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Chapter 2

THE EMERGENCE OF NEW SKILLS: DIALECTIC RELATIONS BETWEEN KNOWLEDGE SYSTEMS

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Abstract

At the beginning of every learning or developmental process behaviors can be described as determined simultaneously by two different knowledge systems. A rather achieved and automatized system integrating a large amount of information in a 'direct' way (bottum-up) reveals itself in practical forms of knowledge. Another system in elaboration reveals itself in conceptual forms which select and reinterpret subsamples of information that are relevant regarding the pursued goals. These two systems maintain hierarchical and fairly complex relations which reverse over time: The conceptual forms produced by the new knowledge system are initially directed or framed by the practical forms of the previous system, but finally end up controlling and integrating them. The term practical is attributed to every automatized behavior (material or mental) for which all the previous cognitive activities having constituted it are not accessible or explicitable anymore.

Introduction

The emergence of new 'sensorimotor' skills *in infants*, such as the various types of reaching for objects or the various solutions in the object retrieval tasks, have been considered by many psychologists as independent from cognitive or conceptual development (for instance,

Hofsten, 1990; Mandler, 1988; Thelen, 1989). In particular, the natural dynamic perspective developed by Kugler, Kelso & Turvey, (1982; See also chapter 5 of Zanone et al. this volume) proscribes the notion of central systems. The position I intend to defend is precisely the opposite one: The emergence of any new skill during infancy, and also during the entire lifespan, results from the involvement of new conceptualizations, new categorizations: That is, stated in a more simple way, from new knowledge. But it is crucial to add that new conceptualizations can only be elaborated on the basis of practical forms of knowledge directed by a previous system. For me new knowledge is produced by new systems of representation and processing which are specialized for conceptualisation. These are the conscious products of our mind that play a temporary but necessary role in the developmental process. From this point of view new skills originate from initial conscious conceptualizations before giving rise to new practical forms of knowledge, which can be more or less automatized (Mounoud, 1990b).

In this chapter I will present the transformation of knowledge in children, which psychologists, in the beginning of the century called the development of intelligence, and which they call today the development of *central* systems. I have to make clear from now on that I am much more interested in central systems than in specific modules. In opposition to Fodor (1983) I believe that central systems are the major topic in psychology. Thus, I consider that knowledge is expressed as much in recognition or recall behaviors as in language production or imitation, or in visual tracking, spatial localization, or reaching for objects in various contexts (lying on a support, moving, located behind a screen, hidden in various places, varying in size, orientation, localization, weight). From my point of view all these behaviors manifest the presence of knowledge or concepts related to objects, events or actions. These concepts (or categories) can be already well constituted and automatized (sensorial input having a direct access to them) or by contrast they can be in the *process of* elaboration. As far as infancy is concerned, these terms (concepts, categories) may seem inappropriate. Nevertheless, as colleagues like Spelke (1991) or Mandler (1988) among others do, I will use them, taking the care to distinguish various levels of conceptualisation. Conceptualizations

manifested by a newborn are different from those manifested by, say, a 3-month-old, a 12-month-old or a 6-year-old child. These levels correspond to different mental organizations or structures (or representational processing systems) which I call in this chapter *knowledge systems*.

From this perspective, instead of being interested in the specificity of various domains, I am more interested in what is general or common to different behaviors for a given level of development as well as in the general mechanisms or processes of change between levels (Mounoud, 1986b). This is not to deny the specificity of each domain but rather to suggest a focus of attention. It is worth mentioning that some neopiagetians like Case (1985) or Pascual Leone (1987) also argue in favour of general mechanisms, obviously in addition to the specific ones.

The distinction between two types of intelligence or knowledge

Independently from the distinctions between domains, researchers in human sciences have introduced at least from the beginning of the century an opposition between two types of intelligence or knowledge most often termed *'practical' or 'concrete' intelligence* (or situational intelligence) and *'conceptual' or 'representative' intelligence* (or discursive or verbal intelligence).

These two types of intelligence have been used to confront levels of development *between species* (humans as opposed to apes, Koehler 1917), or in a given species *between phylogenetic levels* (like in the ethnographic studies on the genesis of the simple tools done by Leroi-Gourhan (1964) (homo habilis versus homo sapiens)), or *between ontogenetic stages* (Piaget, 1936; Rey, 1934; Wallon, 1945), or finally *between categories of impairments* resulting from cerebral lesions, in particular between various types of apraxia or agnosia (without mentioning asymbolia and aphasia) (Seron & Feyereisen, 1987). It is possible to relate these two types of knowledge to the opposition usually made between intuitive and rational knowledge.

This opposition between practical and conceptual knowledge remains present in cognitive psychology under various labels *more or*

less related to the initial ones, like for example, between procedural and declarative knowledge, between know-how and knowledge, between symbolic and non symbolic processing levels, between knowledge accessible to consciousness or not accessible (as data base) or finally between implicit or explicit memories.

In summary, these oppositions have been most often used in the past to characterize non contemporaneous levels and systems of knowledge, but also, as is currently the case, to confront contemporaneous systems of knowledge that are usually considered to be different in nature and clearly dissociated.

In Piaget's writing (1936) it is possible to find both perspectives simultaneously (differences between levels and nature or differences in nature). On the one hand he opposed infants' non symbolic *sensorimotor* intelligence to children's symbolic *representative intelligence*, the latter derivating from the former. On the other hand he considered that *sensorimotor* intelligence is extended into two independent parallel directions: Into *practical* intelligence 'which continues to exist under verbal or conceptual realities' which defines 'decalage' in extension (relabelled later on horizontal decalage) and into *representative* intelligence characterizing the emergence of thought which defines decalage in intension (relabelled later on vertical decalage). It is well known that after the sensorimotor period, Piaget studied and emphasized quite exclusively the development of the so-called representative intelligence and had very little interest in the practical one (except much later in his book 'Success and understanding', Piaget, 1974). At the same period, Rey (1934) developed a quite similar theory but in a certain way symetrical to the one of Piaget (which he was aware of). He opposed the development of *practical* behaviors 'which allow us to solve most daily life problems' to the development of rational thought considered as 'more or less fortunate consciousness related to relationships directing activity' (Rey, 1934, p. 222). Nevertheless, he admitted that these superstructures (rational thought) can sometimes facilitate practical activities in return. Within such a point of view it is clear that his research interests have been preferentially oriented towards the study of practical behavior (contrary to Piaget).

Ever since 1968 in my doctoral dissertation (Mounoud, 1968, 1970), I have strongly questioned the possibility of using the opposition between 'practical' and 'conceptual' knowledge in order to differentiate the nature or the levels between knowledge systems, as did Piaget and Wallon, for instance. By contrast, I suggested that the adjectives 'practical' and 'conceptual' could be perfectly adequate for characterizing two forms (or two distinct states) of any given knowledge system. In the theory I tried to elaborate, the various knowledge systems are called 'sensorial', 'perceptual', 'concrete' (previously labelled 'conceptual') and 'formal'. Each one of these systems (different in nature) can appear under two different forms: That is, conceptual and practical.

On the basis of the above claims, it is possible to state that: (1) The practical forms of a given knowledge system result (onto- or phylogenetically) from the previous conceptual forms of the same system which have become sedimented (or encapsulated), which are no more accessible to consciousness (or which are no more explicitable); (2) the practical forms of a given knowledge system can only be qualitatively modified or transformed by means of conceptual forms of a new, more abstract knowledge system; (3) reciprocally, the conceptual forms of a given knowledge system do not improve without involving the practical forms of an already elaborated knowledge system (consequently a purely contemplative way for conceptualizing called 'the astronomer's perspective' by Lécuyer (1989) should be left out); (4) finally, if cognitive development in humans proceeds through stages, differences between two successive stages have nothing to do with the opposition between practical and conceptual.

Moreover, in all subjects involved in a learning or developmental process there are simultaneously *two knowledge systems* ('sensorial' and 'perceptual' for instance) which differ from each other by their relative maturity. A rather achieved and automatized system reveals itself in practical forms of knowledge, and another system in elaboration reveals itself in conceptual forms which reinterpret the incoming information. These two systems maintain hierarchical and fairly complex relations which reverse over time: The 'conceptual' forms produced by the new knowledge system are initially directed or

framed by the 'practical' forms of the previous system, but finally end up controlling and integrating them. I will develop these ideas further.

For the sake of clarity I have to specify that in my view an elaborated reasoning or an achieved theory also have to be considered as practical forms of knowledge, as know-how. The term *'practical'* can be attributed to every automatized behavior (material or mental) for which all the paths, all the previous cognitive activities having constituted it are not accessible to consciousness anymore, not explicitable anymore (or only to some extent).

Over the last twenty years I developed these ideas with various collaborators (Mounoud, 1971, 1979, 1986b, 1988, 1990; Mounoud & Hauert, 1982; Mounoud & Vinter, 1981; Hauert, 1980, 1990a; Vinter, 1983, 1989; Mounoud, Badan & Zesiger, in preparation).

Modifying the meaning of such an opposition between practical and conceptual knowledge, *which* is so strongly engraved in the history of psychology and also in daily life conceptions, is not an easy project. As of today, the idea of a diachronic difference *between levels* or a diachronic or synchronic difference *in nature* between two systems is more prominent than the idea of differences limited to the degree of achievement, to the degree of accessibility or explicitability of any given knowledge system.

I will now present my conception relative to the qualitative changes from one level of organization to another level. As we have seen, a classical solution is to oppose a practical or concrete level to a conceptual or representative one. I have already explained my disagreement with such a solution. I will then illustrate this conception by means of the development of reaching behaviors. Finally, I will summarize Jean Mandler's theory (1988). She tried, as I did, to suggest a model of cognitive development of the infant based on a dual representational system. For her, as we shall see further, sensorimotor knowledge and conceptual knowledge develop simultaneously and in parallel.

Behavioral development as a process of conceptualisation

One of the major problems in the study of behavioral development is to understand how the child moves from one organization to the next,

which is usually considered as qualitatively different and most often better regarding the subject's adaptation to the encountered environments (physical, social, ...).

I will try to formulate my thesis independently from any specific level of development. Every behavior of a subject involved in a developmental or learning process can be described as determined simultaneously by two different knowledge systems (each system being constituted by representations coupled with procedures).

There is on the one hand a first knowledge system composed of constituted and sedimented representations (or encapsulated) (to which sensorial inputs have a direct access) merged with automatized action procedures. This first knowledge system is expressed in practical forms.

There is on the other hand a second knowledge system composed of *representations* in elaboration (status nascendi) coupled with action procedures in elaboration as well. This second knowledge system initially produces knowledge in conceptual forms, demonstrating an actual process of conscious construction, bringing accessible representations into play.

In summary, these two contemporaneous representational systems express themselves under two different forms which correspond to the 'practical' and 'conceptual' forms previously described; they simultaneously define two kinds of action planning and control (sometimes called 'triggered' and 'controlled'), two types of functioning (automatized versus voluntary or bottom-up versus top-down). It would also be possible to compare these two knowledge systems with the two selection systems for thought or action schemes defined by Shallice (1991): That is, the automatized system called 'contention scheduling' and the supervisory system.

The capacity to produce new behaviors, i.e. to elaborate new representations as well as new procedures, is due in children to the fact that new centers or new structures are brought into action (I have previously called those new coding systems). In adults the acquisition of new behavior (or the capacity to solve new problems) could be due to the reactivation of some centers or structures specialized for the conceptual and conscious elaboration of new dimensions or for the

reelaboration of some already known dimensions in a new context. These specialized centers would be temporarily brought into action until new routines more or less automatized (practical forms of knowledge) are established (Mounoud, 1988; 1990b).

These new centers (or new knowledge systems) are supposed to analyze only a subsample of the dimensions or information automatically processed by the previous centers during the execution of complex actions. These analyses give rise to new representations. At the beginning of the process these new representations or conceptions are necessarily elementary. This precisely results from the selection operated by the new centers with regard to the previous ones.

These new elementary representations are used by the knowledge system to elaborate new action procedures (necessarily simple or elementary as well) limited to a single elementary goal, to a simple action, to a single dimension or idea. These new procedures progressively substitute themselves to, or inhibit, the previous ones.

Then the various elementary representations and procedures are going to be composed, first by juxtaposition and then by a more organic integration, in order to constitute a new totality, new global representations at the origin of a new complex behavior (as for instance the apparition of adult type reaching in the one-year-old child, in which the reaching and grasping phases are not simply juxtaposed any more but rather integrated; or as in the apparition of the first words, in which syllables are not juxtaposed anymore as in babbling, but rather integrated as a whole).

On the basis of the above statements, it is now possible to define what I suggest we call the *process of conceptualisation* (also previously called 'construction of new representations' (Mounoud, 1979) or 'thematizing process' (Mounoud, 1988)). This is the process by which, during activities (mental or material) that are controlled by the constituted knowledge system, the subject consciously selects or samples information that is relevant regarding the pursued goals, by means of the new knowledge system, which brings this new information into representation. The simultaneous existence of two knowledge systems in parallel constitute the dynamic of the developmental process. The motor of development, according to

Piaget's formula, would not be the action, as he stated it but rather the dialectical relations between knowledge systems.

By means of these representations the subject will be able to establish new relationships or comparisons between objects or events, between parts of objects, between actions and above all between objects and actions. These comparisons are at the origin of new *inferences*, new links between meanings, temporarily accessible to consciousness or explicitable, at least partly. This is what Piaget (1936) following Claparéde (1933) called *relations of implication* in a broad sense. Claparède defined implications as 'associations accompanied by a sense of necessity proceeding from inside and not generated by repetition'. (This definition perfectly reflects the process of conceptualisation of the author!). For me this 'sense of necessity' is due to the fact that these 'associations' or 'relationships' are established by the new knowledge system *during the execution of activities controlled by the previous knowledge system. This is* the functioning of the subject determined by previous knowledge (inaccessible to consciousness) which confers to the new 'conceptual' knowledge in elaboration its value of necessity. This is a crucial point.

As a matter of fact, this process would not function in a satisfactory way if the activities of the subject were not determined by previous knowledge (resulting themselves of course from a previous genesis). Without such a partial predetermination the explanation of the origin of new behaviors should be seeked in randomly produced behaviors. I will once again quote Piaget (1937): 'The results (of experience), most of them being fortuituous, acquire nevertheless meanings by means of hidden but acting schemes that enlighten them' (Piaget, 1937, p. 350). These 'hidden schemes' correspond to what is now called encapsulated or modularized knowledge, or sedimental representations.

It is clear that as new conscious inferences, implications or relations are constituted, new procedures for action planning and control are elaborated. As already mentioned these new procedures are going to substitute themselves to the previous ones, on which they have an inhibitory action before taking them under control and integrating or incorporating them.

Putting so much emphasis to the previous knowledge in the process of acquisition of new behaviors leads me to criticize, as I did elsewhere (Mounoud, 1990a), purely inductive theories related to the development of categorization, as for instance those suggested by Harnad (1987) in psychology and by Edelman (1987) in developmental neurobiology. From my point of view, ignoring initial categorization abilities prior to the process they describe gives a wrong picture of the developmental process.

Illustration of the conceptualizing process

I consider the development of reaching behaviors an ideal illustration of the conceptualizing process even though, for many colleagues, it is conceived as concerning only motoric activities having nothing to do with symbolic representations.

Reaching the object presupposes at least the coordination of three major systems: The eye-head system, the arm-hand system and the postural system. In addition, it is possible to consider the act of reaching as a complex action that can be decomposed, in a schematic way, into two elementary actions: Reaching and grasping. From birth on the newborn shows evidence of coordinated or integrated activities between these three systems and displays a behavior described as a precocious type of reaching considered as non functional (Hofsten, 1982). This precocious reach realizes or simulates the two major functions of this complex behavior: The arm extension for the reaching aspect and the hand opening and closing in the direction of visually perceived objects most often in movement (of course in specific conditions or in particular contexts).

In order to describe the *coordination* exhibited by the newborn in this type of behavior (phase 1), various terms have been used (besides coordination), particularly those of synergy, coupling or *pattern* as well as the following expressions: Tight coupling (Rosenbaum, 1991), movements synergetically coupled (von Hofsten, 1990), perfectly integrated pattern (Halverson, 1931), inter-sensorimotor coordination (Mounoud & Vinter, 1981) and also coordinative structures (Bernstein, 1967; Kugler, Kelso & Turvey, 1982).

Subsequent developments of newborn's behaviors have been described by means of a progressive dissociation of the initial coordination (phase 2). Again various expressions have been used, like interruption of coupling or decoupling, *broken up synergy*, individualization of partial patterns, and inhibition of reflexive and automatic behaviors, etc.

These descriptions in terms of breaking or inhibition are followed by descriptions expressed again in terms of *coordination,* integration, synergy, sequencing or composing, which reveal the emergence of new skills usually qualified as conscious or voluntary behaviors (phase 3). Von Hofsten for example describes this phase in the following way, 'integrating and synchronizing subactions in a continuous sequence' (von Hofsten, 1990). Similar analysis of the reaching and grasping development (coupling - decoupling - integrating) have been given throughout the century (cf. in particular Halverson, 1931, von Hofsten, 1990).

Nevertheless, there is another type of partially divergent descriptions that I will call 'Piaget type' descriptions. For Piaget the developmental sequence during the first months of life corresponds to a shift from initially isolated activities (non coordinated or heterogeneous activities) to coordinated ones. (N.B. It is true that for Piaget even an isolated scheme is still a coordinated structure, a structure that coordinates actions and perceptions or means and ends. Nevertheless, a coordinated structure can be isolated from other coordinated structures). White, Castle and Held (1964) have used Piaget's theory to interpret the developmental stages they have analyzed. They talked about the coordination of two systems called visuo-motor and tactilomotor. But it should be noted that their studies started with 1-monthold babies. At a descriptive level it is possible to consider the Piaget type version as a portion of the more complete version presented earlier. But at an interpretative level, it is a different story. What role does the initial coordination or coupling state play with regard to the subsequent phases? It is well known that for Piaget, isolate schemes coordinate with each others because of their natural tendency to

assimilate reciprocally. I have criticized that aspect of his theory elsewhere (Mounoud, 1979).

The development of reaching behaviors has also been analyzed from the point of view of *the role of visual system.* White, Castle & Held (1964), among many authors, have characterized a developmental trend going from visually controlled behaviors (from 3 to 5 months approximately) to visually triggered or elicited behaviors (at about 6 months). On the contrary, other authors have considered the developmental shift as going from visually triggered to visually controlled behaviors, the shift taking place beyond 6 months of age (Bower, 1974). In order to conciliate these apparently incompatible views, we have to introduce the distinction between *proximal and distal motor systems.* In such a perspective, it seems possible to divide roughly the first year of life into two steps.

During the first step going from birth to six months, the major changes concern the proximal aspects of the reaching behavior with the development of a crude palmar grasp and a still global coordination between shoulder and elbow articulations (cf. Manchester, 1988, for a review). In particular the regulation of the muscle tone is still crude and realized by means of simultaneous contractions of antagonistic muscle groups (Mounoud, 1973; Mounoud & Bower, 1974). The paper written by White, Castle & Held (1964) remains one of the best descriptions of this first step, in which the reaching behavior attains some kind of 'top level' (their term) during the sixth month of life. At this level, the reaching behavior has been described as visually triggered. During the previous months the proximal components of the reach are visually controlled (von Hofsten, 1990; Piaget, 1936).

The second step, covering the second half of the first year, concerns the development of the *distal* motor system related to the fine grasp (characterized by a high degree of differentiation between fingers) and the integration between the proximal and distal systems producing refined coordination between shoulder, elbow and wrist articulations as well as fingers adjustment. The approach towards the object becomes direct. During this second step, mainly between the 7th and the 10th month, the visual control takes up a major role again with regard to hand orientation, finger extension, hand shaping and

temporal planification of the grasp. This time, however, the visual control is related to the distal aspects of the behavior.

The importance of the visual control during this second step has recently been emphasized by Diamond and Gilbert (1989) in their research on reaching for objects located behind a transparent barrier (called the object retrieval task). It is between 6 1/2 and 8 1/2 months of age that children need to keep a strict correspondence between their line of sight and their line of grasp. In other words, they constantly have to control the hand and object relative positions.

It is surprizing to notice that some recent papers on the role of visual control in reaching have only studied 5- and 7-month-old infants, especially since they were replicating the research done by Wishart et al. (1978) with babies from 4 to 11 months. This is particularly true in the research done on reaching in the dark (Stark et al., 1989; Clifton et al., 1991). From my point of view the age of 7 months characterizes the achievement of the proximal motor activity as much as the beginning of its distal motor activity. Consequently, it would be necessary to study the role of visual control at least up to the end of the first year. For example Morrongiello and Rocca (1989) speak about an increasing visual control with respect to hand orientation during the act of reaching between 5 and 9 months of age.

Our own research on reaching for objects changing location after movement initiation in infants aged 5 to 14 months also demonstrates the predominant role of visual control, in particular for the 9-montholds as compared to the 7- and 12-month-old infants (Mounoud et al., 1991). Fetters and Todd (1987) mention a tendency to an increase in the number of units per reach in the 7- and 9-month-olds in comparison to the 5-month-olds.

We have seen the importance to distinguish levels of visuomotor control with regard to the proximal and distal aspects of the reaching as underlined by Morrongiello and Rocca (1989) in the discussion of their paper.

Around the end of the first year a type of reaching, considered by Halverson (1931) as very similar to the adult's type, appears. The role of visual control during execution is not as crucial as during the preceeding months. The behavior can be considered again as visually

triggered in a broad sense, even though for many aspects visual control remains essential during the execution of the movement (Biguer et al., 1985).

The interpretation I would like to suggest is the following: The tight coupling or synergy characterizing the newborn behavior described as precocious reaching (and decreasingly displayed during the first months of life) is determined by constituted and sedimented representations (encapsulated) that I have suggested to call 'sensorial''. These representations are merged with automatized sensorimotor procedures (the practical form of the first knowledge system). This is an attempt to describe in psychological terms the functions realized by predominantly subcortical structures which determine the initial precocious coordination.

All the behaviors described as dissociated, decoupled, isolated or individualized, result from the new 'perceptual' representations in elaboration (the conceptual form of the new perceptual knowledge system) coupled with perceptivo-motor procedures also in elaboration. These representations and procedures are elementary at the beginning, they only concern simple actions fulfilling elementary functions, isolated and selected features of the objects. During this period there are no more reaching behaviors in a strict sense but only partly isolated fragments or elements. Examples of such limited behaviors can be observed in infants during the second or third month of life, like opening and closing the hand, rotating the wrist or extending and flexing the elbow under visual control. By means of these behaviors the infant becomes aware of the various segments of his/her body and their functions (new perceptual representations) and gains a progressive control over them (new perceptivo-motor procedures). The infant discovers the various features of the objects and their meaning in a similar way through perception and motoric explorations. Consequently, the importance of the visual control during this period will be revealed by the study of fragmentary behaviors described above rather than by the study of reaching behaviors in a strict sense.

The progressive dissociation or decoupling of the newborn's synergistic activities is a consequence of the elaboration of representations and procedures by the new knowledge system (or the

new processing centers). By means of these elementary representations the infant becomes able to attribute meanings to some features of his body or of the objects encountered, by means of the elementary procedures he/she becomes able to control simple actions. These elementary representations and procedures are progressively going to combine or compose with each others, initially by simple juxtaposition or sequencing and later on by coordinating or integrating into new complex representations and procedures. This is supposed to explain the emergence at about 12 months of the adult type reaching (in which the reaching and grasping phases are not simply juxtaposed anymore but rather integrated).

I have only initiated the first steps of the history of the reaching behavior. The subsequent steps or phases during the second and third years could be analyzed for example by means of the grasping and lifting of objects varying in weight and size (Hauert, 1980; Forssberg, in press; Mounoud & Hauert, 1982) or by means of the fitting together forms varying in size: First, the child performs simple embeddings of forms which necessitate the combined and differentiated activity of the two hands (second year); then, he/she becomes able to produce complex embeddings of objects of variable size, which necessitate the planning of the entire action sequence (third year) (cf. for example the remarkable study done by Greenfield et al., 1972). Obviously it is possible to integrate in the history of reaching for objects the various tasks designed to study the so-called object permanency, including the A not B task which we will discuss further with respect to Mandler.

Many researchers will consider this overview too superficial for a valuable discussion. On the contrary, I will argue that it is necessary to stay at a general level to keep in mind the central problem of this paper, that I will now try to reformulate.

It is relatively usual to consider the development of reaching behavior as mainly determined by the maturation of the ventromedian and dorsolateral systems. Such an explanation is quite exclusively motoric. Nevertheless, it is also possible to characterize the development of reaching during the first year by a major shift in the control structure moving from subcortical to cortical structures (in

particular frontal and parietal areas). In such a perspective the question raised in this chapter could be expressed as follows:

What is the origin of the organization of the new knowledge system which progressively takes the skills under control?
or
How are the new processing centers (or structures) which control new skills structured ?

Four different hypotheses can be considered:

1. The organization of the new centers or systems is preformed; development manifests only the progressive maturation of these centers. Spelke's (1991) position could correspond to this first hypothesis.

2. The organization of the new centers comes from a *redescription*, *transposition* or an *abstraction* from other centers already organized (ahead of the development process under study). This hypothesis corresponds to the reflexive abstraction process suggested by Piaget (1967, 1977), to the representational redescription process suggested by Karmiloff-Smith (1991) and to previous versions of the model I have presented here (for example, Mounoud, 1979, 1986a).

3. The organization of the new centers comes basically from the structure of the situations the subject is confronted with (with no major role played by the organization of previous centers or of previous knowledge). This hypothesis could correspond partly to Mandler's model that I am going to present, as well as to Harnad's model (1987) or Edelman's model (1987).

4. The organization of the new centers comes from experiences realized by the subject with his/her different environments but during activities determined by previously organized centers (or knowledge system). It is what I have called the indirect filiation. This hypothesis corresponds to the position I have developed in this chapter and to the

model recently published by Morton & Johnson (1991) related to the development of face recognition.

Jean Mandler's dual representational system

In her recipe for building a baby ('How to build a baby') that I found spicy, Mandler (1988) defines what she calls a dual representational system. On the one hand, there is *a sensorimotor knowledge system* (or sensorimotor procedures) based on sensorimotor, non symbolic 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 develop simultaneously and in parallel. She makes clear that conceptual knowledge is not due to a transformation of procedural knowledge. Nevertheless, both knowledge systems are interconnected and influence each other (op. cit. Mandler, 1988, p. 132). These two systems differ in the following way: Sensorimotor knowledge is *not accessible to consciousness*, its acquisition does not require conscious accompaniment (op. cit., p. 115), whereas conceptual knowledge is accessible to consciousness, accessible for purposes of recall or thinking, has the potential of being brought to conscious awareness or is potentially expressible knowledge (op. cit., p. 116). 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' (op. cit., p. 118); but sensorimotor knowledge is nevertheless *'preset to parse the perceptual array into objects'* (op. cit., p. 118). Conceptual knowledge is based on a process of elaboration of perceptual input, resulting from *perceptual analysis*, equivalent to a mental comparison process (comparing two objects with each other simultaneously or sequentially).

Conceptual knowledge arises in situations or tasks requesting a *recall* of objects, and sensorimotor or procedural knowledge comes into play in situations requiring only the object's *recognition* without any necessity to recall past events or to imagine the future. As examples of

sensorimotor knowledge, Mandler mentions the infant's first conceptions of objects described by Spelke (1985) as unitary and bounded. By contrast the experiment done by Baillargeon, Spelke and Wasserman (1985) on object permanence or constancy necessitates for her the ability to recall (op. cit., p. 124), which requires by definition 'an accessible knowledge representation' (op. cit., p. 123). In a similar way the acquisition of sign language by infants aged 5 1/2 to 7 months (e.g. Prinz & Prinz, 1979) or of deferred imitation in 9-month-olds (Meltzoff, 1988) requires conscious conceptual knowledge as well (op. cit., p. 121). But activities like reaching for objects necessitate only sensorimotor knowledge. Nevertheless, riding a bike or typing are 'skills (that) require extensive conscious processing during the early stages of their acquisition' (op. cit., p. 115).

I have to confess that I have difficulties in understanding the criteria producing such a dichotomy. Are all behaviors which require only a direct perceptual contact with the environment dependent upon sensorimotor non symbolic knowledge? Or, reciprocally, are all situations which necessitate the adjonction (by inferences) of information not included in the perceptual array in order to be understood dependent upon conceptual knowledge? It sounds very similar to Piaget's sensorimotor theory (Piaget, 1936, 1937), the major difference being the existence of symbolic conceptual knowledge from birth or very early in life in Mandler's model, whereas for Piaget symbolic representations would appear only with the symbolic function at about 18 months. But for Piaget the symbolic function does not appear overnight; it progressively emerges through imitative behaviors. In this perspective Piaget described various behaviors demonstrating the emergence of the growing capacity to symbolize during the first year of life. In fact Mandler refers precisely to some of them as the 'motor recognition' activity or behavior described by Piaget in the 5- or 6-month-olds, in order to testify the presence of very precocious symbolic activity (Mandler, 1988, p. 120). Consequently in a certain way their position are quite close. Nevertheless, given their basically divergent epistemological options, as we will see later on, this proximity is relative.

Albeit I was very seduced by Mandler's ideas, I disagree with her on many problems which I will now systematically consider.

Problems related to early object concepts (in 3 1/2- to 4 1/2-month-olds)

The thesis held by Mandler concerning the fact that 'infants perceive objects as bounded and unitary' is the following. She considers that 'although early concepts about objects are undoubtedly derived from perceptual input, the data of Spelke and others do not in and for themselves speak to conceptual knowledge as defined here'. Her arguments are the following: 'To say that an inherent conception of the physical world determines infant perception (Spelke, 1985) may mean no more than that the system is *preset to parse the perceptual array into objects* rather than, say, color patches. There is nothing antithetic to the notion of an exclusively sensorimotor form of representation *in this view'*.

I consider that at 3 1/2- or 4 1/2-months, infants already had the opportunity to analyze perceptually very many situations they have been confronted with, by means of their visuo-motor systems. For some researchers, they have even already substituted a visual system to another, the former being more cortical and the latter more subcortical (cf. Morton & Johnson, 1991). Consequently, from my point of view their knowledge or conceptions about objects are not exclusively (and undoubtedly!) derivated from the actual perceptual arrays, or based on 'how objects look like', or 'without adding' anything to perceptual arrays, in other words based exclusively on sensorimotor representations not accessible to consciousness as Mandler claims. As a matter of fact, as I already stated, the conceptual knowledge for Mandler results from a perceptual analysis or comparison process, precisely what 3 1/2- or 4 1/2-month-old infants have already been doing during a few weeks or months. Therefore the first 'concepts' of objects could perfectly correspond to conceptual knowledge as defined by her.

On the other hand, if early 'concepts' were based on sensorimotor knowledge or representations, the question of their origin or genesis remains open (phylo- or embryogenesis). How have these

representations been constituted? Is their origin purely perceptual? Are motoric components involved in their construction ? Are their origins perceptual and motoric simultaneously? Answers to these questions will be proposed by addressing further issues related to Mandler's paper.

Problems related to object permanence in 8- to 12-month-old infants

I will briefly introduce an experimental situation initially imagined by Piaget (1936, 1937) in order to study substages in the construction of object sensorimotor knowledge or schemes (stages in object permanence).

At about 7 1/2- to 8-months, infants are able to reach successfully for an object hidden under a cover at a given location in front of them that will be called A. They rise the cover in order to grasp for the object. After having repeated such a situation two or three times with the infant, Piaget had the idea to hide the object at a different location, under a second cover called B, located next to the first one (A) which is still on the table. He observed that around 8 months of age infants had a strong tendency to search for the object under A instead of B. This 'error', initially called 'stage IV error' and more recently 'A-not-B error", became famous in the psychological literature. It has been recently demonstrated by Diamond (1985) that all infants between 7 and 12 months of age produce this 'error' given a certain temporal delay between the time the object is hidden under cover B and the time the infant is allowed to initiate his/her search. The older the infant the bigger the delay requested for the error to appear. During the delay the child is not allowed to look at the table. Piaget interpreted this 'error' by a tendency of children at stage IV to search for objects in places where they have previously been successful (A). This was for him the index of a 'subjective' form of permanence related to a direct assimiliation of situations to the characteristics of their own actions (like their previous success for instance).

A-not-B is defined by Mandler as 'a situation that sets up perseverative motor tendencies'. The error would be due to 'the failure to inhibit the previously trained, successful motor response' (op. cit, p.

125). It is true that such an explanation has been suggested by various authors, in particular by Diamond (1985) as quoted by Mandler. But the main explanation, more recently suggested by Diamond (1988), is based on the infants' limited abilities to relate information separated in space and/or in time. For me Diamond's hypothesis corresponds precisely to what Mandler calls the 'perceptual analysis' or 'comparison process', comparing two objects with each other simultaneously or sequentially (Mandler, 1988, p. 126). (This is what produces the conceptual knowledge, according to Mandler). Consequently it is possible to say that conceptual knowledge (Mandler's meaning) rather than perseverative motor tendency should explain the A-not-B error, or, moreover, that the inability to inhibit a response could be due to the limits of children's conceptual knowledge (what seems more satisfactory to me). This is exactly what Mandler rejects as we are going to see.

Problems related to the status of some behaviors qualified as 'motoric' like reaching for objects

Mandler's point of view concerning the reaching behaviors, and consequently situations like A-not-B, consists in saying that 'less than perfect performance on a motor task such as reaching cannot be taken as evidence for a lack of a conceptual system' (op. cit., p. 126). Moreover, she considers that 'reaching for an object is fundamentally different of having an image of that object' (op. cit., p. 131). And, finally, 'infants of 6 months are not yet skilled at coordinating their motor responses' (op. cit, p. 126). What could be the origin of such a limitation? Is it really purely motoric ?

As already stated, reaching for an object is not a purely motoric behavior that would necessitate only sensorimotor knowledge issued from a direct contact with the perceptual array (or based on the information directly available in the perceptual array), without necessitating recall of past events or plan for future events.

Reaching for objects even for children from 8 to 12 months of age is a task that requires new conceptualizations, new conscious conceptual knowledge as they have been defined by Mandler as recall of

past events. The development of reaching behaviors, as we have seen in the illustration of the process of conceptualisation, seems to me very similar to the development of imitative behavior like blinking the eyes or sticking out the tongue, both taken by Mandler as examples for the development of conceptual knowledge, precisely in 8- to 12-month-old children. Incidentally, I wish to mention that Baillargeon also rejects a motor-deficiency-based explanation of A-not-B in favor of conceptual one: That is, the inability to plan a means-end sequence (Baillargeon et al., 1990).

This problem leads us to the last one raised by Mandler's paper, which concerns the origin of knowledge.

The epistemological problem related to the origin of knowledge

I will briefly recall Mandler's statements about the origin of sensorimotor and conceptual knowledge.

Sensorimotor knowledge derives from perceptual input or is based upon 'how the object looks like'. Sensorial inputs would have a direct access to unconscious sensorimotor representations (modules) which would interpret them instantaneously. Conceptual knowledge results from a mechanism called perceptual analysis (cf. supra).

Mandler focuses her attention exclusively on the perceptual side of the elaborative process. Her statements have a strong empiricist flavor. In particular when she examines the development of imitative skills, she only considers the way infants visually analyze what the model does. But it is obviously not a purely perceptual task. Infants are requested to produce 'motoric' activities (to reproduce a model in action). They are equally involved in analyzing their own activities, the various components of their own behaviors, with most probably a major role played by the proprioceptive information related to movement.

To summarize, motoric components cannot be separated from perceptual ones in a developmental process, the major problem being the matching between perceived models and reproductive activities or more generally between perceived data and produced activities. The

mechanism responsible for the elaboration of conceptual knowledge should at least be called perceptuo-motor analysis.

However, and I have already underlined this point, perceptuo-motor analysis at the origin of new relationships, new inferences and, consequently, of new conceptual knowledge in Mandler's terminology (or new 'perceptual' knowledge system in my terminology) are, only possible because the infant has a previous knowledge system (the 'sensorial' one) which guides or directs his or her current activities and partially prefigures the new concepts.

Concerning the examples referred (reaching and imitation) the previous knowledge system has been well analyzed in the newborn and corresponds to the constituted knowledge system.

Discussion

I will now discuss three questions in more details.

The nature *of the* representational systems

The first question concerns the nature of the representational systems, as for example the 'sensorial' and the 'perceptual' systems in infants. Mandler (1988) evokes sensorimotor (or procedural) and representational (or declarative) knowledge systems. The current dominant conception considers them as different (in nature), the sensorimotor one being qualified as peripheral structures inaccessible to consciousness (non symbolic modular or module like structures), and the perceptual or representational one as central structures accessible to consciousness and of course symbolic. As already stated the accessibility to consciousness is for me a transitory characteristic of the representations at certain stages of their development, inaccessibility to consciousness being in a certain way the final destiny of the majority of our representations. Consequently, I consider the various types of representations (sensorial, perceptual, concrete, and formal) as basically similar in nature which I term 'symbolic'.

Nevertheless, these symbolic representations have various levels of abstraction (or idealization). Taking into account that 'perceptual' representations are abstracted in the course of actions directed by

'sensorial' representations, they are both poorer, as they result from a new selection of information, and richer, as they introduce additional relationships, than the sensorial ones (cf. Mounoud, 1990a, Cognitive development as enrichment and/or impoverishment). The same principle is applicable to the subsequent representational systems called 'concrete' and 'formal". In addition, I have considered for a long time that the representations evolve during their construction or elaboration from an analogical to an abstract code (Mounoud, 1986a). Actually, the two coding systems seemingly do coexist ever since the beginning. They initially function in a disjunctive way and later on in a conjunctive way (Mounoud, 1990a).

Relations between 'practical' and 'conceptual' knowledge

The second question which I will now consider is: In which sense can a representational system (like the perceptual one) be *a derivative from a previous one* (the sensorial one) and from the related procedures? The answer I would like to suggest is in favor of an indirect derivation. First, it is possible to say that the 'perceptual' representations are not direct derivatives from the previous, sedimented ones ('sensorial') since they result from new samplings, new selections of information realized by a new knowledge system (or processing center). From this point of view I will be in agreement with Mandler (1988) who considers that the sole practice of sensorimotor knowledge would never make them accessible to consciousness, to conceptualisation (cf. supra). Second, I consider that 'perceptual' representations *derive indirectly* from the previous representations and procedures since the new samplings or selections of information are realized, at least at the beginning during activities determined by the 'sensorial' representations. Consequently, the newly constructed perceptual representations are oriented or indirectly determined by the structure of the ongoing activities.

The origin of knowledge

The second question leads us to the third and most important one concerning the constructive mechanisms of representations: Is the origin of new representations related to perceptual activities, or rather to motor activities or to perceptuo-motor activities (and in such a case

what will the respective role of each side be)? Is it related to the structure of the environment, or rather to the maturation of the nervous system? Or, finally, is it possible to consider the new representations as emergent properties of the system constituted by the subject and his/her environments?

Regarding this epistemological problem, my feeling is that a large majority of my colleagues still has a strong bias in favor of the empiricist conception. For them, the main origin of constructed concepts or theories is to be found in perceptual analysis activities; the structure of the subject's motor activities for example is not at all taken into account. To illustrate this claim I will refer to the positions recently developed by two colleagues, Mandler (1988) and Medin (1989). Nevertheless, their points of view helped me a great deal to progress in my thinking.

I will take the opportunity to mention the research conducted by my colleague Viviani demonstrating the role of the structure of motor activities in perceptual knowledge (visual perception) (Viviani & Stucchi, 1989). This phenomenon has incidently been discovered in the study we conducted together on visuo-manual tracking (Viviani, Campadelli & Mounoud, 1987; Viviani & Mounoud, 1990). In the analysis of our data we have realized that the perception of the target's trajectories could be influenced by the way our movements are organized in order to produce such trajectories. This has been demonstrated by the subsequent research.

Regarding the epistemological problem, I emphasize the role played by the structure or the organization of the subject's activities, since new knowledge can only be acquired on the basis of previous, already constituted knowledge. Nevertheless, representations are not resulting directly from the internalization of actions or procedural schemes as Piaget claimed nor - and that seems equivalent to me - from 'a process of redescription that extracts the knowledge from the procedure', the 'new acquired knowledge (being) also initially represented procedurally' as Karmiloff-Smith stated (1991). For me, information is selected during activities determined by a previous, already constituted knowledge system; they are not extracted from procedures, although I have held this view in the past, similarly to

Piaget or Karmiloff (see for example Mounoud, 1986a). Indeed I thought that new 'perceptual' representations result directly from a dissociation of the integrated sensorial representations.

Final comments

I will briefly examine how some colleagues currently define the cognitive or intellectual activities. In his attempt to analyze intellectual activities, Richard (1991) starts from the opposition between abstract (or theoretical) and practical (or concrete) intelligence. For him the origin of such an opposition comes from psychometry. He considers it worthless in the information processing perspective. However, he uses oppositions reminiscent of those initially mentioned in this paper, like between symbolic and non symbolic information processing.

He suggests to call *intellectual activities* 'the activities which bring into play inferences based upon explicitable knowledge, what is called reasoning'. On the one hand, he opposes them to the *perceptual activities* 'which consist essentially in extracting information from the stimuli' (bottom-up process), and, on the other hand, to the *strongly automatized activities* (the specialized knowledge typical from the expertise). Nevertheless, he recognizes that intellectual activities are constituents of the expertise, which is problematic for his classification (Richard, 1991). Furthermore, in addition to the stimulus dependent processes (bottom-up) considered by Richard, it is classical to distinguish in perceptual activities concept dependent processes based on representations or conceptualizations (top down) (Bonnet, 1989, 1991). Bottom-up processes dependent on stimuli would be for a major part automatically performed by modules. But following Bonnet it would be similar 'for many concept dependent perceptual mechanisms, automatized through a constant practice'.

What seems to emerge from these various, and partly contradictory, oppositions suggested by Richard (1991), is the opposition between automatic or *automatized* activities and *non automatized* activities typical from active elaboration procedures. This sounds to me very similar to the opposition between 'practical' and 'conceptual' forms of any knowledge system. The underlying processes

to automatized or not automatized activities are not necessarily different in nature if they belong to the same knowledge system. Partially accessible to consciousness at the beginning of the acquisition of a new skill, the processes become inaccessible later on.

Difficulties in classifying cognitive activities appear as well in the oppositions between recall and recognition in mnemonic processes (Lecocq, 1991). As an example, for Kintsch (1974), the access to semantic and episodic representations is automatic in recognition, whereas it is not *automatic* in recall which would necessitate the recourse to other types of information. On the contrary, for Tulving (1972), processes involved in recall and recognition are similar, only the efficiency of recovery indices would be different.

Finally, I will mention how Shallice (1988, 1991), as a neuropsychologist, considers mental structures or central systems. For him the functions of the central systems are very closely related to those classically attributed to frontal cortex and concern in particular the planning, the regulation and the control of activities. He establishes a distinction between two systems: A decentralized system for routine selection of routine operations (action or thought schemas) called 'contention scheduling' and a conscious supervisory system which operates by modulating (the lower level of) the decentralized system by activating or inhibiting particular action or thought schemas.

Once again, we are confronted to the opposition between 'automatized' and 'conscious' processes.

To close this chapter I have thought it is interesting and worthwhile to bring together some divergent opinions of various colleagues in order to explore their similarities. I hope I have succeeded in bringing closer various domains and various concepts developed by colleagues encapsulated as I am in their domain of expertise.

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