The Self in Infancy: Theory and Research
P. Rochat (Editor)

CHAPTER 8

From Direct to Reflexive (Self-) Knowledge: A Recursive Model

(Self-produced) Actions Considered as Transformations

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This book is based on three major assumptions: one of them I fully subscribe to, the other two are on the contrary problematic.

The first assumption to which I subscribe states that object knowledge and self-knowledge are inseparable. It refers to Gibson's theory (1966, 1979), which considers that all perception implies a coperception of the object and of the perceiver him/herself and that all perceptual systems are self-referential. This assumption could be completed by the following statement inspired by Piaget's theory: All knowledge about objects implies knowledge about (subject's) potential actions related to these objects. As a consequence, all that we know about the development of object knowledge could be transposed to the development of self-knowledge, including featural knowledge as well as motion knowledge. Expressed differently, object knowledge includes self-knowledge, particularly as it is correlated to actions.

The second assumption asserts that during the second year of life, a conceptual or categorical self related to self-recognition in the mirror appears, as assessed for example by the Gallup (1970) mirror test. One can wonder, what does the emergence of this level of self-recognition in the general context of self-knowledge development mean more precisely? Does this behavior constitute a final state, a basis for further development or, as I suspect, just a step in the elaboration of self-knowledge as a complex phenomenon that cannot be restricted to self-recognition and even less to a particular form of it? More precisely, self-knowledge cannot be limited to featural knowledge and must include knowledge about actions, which is usually referred to as motion knowledge.

I prefer to use the term *knowledge about action* for knowledge related to (self-) actions that are considered as transformations connecting configurational or featural knowledge. Action knowledge is related not only to self-produced actions, but also to perceived actions. In a similar way, the body schema cannot be considered exlusively as visual identification of the various parts of the body (perceptual aspect) (Pick, 1922) or as a system of postural transformations (motoric aspect) (Head, 1920; Schilder, 1968), but as an amalgam of both points of view (Ajuriaguerra, 1976; Hecaen & Ajuriaguerra, 1952). As Wallon (1959, p. 253) wrote, "the problem of body schema is not only related to its constitutive images, but also to the relationships between gestural space (self-motion) and object space (object motion)." I will try in this chapter to develop and explicate the aspects of self-knowledge related to actions that are considered as transformations.

The third assumption asserts that before the emergence of a conceptual or categorical self, a preconceptual self can exist. Neisser (1993) refers to this as the "ecological self." Now, such a formulation raises delicate theoretical and terminological problems. In particular, what differentiates the conceptual forms of self-knowledge from the preconceptual ones? In fact this is related to (the more general problem concerning) the definition of different knowledge systems and the relationships they maintain among one another. A major part of my chapter will be devoted to this issue. I will base my discussion on the ideas developed by Mandler and Piaget on that topic. But first I will clarify the way I use the terms *direct* and *reflexive* in order to qualify different functioning modes of any knowledge systems.

The Difference Between Direct and Reflexive Knowledge

I will qualify knowledge as "direct" when the subject's processing capacities (structures or networks) are adequate or adapted to certain dimensions of the environment and their variations or when the structures or networks are adapted to some categories of problems encountered by the subject or when the patterns of information (static or dynamic) are in correspondence with action patterns. In such cases, the processing is automatized. For newborns, this direct knowledge results from phylogenesis. When knowledge is direct (or when the processing is automatized), it is as if the subject has no need to "think," to "reflect on," or to "mediate" before acting. There is a direct coupling between subject and environment (homeostasis). It is possible to say that the subject is under a simple stimulus response control, following Neisser (this volume) comments about flies' landing movements in response to optical flow. He concludes that flies do not

necessarily perceive themselves as distinct from the environment. One could ask to what extent humans behave in a similar way when we speak of direct knowledge.

On the other hand, confronted with new problems, subjects can be considered to be in a disequilibrium state or as inadapted (homeorhesis). In such cases, they have to modify their structures or networks or to elaborate new ones. This is usually the case in the course of development. During the elaboration of new structures to the new category of problems (or to similar problems but processed by new structures), subjects are in a state of disequilibrium. In humans, these phases of disequilibrium manifest themselves by *searching behaviors* or *exploratory activities* that are associated with (what is usually called) "thought," "reflection," or "explicitation processes," as well as various states of consciousness and intentionality. The relationship between subject and environment becomes (in a certain way) "indirect" or "mediated." In these cases, I suggest that such knowledge should be qualified as "reflexive." From my point of view, reflexive knowledge is a transitory phenomenon. It is necessary as long as the subject is elaborating new structures or networks. Reflexive knowledge can be related to the executive or integrative functions attributed to the prefrontal cortex (Dubois, Pillon, & Sirigu, 1994). When new structures have been constructed and automatized for new categories of problems, then knowledge manifested by the subject's behavior should again be qualified as direct. Take, for example, when the infant (around 12 months of age) succeeds without difficulties (in an automatized way) to retrieve an object located behind an obstacle, or when the child (around 3 years) succeeds without difficulties (i.e., in a systematic way) to nest cups of different sizes. Because I consider developmental processes as recursive, cognitive development can be characterized by a succession of levels of direct and reflexive knowledge. Consequently, it is no longer possible to consider direct knowledge as more "primitive" than reflexive knowledge. In such a perspective, direct knowledge as manifested in the newborn must be considered as resulting from previous reflexive knowledge in the course of phylogenesis.

The origin of disequilibrium or disadaptation could be internal or external to the subject. Nevertheless, during ontogeny it is reasonable to consider the internal transformations as predominant and responsible for the major restructuring of cognitive systems. If we consider, for example, the setting up of inter- and intrahemispheric connections (the coupling of connected neural networks) as studied by Thatcher (1994), one can figure out their consequences on the equilibrium in the relationship between the subject and its environment.

Considered in relation to these distinctions, my position can be summarized in the following way:

- At birth there is a first knowledge system already constituted, which I call "sensorial" or "sensorimotor," which includes a variety of direct self-knowledge based upon encapsulated subsystems. These various subsystems are integrated into a whole system.
- On the other hand, there is also from birth on a second knowledge system in elaboration called "perceptual" or "perceptuomotor," which makes possible the elaboration of new (self-)knowledge by the different specific subsystems. During the elaboration phases of the new system and its subsystems, knowledge is reflexive and eventually becomes direct when it is automatized. I estimate the achievement of the whole perceptuomotor knowledge system to be at around 3 1/2 to 4 years.
- Knowledge of the first sensorimotor system is "direct" and nonexplicit. At the achievement of the perceptuomotor system (and subsystems), knowledge is again direct but could be explicit if necessary (i.e., if necessitated by the encountered situations).
- From 3 1/2 to 4 years on, another knowledge system (called "concrete") starts in a recursive way. The perceptual system now elaborated will take the turn of the constituted system.

In order to discuss the problem of the existence of different knowledge systems and their possible relationships, I will first examine recent articles by Mandler (1988, 1992). Then I will present Piaget's theory related to knowledge about action-transformations and reflexive abstraction in order to demonstrate how self-knowledge related to action is one of the major components of knowledge systems. Finally I will describe my own conception of the construction of new knowledge systems.

On the Existence of Different Knowledge Systems

Mandler's Point of View

Recently, Mandler wrote two articles entitled "How to built a baby" (1988, 1992). In her first article (1988), which I have discussed extensively elsewhere (Mounoud, 1993a), Mandler defines what she calls a "dual representational system." On the one hand, there is a "sensorimotor knowledge system" (or sensorimotor procedures), based on sensorimotor, nonsymbolic representations, and, on the other hand, there is a "conceptual knowledge system" (or declarative knowledge), based on conceptual and symbolic representations. The existence of this second system is due to the human infant's innate capacity to symbolize.

These two systems differ in the following way: Sensorimotor knowledge is not accessible to consciousness, and its acquisition does not require conscious accompaniment, whereas conceptual knowledge is accessible to consciousness, for purposes of recall or thinking. They differ with regard to their respective origins as well. Sensorimotor knowledge is derived from perceptual input, based on what objects look like, without adding something "above or beyond what the object looks like" (Mandler, 1988, p. 118). Conceptual knowledge is based on a process of elaboration of perceptual input, resulting from perceptual analysis, and is equivalent to a mental comparison process.

In her second article, Mandler (1992) specifies what the process of perceptual analysis in the elaboration of conceptual knowledge is and defines what she calls "conceptual primitives" (constructed). Before being constituted of conceptual representations, the conceptual knowledge system would initially be based on another type of representation called "image schemas" (conceptual primitives), which are derived from perceptual structures. I have to point out that in her 1988 article, Mandler states that conceptual knowledge is not due to a transformation of procedural knowledge. In her 1992 article, conceptual knowledge results from a (representative) redescription of perceptual schemas following a model borrowed from Karmiloff-Smith (1991) and from Slobin (1985), who in turn were inspired by Talmy (1983), Johnson (1987), and Lakoff (1987). Consequently, the process of redescription corresponds to the process of perceptual analysis. Perceptual schemas, before being redescribed by means of language in a propositional form (as conceptual schemas), are redescribed as image schemas. Image schemas are defined as declarative, analogical and nonpropositional knowledge. These representations are rather global in character and are also quite crude. They do not require detailed featural analysis. The major difference between perceptual and image schemas lies in the fact that image schemas contain only fragments of the information originally processed by the perceptual schemas (Mandler, 1992, p. 602).

Perceptual analysis (or representative redescription) takes place "on aspects of the input not previously analyzed" (p. 592), "on a new kind of information" (p. 589). Nevertheless, these aspects have been necessarily processed by perceptual schemas, if one takes into account that perceptual analysis is directly based on them and selects only fragments. There results a new kind of information according to Mandler, only in the sense that "a piece of perceptual information is recoded into nonperceptual forms that represent a different fonnat: a vocabulary of meanings" (p. 589). In addition, she also states that the vocabulary of image schemas is a set of elementary meanings (p. 590). Finally, Mandler declares that a brief structural description of a percept (a perceptual schema) can be done by means of an image schema (p. 601). Insofar as perceptual schema can be described by an

image schema, I have difficulty understanding how the processing realized by perceptual and image schemas differs, except for the filtering process that takes place between the two schemas. How could the major differences between perceptual and conceptual knowledge be grounded?

Although captivating, Mandler's attempt to explain how a nonperceptual understanding of objects develops in opposition to empiricist theories seems to lead to a dead end. She herself considers that Piaget's theory fails to explain in a satisfactory way how sensorimotor schemes are transformed into concepts. (For Piaget, as we will see later, sensorimotor schemas are concepts). She also considers that for Piaget, the emergence of mental images at around 18 months corresponds to the appearance of object concept. Inasmuch as conceptual knowledge is described as a redescription of perceptual schernas, it is difficult to figure out how Mandler could escape to empiricism, unless she considers perception as potential action, as Arbib (1980) has, for example. But nothing similar is found in her articles. On the contrary, she seems to be averse to any attempt to locate the basis of the understanding in action or in what she calls "motor processes," "felt movement of the self," or "bodily experience," without mentioning "manipulating objects" or "physical interactions": concepts she uses in reference to Piaget's theory. Like many other developmental psychologists, she does not conceive of how knowledge related to self-actions could possibly play a major role in cognitive development. We come back to the first assumption outlined in the introduction, which states that self-knowledge is inseparable from object knowledge or includes it. I must confess that if action (knowledge) is limited to manipulation or physical interactions, I have the saine aversion as Mandler. But I am convinced that Piaget's ideas related to action are very different from such a depiction. For that reason I will (briefly) present what I consider to be the essence of Piaget's point of view.

Piaget's Point of View

As an introduction, it is necessary to specify the meaning of the terms *concept* and *conceptual* for both Mandler and Piaget in order to eliminate some misunderstandings. What Mandler tries to explain is the emergence of conceptual knowledge, whose mature form would be expressed through language ("accessible for purposes of recall," "potentially expressible verbally"). Consequently, the emergence of concept corresponds to the emergence of spoken language. For Mandler, a concept is in a way the verbal redescription of previous imagery (analogical) knowledge, which is itself a redescription of perceptual knowledge. In this manner, image schemas (conceptual primitives) constitute an intermediary (representational) level between perceptual schemas and conceptual schemas.

For Piaget, the existence of concepts is neither bounded to the emergence of speech nor to the emergence of mental images, which only provide the configurational knowledge of the states. Concepts are basically dependent upon the coordinations of actions (material or mental) that supply the knowledge of the transformations (production rules). For Piaget, an image or a word representing an object never constitutes a concept. An image or a word become concepts only when they are integrated into a transformational system that defines their relations with other images or other words (or even other percepts). In this manner, a sensorimotor scheme is already the practical expression of a concept. A scheme is a concept in the sense that it allows meaning to be conferred to objects. Consequently, for Piaget the problem is not to explain the transition from sensorimotor schemes to concepts, but rather to explain the transition from concepts expressed by practical activities based upon sensorimotor schemes (coordination of actions) to concepts expressed by reasoning based upon logical operations (coordination of internalized actions) or formal operations. The transition from one level of conceptualization to another is due to a process of interiorization as reminded by Mandler but in the interiorization of action schemes (coordination) and not of imitative activities. To conclude, I would like to suggest that all knowledge systems are conceptual systems in a broad sense and that the conceptual knowledge system defined by Mandler is a particular case attuned to the emergence of language. With regard to the structures of the newborn, the problem is somehow more complex. For Piaget, these structures could not he called conceptual because they are considered as "biological," and for Mandler they are nonsymbolic and nonaccessible to consciousness. However, for many authors such as Jackendoff (1992), they have to be called conceptual. Personally I agree with this last statement.

Let us now consider how Piaget explains the transition from one knowledge system to another. As already mentioned, he calls upon the process of "interiorization" of the action coordinations (also called general coordinations of action), which gives rise to mental operations precisely defined as interiorized or mental actions. This process has been described by Piaget under the name of *reflexive abstraction* (or convergent reconstruction with overtaking), which is a recursive process (Piaget, 1967). Karmiloff-Smith's (1991) process of representative redescription has some similarities with the reflexive abstraction process.

According to Piaget (1967/1971), this process can be defined in the following way:

> Reflexive abstraction consists first of becoming conscious of the existence of one of the actions or operations previously made by the subject himself, that is to say, noting its possible interest, having neglected it so far.... Second, the action notes

> has to be "reflected" (in the physical sense of the term) by being projected onto another plane — for example the plane of thought as opposed to that of practical action.... Third, it has to be integrated into a new structure, which means that a new structure has to be set up, but this is only possible it two conditions are fulfilled:
> (a) the new structure must first of all be a reconstruction of the preceding one if it is not to lack coherence and continuity... (b) it must also, however. widen the scope of the preceding one, making it more general by combining it with the elements proper to the new plane of thought; otherwise there will be nothing new about it.
> These, then, are the characteristics of a "reflection," but now we are taking the term in the psychological sense, to mean a rearrangement, by means of thought. of some matter previously presented to the subject in a rough or immediate form (Piaget, 1967, p. 366; 1971, p. 320).

It is obvious that when Piaget wrote this definition, he had in mind the transition from sensorimotor intelligence to concrete thought or from concrete to abstract thought. Nevertheless, taking into consideration the recursive character of the process and the general background of his theory, the definition could be generalized to any transition, in particular to the transition from reflex to sensorimotor schemes.

According to Piaget's perspective, "concepts" at the level of representative intelligence only appear in conjunction with the emergence of logical operations (as internalized actions), at around 6 to 7 years of age. In a similar way, concepts at the level of sensorimotor intelligence only appear in connection with the emergence of the general coordinations of actions, at around 16 to 18 months of age. However, there are prior to concepts *stricto sensu*, preconcepts, which are characterized by the insufficient regulation between their intension and extension.

At this point, I must introduce a distinction made by Piaget (1961) between two categories of knowledge instruments, respectively called "operative" and "figurative" instruments. Operative instruments are those that provide knowledge about transformations (mainly the schemes or the operations); in contrast, figurative instruments supply knowledge about states of reality or the results of transformations. The figurative instruments correspond to three types of signifiers as defined by Piaget: perceptual indices, mental images, and abstract symbols. For him, these two categories of instruments are inseparable, but they are dissociated in order to facilitate the analytic description. Nevertheless, he has treated them as if they could exist independently of each other.

The distinction between knowledge about states and knowledge about transformations is essential because it makes it possible to understand correctly the notions of action schemes and mental operations, as well as the importance attributed to knowledge about actions. By knowledge about actions as transformation, Piaget refers to the ability of understanding the connection between two successive states of a situation or of an event. It could also refer to the

knowledge about production rules (generative rules, i.e., grammar), logical rules, physical laws, or statistic laws.

It may be useful to give some examples in order to illustrate this distinction between knowledge about states and transformations and their connections.

The scheme or concept of support (prototype of means-end coordination mastered by the infant at around 8 months of age),. which consists of pulling a support in order to reach for an object laying down on it, corresponds to the mental structure that makes possible the connection of the action-transformation "push-pull" to the states "being out of reach" and "being reachable." The scheme integrates knowledge about the states "being on" and "being beside," in a transformational system. At a more analytical level of explanation, it is also possible to describe the various states "being on" and "being beside" as linked by more elementary coordinated action-transformations such as "laying down" or "lifting up," etc.

The scheme of face recognition, acquired at around 2 or 3 months of age (which succeeds a scheme already present at birth), corresponds to the mental structure that connects the various states of a face defined by configurations of perceptual indices (front view, side view, etc.) to action-transformations (head rotations, subject's or object's rotation).

The scheme of (shape or) size constancy is the insertion of the various sizes of an object related to its distance from the perceiver in a transformational system (system of transformations) governing the moves of the object. Present at birth, it can be reconstructed during the first months of life.

The scheme of object permanence (the "objective" form), achieved at around 16 to 18 months of age, is the mental structure that connects the various successive states of a set of objects (their different localizations or relative positions) to their successive displacements (transformations) when these displacements are organized or structured by the subject into a system. I would like to point out that for Piaget, there is already at birth a "practical" form of object permanence (as opposed to the "objective" one), revealed in particular by the capacity of the newborn to recuperate the nipple when lost, i.e., to adequately rotate his/her face (transformations) in order to modify the "state" of the nipple from "out of the mouth" to "in the mouth" (Piaget spoke of the sucking reflex scheme, but as a matter of fact he was referring to the rooting reflex). This permanence presupposes, as stated by Rochat & Morgan (this volume), some implicit knowledge about the mouth. This was for Piaget a practical form of permanence inherent to functioning, as opposed to the "objective" permanence produced by functioning.

I hope these examples clarify the nature and importance given by Piaget's theory to knowledge about actions (about the general coordinations of actions) as

systems of transformations. It is the structure of action coordination or the coordinate actions that connect the successive states of a situation and define its invariants. It is more the whole organization or structure than the actions themselves. It is also in that sense that we are dealing with something more abstract than manipulations or physical interactions, as referred to by Mandler and many other developmental psychologists. For Piaget's theory, the states of the world (the successive states of a given reality) are understandable only as far as they are connected or linked with the transformations that generated them (the production rules). For him, this knowledge about transformations could not be directly derived or extracted from perception. If the 8-month-old baby searches for an object placed under or behind another one, it is not because s/he has perceived the occlusion of one by the other (the information is not incorporated in the structure of the visual flow), but because s/he is able to organize in a system the respective displacements between the two objects. Similarly, if the newborn again finds the nipple, it is not because s/he perceived it escaping from her/his mouth, but only because s/he possesses a structure (called the "sucking reflex" by Piaget) that coordinates her/his actions with her/his perceptions. The newborn can compensate a displacement (head rotation) by its inverse. In addition, these coordinated sucking activities allow the baby to understand the states of "being inside" or "being outside" the mouth and the relationships that connect them. This partly corresponds to the *image schema of containment* as defined by Mandler, following Johnson (1987) and Lakoff (1987). Next, I shall analyze in detail the genesis of this concept of containment as described by Mandler.

The Concept of Containment: A Comparative Analysis of Mandler's and Piaget's Viewpoints

In order to be more concrete, I will present in a critical way the origin of the concept of containment as described by Mandler (1992) and then contrast her view with Piaget's. The concept of containment is the capacity to understand that a given object (the container) can contain another one. The container may be a part of the body such as the mouth or the hand, or an object. According to Mandler, the concept of containment appears in the infant at around 5 months of age as an image schema (conceptual primitive).

First, for Mandler this concept is bounded to *notions* such as "going in" or "going out," "opening" and "closing." These notions are precisely what Piaget calls knowledge about action as transformation. Thus, the infant must have as a prerequisite some knowledge related to these actions and to their meanings. This corresponds to the first step of the reflexive abstraction process: The subject has to

notice or to become conscious of the existence of and possible interest of some actions produced by him or her.

Second, according to Mandler (in reference to Lakoff, 1987), the image schema of containment has *three structural elements:* interior, boundary, and exterior. These elements are based on two different capacities: the capacity to consider objects as having boundaries and an inside separated from an outside (Spelke, 1988) and the capacity to consider objects as being in or out of a container. For Piaget, this is related to the knowledge of three distinct "states" that can be understood (processed and stored) independently from the knowledge related to the actions that produced them. Knowledge about states results from perceptual activities that constitute configurations of perceptual indices (as configurations of haptic and tactile indices corresponding to the perception of an object in the mouth, out of the mouth, or only in contact with the mouth; or configurations of visual indices corresponding to the perception of an object inside, outside, or in contact with another one). In addition, Mandler mentions that according to Johnson (1987), bodily experience can be the basis of the understanding of containment. Nevertheless, she is not convinced that bodily experience is a necessary condition for perceptual analysis. She considers that it is "easier to analyze the sight of the milk going into and out of a cup than milk going into and out of one's mouth." But she does not explain the reasons of this relative ease. However, she concedes that "food as something taken into the mouth" could be an early conceptualization of containment (Mandler, 1992, p. 597).

Third and finally, the concept of containment would result from the cluster of related image schemas. For Piaget, the sensorimotor scheme or concept of containment results from the coordination (the cluster!) of elementary (noticed) actions (going in, going out, opening, closing, etc.) themselves, connected with the corresponding resulting states of reality (being inside, being outside, being opened, being closed, etc.). The coordination of actions gives access to the transformation rules, to what organizes the successive changes of states, to what gives them a meaning. From my point of view, there is already at birth schemes or concepts of containment belonging to the first knowledge system (sensorial). Other concepts elaborated by means of the second knowledge system (perceptual) would follow the first ones.

Taking into consideration (self-)knowledge about actions in the construction of new systems seems to me the only way to locate the origin of knowledge "above or beyond what the object looks like" (i.e., beyond the perceptual similarities and differences, Mandler, 1988, p. 118; 1992, p. 595). This is the reason why Piaget has always been opposed to empiricism. Knowledge is not mainly derived from perception, but from the understanding of (self-)actions as transformations (which I consider essential to the construction of "conceptual

primitives," in spite of Mandler's reluctance). Actions as transformations cannot be reduced to the concepts of motion, manipulation, or interaction. Knowledge about actions is more directly connected with concepts such as plans, programs, templates, potential actions, or more generally to the whole organization of actions, the coordinative structures as labeled by Bernstein (1967). The concept of body effectivities suggested by Rochat (this volume) is another attempt to specifiy this complex notion.

Limits of the Piagetian Approach

The preceding pages constitute an argument in favor of Piaget's ideas on the knowledge about action coordination or logico-mathematical experience. Nevertheless, this conception has several gaps, which explains at least in part, why it has been rejected and distorted. The major problems of Piaget's theory are due to his radical structuralist approach. When Piaget defined the structures underlying behaviors, he did so by taking exclusively into consideration actions (physical or mental) independently of the object categories (the various contents) to which they apply. In other words, he defined the knowledge about actions (operative knowledge) independently of the knowledge about states (figurative knowledge) or more precisely in relation to abstract, nonspecified states. Action-transformations have also been characterized in a very abstract way and have been qualified for example as "direct," "inverse," "reciprocal," and "correlative." These transformations have lost all of their functional dimensions and above all their meanings, and have been reduced to their logical aspects. Whole structures have been defined in order to explain very general competencies without any specificity and functional values. The difficulties and criticisms generated by this approach are well known. By rejecting whole structures, researchers also rejected or lost the ideas related to action-transformations as a possible base for the production rules at the origin of our behavior and also of a possible basis to understanding cognitive development. The central concept of actions as transformations has been denatured and reduced to the trivial idea of manipulations and physical interactions that correspond to what Piaget has called the "physical experience" or the empirical abstraction (also called simple or Aristotelian abstraction), to which he conceded very limited credit. The essence of cognitive development for Piaget is based on the *logico-mathematical experience* as related to actions and corresponding to the reflexive abstraction process.

Thanks to his radical structuralism, Piaget was able to formalize very different types of behaviors by means of the same formal structure. Thus, at the sensorimotor level, he defined the behavior of the newborn and the 18-month-old

with the same structure (Piaget, 1937). Because his goal was to demonstrate the emergence of new formal structures, he was forced to qualify them as "practical" and "objective" in order to differentiate them. The structure related to the reflex schemes was called "practical" and "biological." It was described as *inherent to the action,* as opposed to the "objective" one related to the sensorimotor schemes that are considered to be *produced by the action* and qualified as mental or psychological.

A similar opposition has been suggested more recently by Karmiloff-Smith (1991), who compares knowledge *in* the humain brain, not accessible to consciousness, biologically specified (knowledge in the cognitive systems, embedded in procedures) to knowledge accessible *to* other parts of the brain as data structure.

From my point of view, it is possible to say that any knowledge system is biologically determined and inherent to actions. The knowledge system manifested by the newborn results from a phylogenetic construction and *does not radically differ from the other systems.*

To increase the confusion, Piaget subsequently relabeled the "objective" structures as "practical" without giving any explanation for this major change (e.g., Piaget, 1947). I have discussed this problem in various articles (see Mounoud, 1979, 1993a; Mounoud & Hauert, 1982; Mounoud & Vinter, 1981; see also Hauert, 1980, 1990; Vinter, 1985, 1990).

Finally, I have to mention that the majority of the general coordinations of action that Piaget described in the course of the sensorimotor stage is already part of the newborn's repertoire, such as for example hand and mouth coordination, visual and manual coordination, means-end coordination, the actions of adding and substracting, etc. These are some of the reasons that led me to consider the structures defined by Piaget as preformed (Mounoud, 1979).

From my point of view, it is obvious that knowledge about action-transformations cannot be defined separately from knowledge about the states of objects and that both cannot be characterized in such an abstract way as Piaget did. Furthermore, meanings only result from the connection between knowledge about states and transformations expressed by the *functional properties* of actions. The concept of body effectivities suggested by Rochat (this volume) integrates these two kinds of knowledge. Apart from their formal dimensions, actions have functional properties at the origin of the meanings manifested in the behavior or attributed to the objects. Consequently, the origin of the concept of containment is not to be exclusively found either in the perception of the object (in the perceptual analysis of the object) or in the general coordination of the actions of opening and closing the hands or the mouth, but in the discovery of the functional properties of these actions (their meanings) such as grasping or releasing objects, containing or

being contained, and of the values attached to these functions. This is done by means of implicative relations, declarative representations, or predicative functions. Conceptualization or thought precedes action in cognitive development.

To conclude, it is possible to say that if Mandler gave an exclusive role to perceptual activities in the elaboration of knowledge systems, Piaget gave an exclusive role to the formal aspects of the action coordination. Below I will suggest a point of view that tries to combine these two aspects and also introduces the functional aspects of actions.

Do Knowledge Systems Indude Knowledge About Actions?

At this point, we must discuss whether the knowledge systems or the conceptual structures include only perceptual data or if they integrate other data, such as knowledge related to transformations (production or generative rules) as manifested in actions. Do representations incorporate potential actions, action plans, or knowledge about the effectivities of the body?

According to Piaget, transformations (or production rules) are initially only accessible to the subject by means of his/her own actions. Consequently, it is important to specify if knowledge about self-actions is exclusively based on perceptual information or the perceptual analysis that accompanies them, or if the organization itself of the action, its planning, could be at least partly available. If knowledge about actions is only accessible through perception, then it still has exclusively a perceptual origin. On the contrary, if knowledge about actions is represented in the form of rules, plans, programs, strategies, recall schemas, etc., then there could be some good reasons to search in that direction for the origin of an essential part of our knowledge, which precisely concerns transformations.

To conclude this point, I will briefly refer to an idea recently suggested by Jackendoff (1992) concerning conceptual structures. For him, one of the components of innate conceptual structures could be *body representation,* which encodes internal states of muscles and joints and the locus and character of body sensations. With such a definition, the body is exclusively considered on the perceptual side or in Piaget's terminology, with regard to knowledge about states without any connection to knowledge about transformations. As I mentioned in the introduction, body schema is not only related to perceptual configurations (featural knowledge), but includes a system of transformations as well that connects the configurations — usually called postural schema. For Jackendoff, body representation is a way station between the *intention to act* (part of the conceptual structure) and the form of motor commands. I consider the intention to act as a concept very close to knowledge about actions, and I am very much in

favor of introducing it in the conceptual structure. One could say that the reflexes and sensorimotor schemes are basically intentions to act or potential actions. In my opinion, the newborn has a preformed conceptual structure (called **"sensorial"),** which includes a body representation (knowledge about states and transformation; Mounoud, 1979, 1981). This perspective diverges from Piaget's and Mandler's points of view. Now we still have to deal with the crucial problem related to the construction of new conceptual systems. The problem will not be settled in the same way according to the position regarding the initial state of the newborn, but this issue will not be discussed here.

The Construction of New Knowledge Systems

According to Mandler, what are the necessary ingredients needed in order to explain the development of new knowledge systems? As we have already seen, the redescription of perceptual schemas into image schemas should be sufficient. However, image schemas provide only knowledge about states or configurations (which can include motion perception as changes of states), but this knowledge excludes the understanding of transformations inherent in action coordinations. All of the knowledge related to the "intention to act," "potential actions," the "effectivities of the body," and action plans is missing. Consequently, in order to (re)construct a (new) knowledge (or conceptual) system, it is necessary to postulate, in addition to the construction of *image schemas,* the construction of *abstract schemas* (propositional in nature), which provide knowledge about action-transformations. In such a perspective, the infant becomes conscious not only of fragments of the information originally processed by the perceptual schemas recoded into image schemas (featural knowledge of featural self) as stated by Mandler, but also of some intentions to act or action planning (motion knowledge or motion self-knowledge). In that manner, s/he will discover not only the successive states of an object that "goes away" or "comes near" her/him (variations in the apparent size) or that turns around (variations of shape). but also transformations (production rules) that connect and explain them (extension and flexion of the elbow, rotation of the wrist). (By bending or stretching my elbow, I can bring near or move away my hand or an object held and can vary its apparent size. By twisting my wrist, I can rotate my hand and modify its apparent shape). Such representations must be declarative in nature and could be expressed or formulated in a more abstract way.

The new representations (image and abstract schemas) would be initially partial and elementary. Their coupling would form the connection between the knowledge of states and transformations (elementary) at the origin of meaning (the

effectivities of the body). Thus, the infant discovers (becomes conscious of, notices) some aspects among the whole set of aspects processed by his/her first constituted knowledge system (sensorial), as for example his/her hand as one part of his/her body that could be in various states (opened or closed, prone or supine, near or far away) as well as in the action-transformations that connect them (opening and closing, rotating, bending and stretching). In a similar way, the infant discovers his/her milk bottle as an object that could be in various states (stand up or reverse, fully or partially visible, etc.) and the transfonnations that connect them (turning up, turning down, turning back, moving behind or in front, etc.).

To summarize, it is by the construction of abstract schemas (representations) propositional in nature and of image schemas (representations) analogical in nature that the infant reconceptualizes the states and transformations of objects, of others, and of her/himself (her/his body), which define the events to which s/he is confronted. For many years, I have thought that these two types of schemas (analogical and propositional) followed one another within a stage (Mounoud, 1986b). More recently (Mounoud, 1990; 1993a), I have begun to consider that they may coexist initially in a partially dissociated way and may later on operate in a combined, integrated way. The conceptual (sensorial) system of the newborn is also composed of image schemas like the 3D model structures of Marr (1982), including representations of the various states of the body; and of abstract schemas, including representations of the action-transformations of the body.

Conclusion

The exceptional abilities of humans to modify behavioral determinants duˈing development can be explained by the emergence at various periods and in particular at birth of new coding capacities. These new capacities force the organism to retranslate, redefine, reinterpret, and reformulate some of the information accessed, that is to say, to construct new representations, new frames of reference, and new categories. The construction of these representations is made through a relatively slow and complex process requiring a few years. I have described several times and again recently this construction process, so it will not be presented here (see Mounoud, 1984, 1986a and 1986b, 1988, 1992, 1993a, 1993b, in press; see also Vinter, 1990).

According to this perspective, the newborn's exceptional competencies are explained by preformed representations qualified as sensorial or sensorimotor. They account for the intersensorimotor coordinations that characterize the newborn's behavior. During their first weeks, infants behave in certain situations as if the

surrounding world and their body are meaningful: Numerous stimuli constitute for them organized patterns of information in response to which they produce organized action patterns (e.g., early prehension, imitation, direct knowledge). But more or less simultaneously, infants behave as if the situations they confront constitute "polymorphous sets" or a "confusing and ambiguous universe" without precise functional meaning (in other words, with problematical situations), as, for example, in their awkward attempts to reach for an object between the 2nd and 5th months (from approximately the 6th to the 20th week) or in their unskillful attempts to retrieve a hidden object (the A-not-B error) between the 8th and 10th months (all of these situations can be characterized by a disequilibrium state). Thus, infants need several months to be able to recategorize situations and reorganize or replan their actions. It is not before 6 months that infants are able to grasp in a partly adapted manner a visually perceived object; not before 1 year that they succeed in regulating or in accurately planning in advance the orientation and the shaping of the hand as a function of the size and orientation of the object; not before the age of 16 to 18 months that their grasp begins to be regulated as a function of the object weight inferred from its size and/or texture; not before 20 to 24 months that their prehension adjusts to reciprocal orientation between two objects; and not before 36 months that they fit together five cups of different sizes (i.e, Greenfield et al., 1972; Hofsten, 1989; Lockman, 1990; Mounoud, 1983).

It seems as if the infant possesses at birth action procedures (or procedural sensorimotor representations) adapted to a set of situations (direct knowledge). These representations are by nature unconscious, or they relate to a nonreflexive consciousness (cf. Marcel, 1983), as all automatic or automatized behaviors can be considered unconscious in nature. The emergence of new coding capacities causes the infant to elaborate new representations that I have called "perceptive" and that go along with reflexive knowledge.

Another way of expressing the same story is to say that infants, in the course of their development, construct knowledge (or concepts) that must lead them to construct new know-how. Development is therefore a matter of shifting not only from direct know-how to reflexive knowledge (as argued by Piaget), but also, and in an equally large extent, shifting from reflexive knowledge to new, unconscious know-how. Rey (1934) spoke of the withdrawal of active intelligence during automatization processes. It is in this way that new know-how — new skills — are learned and automatized (prehension, walking, imitation, localization, etc).

To conclude, it is possible to consider development as an alternation between: a) periods of adaptation (adaptation in the different domains is more or less optimal according to the experiences realized); and b) periods of reorganization. Periods of adaptation are characterized by automatized behaviors that can be described as reactive or interactive (direct knowledge); periods of reorganization are characterized

by transitional conscious activities that provide to the infant's behavior an active and intentional character (reflexive knowledge). These functioning modes depend on infants' planning abilities and vary as a function of infants' developmental level and the situations confronting them.

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