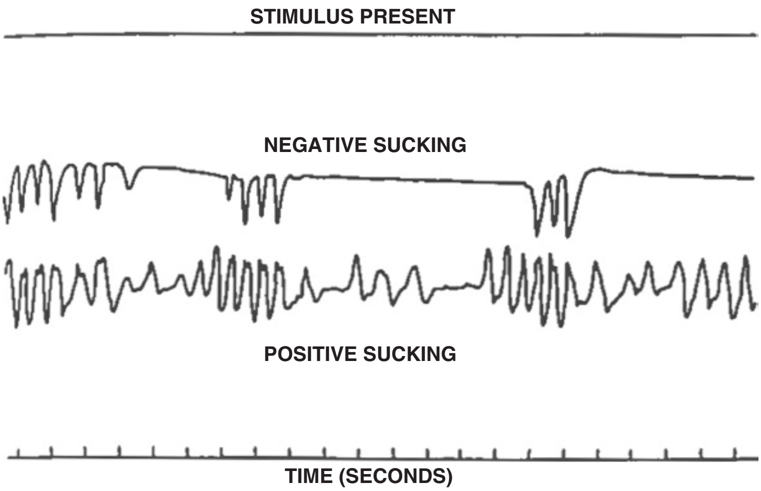


**Fig. 7** Positive sucking being used as "place holder" during disruption of negative sucking by a stimulus

exploration. Jolly's (1966) careful work on lemurs, who show more dependence on the mouth than on the fingers for adult exploration, suggests that the mouth in exploration is never freed entirely from its nutritional function. Yet, from the start of human infancy, a good visual stimulus, concentrically organized and sharply contoured, will have the effect of inhibiting sucking altogether, suggesting that the epistemic needs of the newborn organism are not completely swamped by the need for food and comfort.

This brings us directly to a final experiment concerned with the nature of sucking, this time sucking in the interest of a quite arbitrary goal. We can properly argue that one of the features of voluntary control of an action system is the degree to which it can be utilized as a means to a new end. We had been impressed by experiments conducted by Siqueland (1968) at Brown indicating that infants of three months were quite capable of sucking to increase the illumination of a picture on a backlighted screen in an otherwise darkened room. In an experiment in progress, Kalnins has altered this procedure in one crucial respect to assure that what was involved was not the preference of the young child for a lighted environment. In her procedure, her infants varying from one month through three months in age are shown a picture that is initially out of focus on a large and close backlighted screen. By sucking on a pacifier, the child can bring the picture into focus. If the distance from out-of-focus to in-focus be arbitrarily assigned the value of one clair, then each suck by the child im proves the focus by .16 clair, and six sucks bring the picture into full focus. If sucking should fall below the rate of one per two seconds, the picture starts out of focus. The brightness remains virtually constant throughout. In a control condition, the picture is in focus, and sucking drives it out of focus at the rate mentioned above. Refraining from sucking at the prescribed rate lets the picture come back into focus.

First let me say that a six-week infant can in fact learn to suck to bring the picture into focus and to desist somewhat when his sucking blurs the display. Infants plainly will work for visual clarity. What is especially interesting is how the child learns to *coordinate* the two ordinarily independent activities of sucking and looking. Let me bypass differences in age, since these are not yet resolved by the study. What is already quite plain is that the learning functions for the two activities do not run parallel. For one thing, the six-week-old may typically learn first to suck the picture into focus, but the moment it is in focus, sucking is inhibited by looking and the picture is allowed back out of focus. This dilemma may be resolved by sucking without looking until the picture is in focus, then looking and sucking for a brief period. When he stops sucking and the picture starts blurring, he immediately averts his gaze. Gradually the amount of time during which he can suck and look increases. The child seems to be learning not so much a *specific* response, but rather a sequentially organized, adaptive strategy of responses.

There is in infant sucking, to sum up, an early present and soon modified capacity for adaptation. Human sucking, for all its primitive origin in mammals, adapts from the start to the shape and tempo of nutritive sources. It is anticipatory from the beginning, and from the start moves toward a state in which it can be fitted into multiple enterprises. The course of its integration with other activities can be described in three phases: suppression, alternating succession, and place holding—steps toward the achievement of a genuine hierarchical ordering of multiple activities. Indeed, before the third month of life, there is ample indication that the activity of sucking not only serves innately predetermined multiple functions—nutrition, pain reduction, and exploration—but that it can also be diverted to arbitrary and intelligent instrumental activity that could not possibly have been preordained by evolution.

## Volition, Skill, and Tools

We come now to the development of the intelligent use of the hands. It is a much neglected topic—perhaps because we professors are intellectuals who are more preoccupied with words and images and ideas than with tools and tool-making. Yet, one cannot go far into prehistory (e.g., Burkitt 1963; Oakley 1960; Buettner-Janusch 1966) without being impressed by the role of "clever hands" in human evolution. Yet very little has been written about "manual intelligence." The gifted Russian neurophysiologist Bernstein (1967) poses the problem well in discussing the physiology of activity:

> … a first requisite for the programming of any activity is the formulation of motor problems, or problems of action (in terms of codes as yet unknown to us) and this latter process is based on a modelling of the future by the organism. In this case the model made by the brain is not merely an extra polation of observed variations in the immediate surroundings of the organism, but it is essentially a model of the *future requirements of the individual,* a model of that which is not yet, *but which must he the case.* The basis for this model

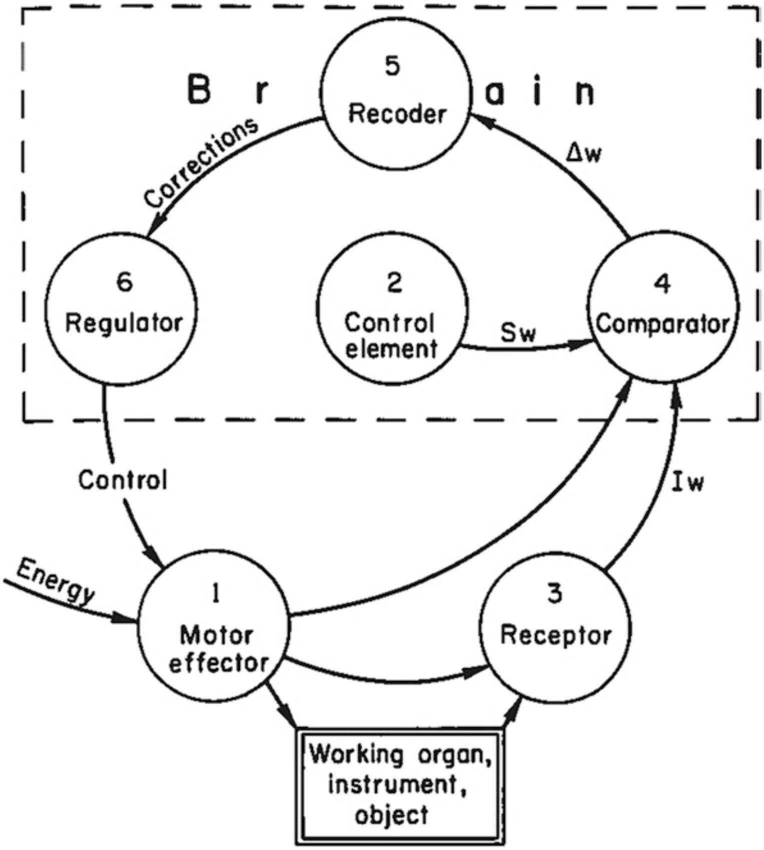


**Fig. 8** N. Bernstein's model for a system capable of voluntary activity directed toward objects or states of the environment (from Bernstein 1967)

> of the process of programming an action which is to be brought to realization most closely resembles *an interpolation* between the current moment of time *t* and the state of affairs at a moment some period Δ*t* in the future, which is modelled in the brain (pp. 186–187).

Bernstein's proposal for a minimum system capable of effecting such voluntary control of activity is indicated in Fig. 8.*[1]

Note that *activity* contrasts with mere *movement* in that the former requires the coordination and regulation of the latter *in the attainment of some particular objective.* A ball is to be thrown a certain distance and has a certain weight, or a screwdriver to be turned requires the application through the hand and arm of a certain torque. Again, to quote from Bernstein (1967):

[1]The reader will find comparable models proposed for some-what different aspects of intelligent behavior, by Ashby (1952), von Holst and Mittelstaedt (1950), Miller et al. (1960), Gregory (1966), Held (1965), MacKay (1966), and others. We choose the Bernstein variant since it is more adaptable, hopefully, to problems of voluntary action and its development.

All systems that are self-regulating for any given parameter, constant or variable, must incorporate the following elements as minimum requirements:

(1) *effector* (motor) activity, which is to be regulated along the given parameter,
(2) *a control element* which conveys to the system in one way or another the *required value* of the parameter which is to be regulated,
(3) *a receptor* which perceives the *factual* course of the *value* of the parameter and signals it by some means to
(4) *a comparator device* which perceives the discrepancy between the *factual* and *required* values with its magnitude and sign,
(5) an apparatus which recodes the data provided by the comparator device into correctional impulses which are transmitted by feedback linkages to
(6) *a regulator* which controls the function of the *effector* along the given parameter.

For Bernstein, finally, the achievement of control always involves a reduction of or "mastery" over degrees of freedom in the action-system being regulated. There are joints and tendons in fingers, wrists, elbows, shoulders, and trunk that can operate independently of each other. A hammer or a screwdriver or a thrown ball can slip this way or that. The system without a highly intelligent control, or without locking off some of its flapping, can be very noisy indeed. Let me propose two ways that control over degrees of freedom in directed activity can be effected: one is through the development of sequentially organized skill; the other is through brute limitation or restriction, as when one uses the arm with elbow locked almost as a sweep.

I shall argue in what follows that the mastery of intelligent, visually-guided manipulation in infancy and childhood involves precisely a cycle of brute restriction of movement and of skill formation within the limits of that restriction, with skill moving to a next step only when restriction is altered. Any *given* program of skilled voluntary action is gradually consolidated within its own restrictions. Its consolidation is signaled by the well-known plateau in the learning curve. Progress points in the infant's development are qualitative rather than quantitative changes of skill. These involve not consolidation but the formulation of new strategies of action which in turn must be consolidated. Each new program of action involves an increment of degrees of freedom. The process, moreover, continues throughout life. The difference between "good skiing" and "bad skiing" is, alas, qualitative.*[2]

What leads to the qualitative shift in strategy when there is a leap forward in skill? Bernstein proposes that it comes after sufficient practice with the variant

[2]In the classic study of Morse code transmission by Bryan and Harter (1899), the telegrapher shows a series of increments in speed, followed by plateaus. He begins with single letter units (of which there is some multiple of $10^1$), and reaches a plateau. Then he starts up again, organizing in terms of words (of which there is some working multiple of $10^3$), and hits a plateau. He then goes to phrases (of which there must be some multiple of $10^6$). In each case, the number of degrees of freedom increases by orders of magnitude.

versions of a particular skill strategy. I would agree with this, and add a speculation. The practice of variants of a skilled act is, in effect, practice with instances of a concept. I suspect that when an act can he more easily reduced to a conceptual rule, with attendant reduction in the strain of information processing, we are then ready to tackle more complicated motor problems.

Let me say a word about Fig. 8, for its terms will be useful in examining observations on the growth of directed reaching in infancy to which we shall turn. About the sensor or receptor, first, we need only remark that there is a long line of research that shows the enormous importance of sensory information in voluntary activity. The classic experiment of Mott and Sherrington (1895) was the first to show that if a monkey's arm be deafferented by section of the appropriate dorsal roots of the cervical and thoracic outflow of the spinal cord, the animal's limb becomes, in effect, paralyzed as well as anesthetized. As in the earlier experiment, Twitchell's (1954) and Lassek's (1948) repetition confirmed that in a free situation the operated animals did not use the deafferented forelimb. But interestingly enough, Knapp et al. (1963) have shown that monkeys are able to perform a conditioned avoidance response after deafferentation of the limb, or indeed were able to acquire a new conditioned avoidance response with the limb. There are various interpretations one can put on this important experiment. There is a long distance between *spontaneous* use of the hand in *voluntary* behavior and a conditioned avoidance response involving the removal of the hand from danger of shock at the sounding of a buzzer. Conditioned avoidance is supported by an external, evoking stimulus; spontaneous use of the hand in goal-directed, instrumental behavior involves internal signaling with the type of corollary discharge that Teuber (1966) has recently proposed as the neural hallmark of consciousness. The corollary discharge, of course, is the $S_w$ of the Bernstein diagram, the *Sollwert* or required value which, taken by the comparator along with the *Istwert,* the $I_w$, yields $\Delta_w$ that is then recoded for correction of effector activity. A conditioned avoidance stimulus apparently is able to evoke an action order, where spontaneous effort cannot—which should give us pause in our reductionism!

Let me turn now to observations on infant reaching. In the early weeks the child is capable of several highly organized forms of reflex grasping that are evoked by quite specific tactual or proprioceptive stimuli. These reflex patterns have recently been described with great care by Twitchell (1965). At birth, but usually gone by the end of the second month, there is a "traction response" of the arm and hand, a proprioceptively elicited hand flexion produced by stretch of shoulder adductors and arm flexors. It is not produced by contact but only by stretch. At about four weeks, the "grasp reflex" proper makes its appearance. It involves a catching and a holding of the contacted object. A distally moving contact stimulus between forefinger and thumb initially evokes abduction of those two digits. Later, the reflex spreads to the other fingers and the whole hand. It can be produced only by contact. At about four or five months, there begins the more interesting "instinctive grasp reaction" (I am using Twitchell's terminology throughout). A light contact on ulnar or radial side of the hand produces now a groping toward the object with appropriate pronation or supination for orienting and hunting. If appropriate contact is made with an object, then grasp proper occurs. The grasping-groping reaction is initially quite independent of vision and is elicited by a light touch alone even with the baby's gaze averted. To this list should be added as well the tonic neck reflex involving the child in the fencer's posture, a gross pattern involving the arms and trunk that gradually fades in its sharpness during the first year although remnants of it may be found in adult sleep postures.

The role of these reflexes in visually-controlled, voluntary reaching is a moot point. The growth of visually-guided reaching has been carefully described by Halverson (1931), by McGravv (1943), by Piaget (1952), by White et al. (1964), all for somewhat different reasons and at different ages. Piaget Was attempting to reconstruct the development of sensorimotor schemata. McGraw proposed to verify the view that cortical control was critical—though Conel's anatomical (1939–1963) studies have indicated that the cortical representation of the hand grows at the fastest rate of any part of the brain during the first month of life. Halverson, like others in the Gesell group, was trying to give a normative picture of the maturational unfolding of the infant's voluntary manual activity. White, Castle, and Held were exploring the sources of plasticity in behavior. Whereas Piaget and the Held group were principally concerned with the period from one month to four or five months, Halverson began at four and a half months. Most of the studies were done with infants lying supine. The reaching pattern of the supine infant, we have reason to believe, is quite different from that of the infant in a semi-upright, supported position where the hands are free to reach forward and explore.

In any case, this is not the place to sort out the strands of these various, often excellent observational studies. Only a few points need be made preparatory to considering voluntary control in the light of the model proposed. It is plain from the conclusive work of Held and his associates that the earlier views concerning "maturational unfolding" unaffected by the environment are just as false as the view which states that it is *only* through opportunity for interaction with the environment that control develops. The burden of these studies is that visual deprivation of primates, particularly the lack of an opportunity to observe their own hands, severely limits hand-eye coordination as well as voluntary control of the manipulatory system. Certainly Piaget's view of the role of action and its feedback into a sensorimotor schema has been well supported. But it is also quite plain that once Held's deprived monkeys are given the opportunity to use and view both their hands, there is a very swift restoration of normal functioning, no matter how clumsy the initial efforts of the deprived animals might be. The work of Alt (1968) and of Trevarthen and Richards (in preparation) in our own laboratory suggests to what extent there is a considerable amount of preadaptive sensorimotor organization ready to be activated by experience in the visually-guided use of the hands. Alt has shown that the naive infant does *not* have to watch his hand while reaching for an object. He did this by placing an occluding screen so that the child could see the object being reached for, but not his hand. Trevarthen and Richards are describing in detail the extent to which the child's initial swiping and reaching out is seemingly controlled by an adequate model of "behavioral-visual" space, even without experience. So, quite plainly, visual experience of the hands matters, but its effect is dependent upon the existence of preadaptive structures that make possible a comparison of what is intended in an activity, and what is accomplished—the operation of a comparator that can yield $\Delta_W$ from a discrepancy between $S_W$ and $I_W$.

Twitchell (1965) argues that in development, voluntary control rests upon a substratum of reflex activity and often it takes the initial form of self-evocation of the reflex in question, much as in the recovery patterns of hemiplegics. Piaget's conception of interaction between response (however evoked) and environmental feedback providing a sensorimotor schema is a quite irresistible solution. As Bernstein would put it, the existence of a guided response has all the elements necessary for a "motor problem" and the neural apparatus described in Fig. 8 can be brought into play.

But to let the matter rest there misses one crucial aspect of voluntary activity—its volitional component. There is much about the earliest voluntary activity that is *precisely without* the aid of the prepared reflex mechanisms, a kind of unskilled expression of voluntary action without an appropriate program for limiting the large number of degrees of freedom of the trunk, arms, head, and hands. This *undifferentiated* voluntary action takes the form of diffuse activation and the movements that result are far more akin to athetosis than to organized reflex activity. These are preskilled and precoordinated forms of voluntary action. It is *after* the infant has abandoned the reflex pattern of response, and after a period of diffuse athetoid activity, that *directed voluntary activity* begins. Indeed, this more diffuse activity of orienting toward objects with intense preoccupation and antigravitational movement of the arms and trunk (around four months) is probably to be taken as a sign of growth. Now consider some particulars.

In our observations, infants between the ages of one and eight months are seated in a specially designed chair, leaning 30° back from the upright. They are held steady by an elastic belly band that passes through the legs to the seat, and by a loosely attached chest band passing under the arms, which gives support if the child leans forward, and also prevents him from falling to either side. Figure 9 illustrates an infant in such a seat. It appears to be reasonably comfortable, for infants will sit as subjects in visual experiments involving moving images for as long as a half hour with no signs of fretting.*[3]

The course of "reaching" can be sketched briefly here. At a month, as White et al. (1964) have noted, a peripherally-moving stimulus will cause the child to move his head in pursuit, and as the object approaches he will change in general activity—becoming quieter if active before, or more active if quiet before. As the object moves into the range of good accommodation, there tends to be a heightening of tension in the trunk, which by six weeks takes the form of antigravitational activity in the shoulders and flexion of the arms. By ten or twelve weeks, the approach of the object, as it moves from "spectator space" into "participant space"

[3]Much of our apparatus for recording responses and presenting stimuli was designed by Mr. Andrew Marshall, III, to whom we are very grateful. We are indebted to Mr. Robert Howe for his skill and patience in helping us design various infant seats, saddles, and supports.

**Fig. 9** Infant in seat used for reaching experiments

(between eighteen and twelve inches) produces “pumping up” behavior of arms, shoulders, and head, with fixated gaze and actively working mouth. From this position, there may be launched the well-known swiping movements, with fisted hand moving ballistically in the general direction of the object. I have seen babies blink with a slight startle when the swipe occurred. It is as if the “connection” between the willed act and the execution were unexpected.

At about three and one-half months to four and one-half months, there is finally sufficient mastery of the situation so that activation is less explosive, and there occurs a slow reach toward the fixated object with hand wide open and, often, with mouth and tongue working. If bilateral, the reach closes on the object at the mid-line, the widespread hands closing only when there is contact with the object. If the reach is unilateral, then the “unattended” hand may show no tension at all, as if simply not included in the volitional command.

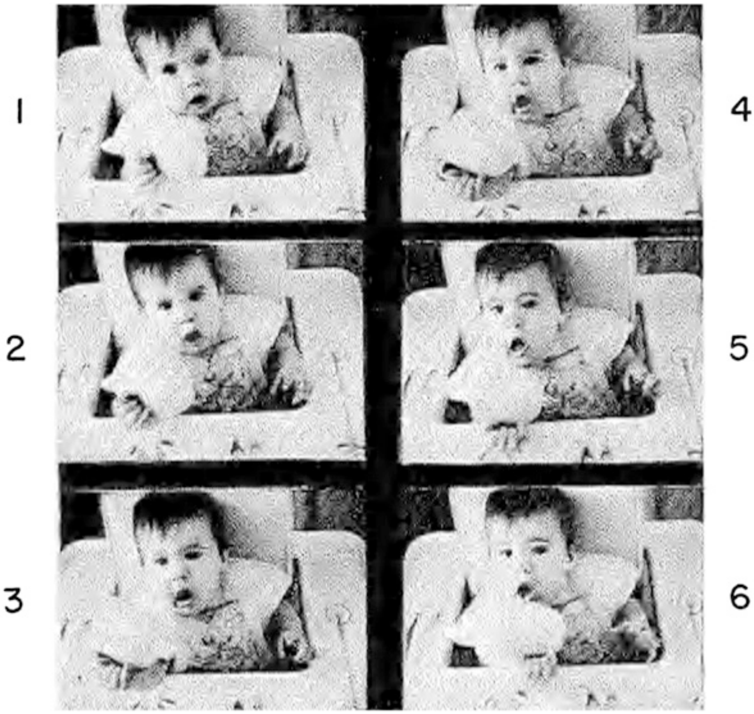


**Fig. 10** Anticipatory mouth-opening and mouth-aiming during cup-lift in seven-month-old Kathy

This slow reaching has the mouth as its inevitable terminus. There is an invariant sequence: activation, reach, capture, retrieval to the mouth, and mouthing.

While the arms are being raised, there is a notably fixed, riveted gaze directed at the object, a gaze that seems to sustain the action of arm raising. When the arms are up, and there is movement toward the object, the mouth begins to work, lips moving and tongue in action, or the mouth may simply open (Fig. 10). The object is plainly destined for the mouth. If, as it approaches the infant’s mouth, you insert a finger for him to close on, you will stop the action. (We have used a “hypertoy” as the object, a red ball of two inches diameter, with concentric, white bull’s-eye stripes outlined in black, the center of the area being a circle of black velvet glued to the ball, surmounted by iridescent pearls.) The child may now take his own hand from the object and thrust it, too, into his mouth.*[4]

[4]In the semi-upright position one sees little or no looking back and forth from hand to object prior to reach, though one sees it when the baby is lying on his back with a ball suspended above, as in the observations of White et al. (1964) and of Piaget (1952). With the baby supported in a semiupright position, the visual inspection is all for the object, with the hands being guided by a locational command that seems not to require direct visual checking. It may well be that the upright reaching position provides the child with more usable proprioception and kinesthesis for guidance.

A word about the role of vision: even the sophisticated seven-month-old is likely to launch a reach with visual guidance, but to execute the reach without it. The guidance takes the form of fixing visually on the object, not on the hand. We have seen no indication in these observations of children looking back and forth from hand to object, as Piaget (1952) has suggested. In any case, action is initiated with eyes on the target. Once the action is launched, the eyes may no longer fixate the target. As you can see in Fig. 11, when seven-month-old Kathy is in the midst of reaching for a cup, her eyes are closed. And if the reaching involves some conflict between linear visual direction and the directional course that the hand must follow (detour-reaching), gaze aversion or eye closing may accompany the execution of reach. Or note (in Fig. 12) what happens when Kathy tries to get a two-handed hold on a cup already held with one hand: the conflict in proprioception is *not* adjudicated by visual guidance (which failed the first time it was tried). Degrees of freedom are drastically reduced by the simple expedient of shutting the eyes.

The account we have given illustrates vividly the growth of skill by reduction in degrees of freedom, with the development of programs to operate within the reduced dispensation. Where there is failure of reduction, then we see athetoid behavior, disruption in crying, or immobilization. With growth, there are longer and more variable sequences of directed activity, involving a more complex integrative task. At the same time, there is a notable tendency toward increased uniformity in the time and effort put into the component gestures of the child's acts. His reach takes about the same time for near and far object, his lift of objects is about equal in time whether the object is heavy or light, etc. It seems not unreasonable to suppose that this modularization of the child's timing helps make possible the more flexible and variable sequences of behavior, precisely by permitting their predictable incorporation into a variety of plans.

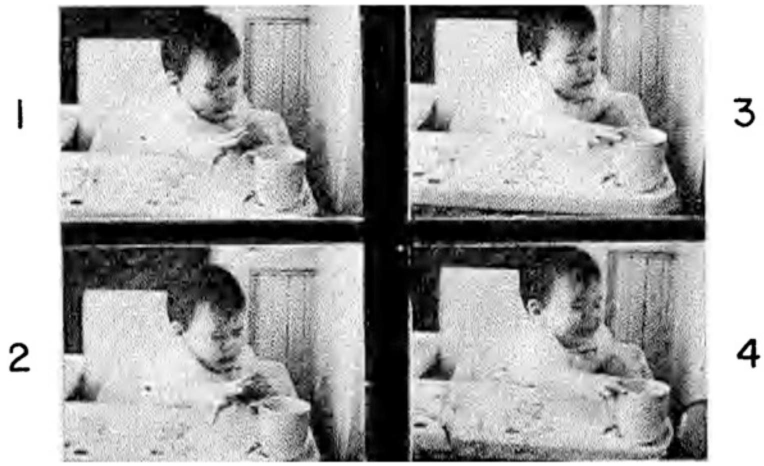


**Fig. 11** Kathy reaches for cup with eyes closed during execution of act


**Fig. 12** Kathy attempts to capture a cup with two hands and excludes vision in the process

The means available for reduction in degrees of freedom are manifold. There is, obviously, a restriction in the movement of joints—fingers are spread wide, the elbow is rigid, and the child moves on the object with a locked pounce. The midline’s critical role is to be seen in much the same way. Reaching is most likely to occur when the midline of head and trunk are in line and when the object is presented on this midline at some critically close distance. Off that combined line, the object is not so likely to be reached for, nor is reaching so likely to occur if head and trunk are not lined up. Finally, it is crucial to recognize the significance of eye closing and gaze aversion during troubles in reaching or grasping. Functionally, this too must be interpreted as part of the general program of reducing complexity in the interest of the exercise of limited skill.

A word, finally, about the role of the open mouth and wide open hand. Recall how rhythmic mouthing of the nipple served as a place-holder during visual inspection, tiding the infant over the distraction so he could then get back to nutritive sucking. The open mouth during early reaching is one step more sophisticated: it keeps the terminus of the act in evidence during the running off of the component parts. It is this that, in Lashley’s terms (1951), maintains an “atemporal” organization through the sequence of the act and converts it from a kind of Markovian chaining to an intentional act. So, too, the rigidly opened hand is a measure against the more primitive form of fist-closing: a tactic for maintaining, through exaggerated action, an intention whose fulfillment has been delayed. As with so much early development, processes that later become internal—intention, attention, etc.—have an initial external motoric being that later goes underground.

The voluntary use of the hands from seven months to two years is a bit more familiar, though it has its revealing surprises.

Let me illustrate by a study of detour-reaching. Infants from six to eighteen months are seated before a large box on which there is a screen extending to the midline from the right side or the left.*[5] The screen is either opaque or transparent. An object is placed either in the open, at the edge of the screen, or behind the screen so that it can be reached easily by the hand on the side contralateral to the screen. The object is a hollowed cube with a jingly bell in it, easily held in the hand of a seven-month-old, the age of our youngest subjects. The other groups were approximately 12–14 and 16–18 months. Consider the three major responses observed. The youngest infants mostly reach with the hand on the side where the screen is, directly where the object was last heard, or (it the screen is transparent) where it is to be seen. There is some clawing and banging, and the child is soon distracted to something else. In the second pattern, the year-old more often moves his ipsilateral hand from where it rests on the screen to the edge of the screen at the midline, eventually continuing around with a backhand reach until the object is grasped. In both of these patterns, the unoccupied hand remains on its side of the midline. Finally, the eighteen-month-old child will nearly always reach in with the contralateral hand and straightforwardly capture the object. Within each strategy, one can find a gradual growth of skill as measured by the time required to complete the task. But over the sixteen trials given to each child, there is no greater likelihood of his succeeding on the last reach than on the first, or of his reaching with the contralateral rather than the ipsilateral hand. The learning curves for *strategy*-change over the sixteen trials are simply flat. The youngest children were limited to a reach along the line of sight. Older children operated in a space of motoric continuity. A reach begun with the ipsilateral hand continued to completion with that hand. Finally, the children were able to take account of the geometry of the task itself. Rather than starting with the hand *on the same side of the midline* as the screened object, they could now begin with the hand whose trajectory of recovery would be the shortest.

This developmental sequence is interesting from several different points of view. It is a striking instance, to begin with, of an early form of what Piaget (1954) calls *decentration*—removal of the self from the position of being the sole origin and metric of space and spatial relations. With growth, there is increasing representation of the environment that is independent of the action that is guiding or has guided our use of spatial relations. In another context, I have referred to this development as the transition from enactive representation to ikonic representation (1966), an objectivized form of imagery taking over as the prevailing mode of

[5]This experiment is being conducted by Bruner, Lyons, and Kaye.

summarizing behavioral space, rather than behavioral space being represented by kinesthetic or proprioceptive patterns. Again, I find myself very strongly in agreement with writers like Washburn (1916) and Piaget (1966) who underline the origin of imagery in action. Indeed, I would argue that one can attribute the shaping of imagery to the interplay of *Sollwert, Istwert,* and $\Delta_w$ as set forth in Bernstein's theory of action (Fig. 8). If this is the case, then one of the principal steps forward in the development of any skill is the development of an *objectivized* image or representation of performance that permits one to "get outside oneself." It is this kind of decentering that constitutes the base for the further growth of childhood skills.

Another perspective on the lines and paths of early manipulatory space is provided by a high-speed photographic study of three children using cups, at seven, fourteen, and twenty-seven months. With the seven-month-old, reaching is a pounce from slightly above the visual line (Fig. 13). Such a reach has no place for detours. By fourteen months, reaching movements can almost be described as successively Cartesian—a spreading apart laterally of the hands and arms from the resting position, then a reaching straight out with both hands moving parallel to the midline or sagittal plane until the hands are about extended to the distance of the object, and then a closing in of the hands on the object (Fig. 14). Indeed, there is a slight pause at each crease or boundary marker in this sequence. I believe that this decomposition of the line of reach into successive elements is what permits objects to be reached by means other than direct line of sight. But at the outset, there is conflict between the visual way and the manual way, and it is this that leads to gaze aversion and eye shutting.

What is so crucial about this sequence of events is that, with development, reaching is occurring *in* a represented space. It is not a case of action and the space within which it occurs being inseparable, as with the youngest child. Once the child achieves a constructed space that is independent of action, it becomes possible for

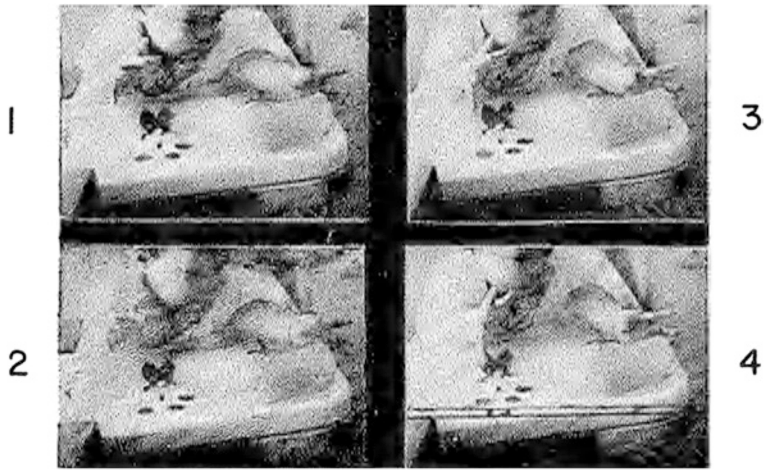


**Fig. 13** Pounce-reach of seven-month-old Kathy

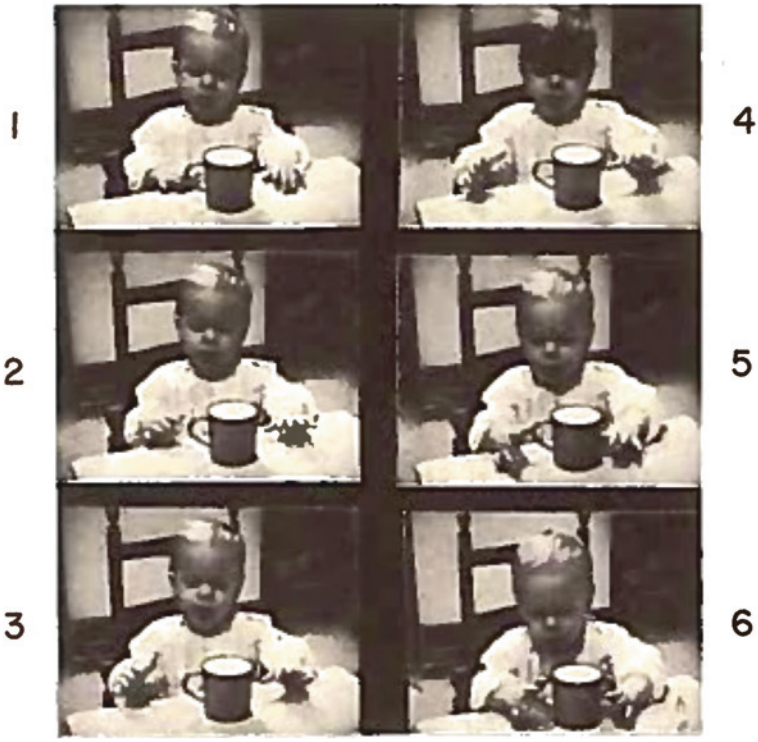

**Fig. 14** The "successively Cartesian" reach of fourteen month-old Oona

him to deal with such interesting and important contingencies as those involved in dealing with objects where the line of sight and the line of reach are not the same.

In general, then, the first phases of skill development involve the perfecting of the means for mastering voluntary control in "motor problems," of translating intention into action, and of improving action through correction. The second phase is the process of developing guiding representations of the behavior space that can provide points of reference in terms of which action can be regulated. The first of these steps is crucial for enactive representation, the second for ikonic.

* * *

I would like now to cross the threshold from the intelligent use of the hands to the use of tools. But there are several preliminaries, prerequisites to tool use, that need close examining first. One was set forth forty years ago by Grace de Laguna in her classic *Speech: Its Function and Development* (1927). Let me quote from that book:

> The club or stick that is used to strike or poke things is in certain respects like a supplementary limb. It enables the ape or man who uses it to act at a greater distance…. He would come to use the stick virtually as a part of himself, as the blind man uses his cane…. But sticks are not all the same length. Some are too long to be wielded, some

too short. He must learn to choose those of usable length, and adapt… to their differing sizes…. But this discrimination is still only of lengths relative to himself…. To strike an effective blow with a stick, his movements must be regulated and controlled *both by the distance of the object and the length of the stick*…. He learns to attend to the length as a determinate and variable feature, and *he perceives it in terms of the distance to be reached.* So, too, he learns to see the distance of an object not merely in terms of the movements of his own body in reaching it, but *in terms of the length of the stick he must choose*…. As the indirect dealing with implements becomes extended, it is not merely the distance of the object from himself that comes to be perceived in terms of length, but distances of objects *from each other* (pp. 219–220).

Our observations on cup use, conceiving of the cup as a tool, have taught us a little about this skill. In a seven-month-old in the first week of cup use, there is no appreciation of the problem of maintaining the rim of the cup at an angle compatible with the horizontal level of the fluid within. Our camera speed of fifty frames per second indicates no adjustments between hand and mouth. The result, of course, is a cataract down the child’s bib. The parent may respect the reduced degrees of freedom of the rigid cup handling by filling the cup only slightly. Or the child may lean forward toward the cup in the course of the reach. At fourteen months, the child achieves the match of cup with water level by the application from lift to mouth of four to six corrective, gimballing movements of the hands, wrists, and elbows. By twenty-seven months, the discreteness of correction is all gone, and the hand-wrist-arm system maintains the rim through what in effect is a zero deviation from horizontal. We can say that tool using is on the way (see Fig. 15).

But it is obviously pretty crude; something is missing, some more preliminaries. For one thing, there is in early childhood a singular lack of sustained direction. Jonckheere (1967) in our laboratory did some observations on two-year-olds, involving tasks where rewards could be got by pulling in one of several strings; other strings were perceptibly not attached to the reward object, as in Klüver’s


**Fig. 15** The flexible, oblique reaching of twenty-seven-month-old Nathan

study (1933) and in Richardson's (1932). It is known that forty-week-olds will pull in single baited strings (Richardson 1932). As with earlier studies, the children failed, pulling in all strings or the one closest to them.

Three things made it difficult for the two-year-olds to maintain problem solving long enough to resolve the simple problems given them. The first was "play": exploring and manipulating the string itself, or the edge of the playpen, etc. It is very reminiscent of the neuro surgeon Rylander's (1948) lobotomized cook who could never get to the center of the city to shop, such were the tempting objectives encountered en route, or like Luria's (1966) frontal lobe lesion cases who suffer the same alterability of goal. I shall then take "play" to mean altering the goal to suit the means at hand whereas "problem solving" (including games) involves altering the means to meet the requirements of a fixed goal. The obvious importance of play as a means of exploring means-end compatibilities is, of course, hardly to be minimized. But the dominance of the play set is clearly incompatible with directed tool use.

A second interfering factor was the child's routine use of other human beings as "tools." If the experimenter or the parent is in view, the result would usually be the use of "pleading" rather than tools—the out-stretched arm or the crying plea for the object out of reach. I commented earlier on the "shield of infancy"—and surely the provision of service by the adult in response to signal from the infant is one of the most important lamina in that shield. To be sure, as Sears et al. (1957) have emphasized, the major aspect of dependence and independence is an affective relationship in a parent-child dyad. But there is also an instrumental side to the matter that certainly bears closer inspection than it has had.

A third interference was, plainly, "channel capacity," the number of features that the child can deal with simultaneously. The child may look at the object, at the strings, at the bars of the playpen, and seem (as in Richardson's [1932] earlier study) to be overwhelmed. Let me note in passing, very briefly, some amusing observations Simenson, Lyons, and I have been making on the infant's ability to deal with multiplicity. Briefly, the experimenter hands the infant a "hand toy" at the midline, then immediately, before he can do anything with it, another is handed to him, again at the midline. Then a third in much the same way. The timing is a function of how long the child requires to get his hand firmly on the toy. At about seven months, if the second toy is handed before the first is started on the way to the mouth, the usual picture is for the child to abandon the first, pick up the second with the same hand and move *it* to the mouth, the abandoned toy being ignored during the act. Usually by twelve months, the second toy at the midline is taken by the free hand, and if a third is now put at the midline, one of the others is dropped and the new toy picked up. At about a year and a half, if not sooner, the same task is dealt with by the child taking the first toy in one hand, the second in the other, and when the third is presented, putting one of the held ones in the crook of the contralateral arm, thus freeing one hand for taking a new object, which he will continue to do if further toys are proffered by the experimenter. The child has gone from a limit of one, defined by the mouth, to a limit of two, defined by the hands, to a limit of many, defined by a reserve. Likely the reserve is governed, like so many other things, by George Miller's magic number $7 \pm 2$ (1956).

And so it goes with other aspects of multiplicity. One’s ability to process multiple events is precisely a function of the ability to process rather than merely to recognize or perceive that objects are present. The infant is *constructing* forms of multiplicity by his way of coping with the situation, and these ways may even be as overt as in the experiment just described.

The development of tool use will depend, then, on the child’s capacity to extend or amplify his range of means by converting features of the environment to his own ends, by doing this in preference to using a caretaker as an amplifier, by holding a goal invariant so as to examine the relevance of alternative means, and with a strategy that makes it possible to hold multiple considerations in relation to each other. It is astonishing how little we, in an advanced technological society, know about these matters.

* * *

## The Achievement of Codes

Finally, we turn to the child’s acquisition of rules that precede the rules of syntax. Some of my colleagues think the latter arise from innate ideas (e.g., McNeill 1966; Katz 1966; Chomsky 1967). Goodman (1967) has published a critique of this view in the form of a dialogue between Jason, just returned from a visit to the nomads of Outer Cantabridgia, and Anticus who suspects that what Jason has brought back is more fleece than golden. Anticus says,

> What we call a language is a fairly elaborate and sophisticated symbolic system. Don’t you think, Jason, that before anyone acquires a language, he has had an abundance of practice in developing and using rudimentary prelinguistic symbolic systems in which gesture and sensory and perceptual occurrences of all sorts function as signs?…. I submit that our facility in going from one symbolic system to another is not much affected by whether each or either or neither is called a language (p. 25).

So let us begin with limited subspecies of symbolic learning involved in social interaction, for which I shall use the term *code learning*.

Let me first suggest that one may draw a rather sharp distinction during the first year or eighteen months of life between what my colleagues Richards, Brazelton, and Trevarthen refer to as “doing” behavior and “communicating” behavior-behavior addressed to ward “things” and behavior addressed toward persons. There are several specific and obvious features (as well as several general ones) that differentiate the two forms of behavior: eye-to-eye contact is a major link between caretaker and infant, we know from Robson’s (1967) excellent review, and it has no counterpart in “doing” behavior. The same can be said for smiling, for crying, and for vocalization. The differences in the non-specific response patterns are only now being examined by Brazelton and Kelly in our laboratory, so it would be premature to say anything about them at this juncture.

We know from a few studies, such as those of Rheingold et al. (1959) and of Brackbill (1967) that there either is an innate predisposition to expect reciprocation of some kind to these specific gestures or there is a very quickly acquired expectation of reciprocation in social communication. At four months of age, for example, Brackbill (1967) finds that the infant smiles more to a face that smiles back than to one that does not respond. Now, if a face that has been smiling back now discontinues doing so, vigorous gaze aversion may result each time the non-responding face appears. Failure to obtain reciprocation produces an active avoidance—indeed, the child will struggle bodily to look away. Papoušek and I have been studying the manner in which three-to four-month-olds respond to unpredictable disappearance of mother, and again the effect produced in the body is a reduction in time spent looking at the mother and in engaging her in eye-to-eye contact.

What seems to get established very quickly between infant and parent is some sort of code of mutual expectancy. It seems to get established when the adult responds to an initiative on the part of the child, thus converting some feature of the child's spontaneous behavior into a signal. In turn, the child comes to expect response to follow from behavior he has initiated. Ainsworth (1967), Sander (1962, 1964), Freedman (1967) and David (1967) have all described this pattern of endowing the child's response with signal properties by linking the infant's initiative with adult response until such a time as the child performs an act with the expectancy of obtaining the adult response. Indeed, Sander (1968) is of the view that this pattern is discernible by the end of the first week of life with respect to crying. Neonates raised in a conventional hospital nursery provide a sharp contrast with ones raised by a living-in caretaker. The nursery infants fret and cry without the immediate response provided by a one-to-one caretaker. In consequence, when the nursery babies are shifted at ten days to a home nursery with an individual caretaker, they are slower in responding to regular feeding schedules than the one-to-one babies. They have not come to expect regularity in response to their initiative. The one-to-one babies quickly come to expect response, cry less, and in general are much more readily shaped to a schedule of daytime feeding and night sleeping. Their expectancy of response to their crying and fretting lead them to expect and respond to regularity in caretaker behavior more generally.

There is a subsequent development that follows upon this that has been called *conventionalization.* Once the infant expects that he can produce a predictable effect, there is a "stripping down" of the producing act to the point where it operates as a signal or isolated symbol. The nature of the cry changes—becomes less intense. And, of course, it is not a phenomenon limited to vocalization. It also characterizes the growth of gesture signs as Latif (1934) most vigorously insisted, pointing out as well that there is a corresponding conventionalization in the reaction of the parent or caretaker.

Suppose we grant the importance of these interaction codes for some later aspects of communication and language. Does this kind of learning have any kinship to the *formal* rules of language that the child will have to acquire? One must be very wary here. Even in so simple a case as the acquisition of *babbling* sounds and *speech* sounds, there may be a disjunction that is striking (McNeill, in press). The order in which the sounds of babbling are acquired between three and ten months is, for vowels, from front to back, and for consonants, from back to front (Irwin 1947, 1948; Bever 1961). Yet, as Jakobson (1941) has shown in his celebrated paper on the acquisition of *speech* sounds, the reverse holds in language acquisition. Vowels come in from back to front, consonants from front to back. The first acquisition is the sharp oppositional distinction between the closed, unvoiced front consonantal stop of minimal acoustic energy /p/, and the open, voiced, maximum energy back vowel /a/. Acquisition of a *speaking* rather than a *babbling* phonology consists, as McNeill (in press) succinctly puts it, in filling the space between /p/ and /a/ through differentiating of consonants into oral and nasal, /p/ and /m/, then the orals into dental and nasal, /p/ and /t/, and so on. The vocalic side goes through similar differentiation into narrow and broad, /a/ and /i/, etc. Now, the underlying basis for acquiring *speech* sounds may represent quite a different case than that for the acquisition of *babble* sounds. The latter may represent a maturing of the speech-generating mechanism; the former may be genuinely related to some underlying preference for the use of these sounds in communication. Babbling sounds may be a prerequisite for the use of these sounds in speech proper. But to confuse babbling with speech would be a grave error. So too, to treat interaction codes as if they were the same as linguistic codes proper would be in error, even though one is a prerequisite for the other.

Language is a rule system on several levels, such that a handful of distinctive features is permuted into a few dozen phonemes, from which in turn is formed a vast stock of morphemes, out of which a practically limitless flood of proper utterances can be generated. The *channel* for this system derives, I believe, from the continuous enrichment of interaction codes. But the *form* of the code must come from elsewhere. I believe it constitutes a refinement of human sensorimotor *skill.* Indeed, the growth of phonology is itself the mastery of a neuromuscular skill—the delineation of modular sound production from the mouth as a funnel opened *outward,* the voiced /a/, and as a funnel opened *inward,* the unvoiced /p/. I would even be so outrageous as to suggest that the kind of modularization that is present in phonology—the formation of binary oppositions—can in a cruder form be seen in other forms of human skill development. We have already noted how the infant's hand movement grows from the babble of athetoid movement of the fingers, to a sharp contrast of "hand wide open" and "hand tight-fisted" during reaching. We have also noted the modularization of part acts into roughly equal time segments and how these may be coordinated into different sequences that Lashley (1951) likened to syntactic structures. It is astonishing that we psychologists have never examined the later stages of this development more carefully—not to find analogues, but to explore in detail the continuities and discontinuities between, say, skills of the hand and skills of the speech production apparatus. I realize that such speculative arguments leave much about language unexplained. My object is not to propose a comprehensive account, but to suggest, rather, that we look elsewhere than to early vocal interaction for precursors of language rules.

Indeed, I believe it is even possible to make a not utterly absurd case for a non-linguistic origin for so essential a rule of language as *predication.* All languages, with no exception whatever, are organized by predication.

John is a boy.

John has a hat.

John caused a riot.

John became a man.

Basically, predication involves the differentiation of an event into *topic* and *comment* (McNeill, in press; de Laguna 1927). John is the topic; his boyhood, his possession of a hat, his riot production, his achievement of manhood are the comments on the topic. Is there a homologue in human non-linguistic behavior that would predispose language to the form of predication? Let me again suggest that there may indeed be. Only closer inspection will reveal whether they are non-trivial. One candidate is on the side of information processing; the other derives from manipulative skill.

Information processing, described by theorists as diverse as Neisser (1967) and Sokolov (1963), seems to involve a comparable differentiation. Neisser, for example, distinguishes *focal* attention from a more diffuse aspect of sensing, and takes the constructionist view that we organize events through syntheses of successive focal attendings. Each instance of focal attention may be conceived as a comment on a topic, an extraction of a feature from a more general sensory input. For his part, Sokolov notes that in the orienting response we attend to a deviation from a "neural model" of some steady state on which we have been fixing over time. When the deviation is at some critical level adequate for activating a system of extrapolatory neurons, we attend or orient. The deviation in some feature of the event is, in effect, the comment, the topic being the steady state neurally represented.

On the manipulatory side, there may be evolutionary as well as developmental parallels in the differentiation of manual prehension into a power or "holding" grip and a precision or "operating" grip. The evolutionary history can be sketched briefly as follows (cf. Buettner-Janusch 1966): Among prosimians, there is very little distinction, and the grip is a whole-hand grip varying principally in the force applied. There is even some dead-end morphological specialization away from the precision grip among lemurs toward a so-called "tooth comb" to aid the mouth in grooming. The precision grip appears in the monkeys and is well developed in the great apes. It is not until one comes to man with his asymmetry that the power grip migrates to one hand (normally the left) and the precision to the other. At this point, many routines are worked out for holding an object with one hand while working it with the other, a predicative procedure that probably has a profound effect on tool use and tool making.

In the human infant, it is not until well toward the end of the first year of life that he is able to use his hands in a fashion such that one holds or prepares an object for the other to operate upon. In our laboratory, we have used a rather

**Fig. 16** Two-handed obstacle box for studying the complementary role of right and left hands

simple device consisting of a sliding transparent cover that must be pushed up and held by one hand while the infant reaches inside for a toy. If he attempts to do both acts successively with a single hand, the cover slides back into place on its ball bearings and covers the toy (cf. Fig. 16). Prior to mastery, the child is likely to use a single hand or both hands together successively. It is at about the time of mastery that the child begins showing some preference for one or the other hand.

Let me risk the speculation that the differentiation of *holding* and *operating upon what is held* may be the same rule as diffuse and focal attention and that both may presage the development of *topic* and *comment* in human languages.

What I offer by way of apology for this rather unbridled speculation is my wish to take Anticus seriously when he urges Jason, in Goodman’s (1967) dialogue, to consider whether there may be rules or systems which, when learned, might predispose a human infant to language. The *channel* of language is doubtless dependent on the growth of interaction codes. The origin of the uniquely human *form* of language remains very much a mystery. I have proposed that it is a refinement or extension of human skill as exhibited in the attentional system and the motor system as represented by man’s clever hands. It seems to be a not unreasonable hypothesis that human skill, human information processing, and human language might conceivably be a set of related responses that differentiated man as he evolved from his hominid ancestors.

## Epilogue

In these pages we have been occupied in close detail with the growth of human competence. The focus has been upon the manner in which voluntary, skilled, codeguided behavior first emerges in infancy. Research on early development is only at its beginning, and there is emerging here and abroad the beginnings of a comprehensible picture. Much remains to be done, and I hope that the work of our laboratory at Harvard will contribute to the increase in understanding.

I would like, by way of an epilogue, to voice some strong biases that our work has produced in my own thinking—they are biases, not truly conclusions. They concern not only the nature of infant cognition and how it should be studied, but also how this work might better shed light on the nature of adult cognitive functioning.

*Functional systems.* The first is that organic activity can be understood only by recourse to the idea of systems conceived as designed to fulfill functions. It is not quite as in morphology where one differentiates nervous system from digestive system. Rather, it is much more as in systems engineering where one thinks of what it takes to deliver cargo over a particular set of terrain, with certain limits on time, cost, etc. The major functions of living require systems for their fulfillment, and at different stages these will vary drastically in their components, sometimes automorphic, sometimes alloplastic and dependent on tools and social organization. An infant can feed at his mother's breast; a civilized adult may require refrigerated imports. Breast feeding is embedded in a series of related activities and is dependent upon them—just as surely as dependence upon imports and refrigeration presupposes other supporting activities. When one examines infancy carefully, one is struck by the artificiality of analysis that is based upon the examination of isolated responses. Responses are parts of larger systems, and these larger systems are what require deeper study.

*Order.* There is a vast amount of order built into the human body and its nervous system that serves to shape, constrain, and support organic functioning. The morphological constraints include such specifications as the fact that we reach close to two meters in length, have two eyes, that our ears are facing sideways, that our interocular distance is a few inches and our arms about a meter long, that we are bilaterally and not radially symmetrical, that we are bipedal and our hands asymmetrical in skill. I mention these particular banalities because it is extremely difficult to understand the growth of human functional systems without bearing in mind that man's structure imposes a shape on human skills just as crucially as do the bizarre proportions of science fiction characters. From these constraints of morphology derive crucial constraints on cognitive learning. We have been particularly attentive to this issue in examining the growth of skill, with its many preadaptive constraints that operate to lead the hand-eye system to develop as it does. But it is, I believe, a more general rule that the inheritance of evolution is structural order that leads to language taking a particular form, to attention being organized along certain lines, etc. It is a commonplace, but one too easily forgotten—until one examines such compelling phenomena as the emergence of order behavior in infancy.

*Evolutionary inheritance.* Granted ontogeny does not recapitulate phylogeny, we would do well to continue to attend to the relation between the two. Human infancy probably reflects the trend toward neoteny among primates, as LeGros Clark (1963) speculates, a tendency for evolution to select among primates of infantile characteristics. As LeGros Clark remarks, the adult nervous system is much closer to the *fetal* brain of higher pongid apes than it is to their mature brains. And there is, moreover, a strong trend in primate evolution toward distance receptors, toward bipedalism, toward the exaggerated pentadactyly of independent digits, toward cortical control. These are matters of crucial importance, and a developmental science of man without a sense of man’s primate origins would be shallow.

*Immanence.* I shall assume, here strongly influenced by Lashley (1951), that cognition—the achievement, retention, and storage of information—is inherent or immanent in the functional enterprises of organisms. It can never be studied independently of the decisions that organisms take individually or evolution takes collectively concerning the grammar or logic of action. So, when we study the changing responses of the three-week-old infant to changes in the pay-off for sucking, we are studying not just sucking but the infant’s mode of coping cognitively with a changing environment. Cognition has its origins in the early development of intelligent action, and the nature of intelligent action is obviously a proper study for the student of cognitive processes.

*Terminus.* The unique terminus of human growth is that to survive, humans, like other animals, must take their place as members of the species. In the case of humans, this is quite a special order: to become members of linguistic and mythologically instructed communities, to join a common data base, to use a pool of technology, etc. Just as the notion of functional systems need not trap one into “explaining” a phenomenon by referring to the function it serves, so an appreciation of terminus need not lock one into the doctrine of final cause as an explanation of growth.

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