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THE FIVE TO SEVEN YEAR SHIFT:

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CHAPTER FIVE

A Recursive Transformation of Central Cognitive Mechanisms: The Shift from Partial to Whole Representations

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The numerous transitions observed in the behavior of children between 5 and 7 years of age testify, from my point of view, to a general transformation of the central cognitive mechanisms. This transformation expresses itself in particular through the shift from new, fragmentary, and *partial representations* constructed by the child between 4 and 5 years of age to *whole representations*, which appear around the age of 6 years. These whole representations integrate the relevant dimensions previously processed separately. This transition is similar (isomorphic) to the one taking place around 12 months in infancy. That is the reason why I consider it as recursive. I have defended this position for several years and documented it in various ways (Mounoud, 1981, 1986a, 1986b, 1988, 1990a, and 1993a).

Characterizing the transition from 5 to 7 years by the shift from partial representations (fragmentary, piecemeal, elementary) to whole representations (which integrate relevant dimensions previously processed in a split or juxtaposed way) must initially appear as a very traditional position. As a matter of fact, it is the classical shift from uncoordinated (or loosely coordinated) structures (or mental activities) to coordinated structures. Nowadays very few researchers are ready to consider such a transition as general and as related to central cognitive mechanisms. The current credo is in favor of the domain specificity and of the prevailing role of contexts. Furthermore, many examples that seem to contradict the conception I defend immediately come to mind, in particular the whole set of behaviors that can be termed *precocious competencies*. These are defined as 3- to 5-year-old children's successes at tasks that are partly isomorphic to those tasks at which children around 7 years of age are usually successful (for a discussion, see Mounoud, 1986a).

But before considering these contradictory points of view, I examine in more

detail how the shift from partial to whole representations affects the way children between 5 and 7 years conceptualize objects (new declarative knowledge) and, consequently, the way they act on them (new procedural knowledge).

This transition corresponds to the shift from conceptions that take into consideration a single *aspect* of a situation, an isolated object *characteristic* (dimension) regarding a given context, or a particular interaction (centration effect) to conceptions involving the *whole set of relevant dimensions* (critical features) of a given object or situation.

Another consequence of this transformation is the shift going from a *successive* to a *simultaneous* organization of behaviors. What the child does, previous to this change, by the juxtaposition or by the succession of distinct, elementary behaviors becomes a single, complex behavior.

Finally, concerning the way actions are connected, the transition has the child going from *local planning of elementary actions* (step-by-step planning) to the *planning of coupled or coordinated action sequences*.

Various descriptions of this transition and analogous or related transitions occurring at different ages can be found in the literature. For instance, authors write about the shift going from piecemeal to whole organization (Keil & Kelly, 1987), from unbounded to bounded engrams (Harnad, 1987), from partial to integrated patterns (Halverson, 1931), or from local to global mappings (Edelman, 1987). It has also been presented as the capacity of integrating and synchronizing subactions in a continuous sequence (Hofsten, 1990). Finally, Diamond (1988) has described this transition in terms of a general capacity to establish relationships between data separated in space, time, or both and the conjoined capacity to inhibit the prevailing responses. Following Diamond I am in favor of considering this major transformation of central cognitive mechanisms as principally determined by internal structural changes (involving mostly frontal and callosal structures) and as secondarily dependent in a non-specific way on environmental factors (Mounoud, 1993).

Albeit central, this general transformation of cognitive mechanisms does not necessarily manifest itself at the same time in the various cognitive domains by changes in representations. The new cognitive mechanisms intervene only in as much as they are required, that is, depending on the type of experience done by the children relative to the various contexts or domains they confront.

It is possible to show evidence of this transformation of cognitive mechanisms as well as of the visible derived transitions in various domains and at various developmental periods. In infancy, the transformation takes place around 12 months. One of the best examples is the capacity to coordinate differentiated activities of both hands, the capacity to coordinate the various functions involved in complex prehension behavior (reaching, grasping, etc.), or the capacity to coordinate syllables in order to constitute the first words (Mounoud, 1988, 1993a). This transformation is also responsible for the success in

the A not B task as well as for the success in detour behavior (reaching for an object located behind a screen or inside a transparent box) ("object retrieval"; cf. Diamond, 1988; Diamond & Gilbert, 1989). In childhood, the transformation takes place around 6 years of age. Behaviors like categorization and seriation activities seem good illustrations, in particular the capacity to consider the relationships between an object and the multiple classes it may belong to, which involves the mastery of concept intension and extension (the all and "some" coordination in Piagetian terms) or the capacity to consider the relationships between a given object and its predecessor and its successor in a series (Bideaud, 1988; Houdé, 1992). The same transformation should still explain the success in conservation tasks: The child must become able to integrate the various aspects taking place in a transformation such as the length and the density concerning number conservation (Fayol, 1990). The shift from partial to whole representations does not explain in itself the emergence of inclusion, of conservation behaviors, or of systematic strategies in seriation. It constitutes a necessary but insufficient condition. Whole representations must be decomposed and analyzed in order to make possible the mastery of the relationships between parts or elements and totality (the partitive or inclusive logical relationships between elements and totalities) as well as the relationships between various totalities regarding one or several of their dimensions.

Although the shift from partial to whole representations sounds familiar to developmental psychologists, it is less common to consider the shift recursive. From this point of view one has to look at the inverse shift, that is, the shift going from whole to partial and fragmentary representations. This transition, recursive as well, occurs at other developmental periods such as, for example, around the age of 4 years (as well as during the first months of life).

The major point of this chapter can be summarized in the following way: The transformation we are trying to capture (the 5 to 7 year shift) could be considered only as one aspect of a more important transformation that constrains the child at different stages, in particular around 3 to 4 years (as well as soon after birth), *to substitute for automatized processes* (performed by constituted knowledge systems) *new processing modes* (coming from new knowledge systems in elaboration). I consider that unfortunately we still are unable to label and characterize these various knowledge systems in a satisfactory way. For the new systems various terms have been used such as *conceptual*, *conscious*, *explicit*, *declarative*, or *discursive knowledge*, to enumerate only some of them. I come back to this topic later in the chapter.

Thus, the transition from 5 to 7 years, as I define it, basically corresponds to one *step* in the genesis of new knowledge systems. Its major characteristic is precisely the shift from partial to whole structures or the shift from centrations on isolated aspects of a situation to their integration.

In contrast, the transition occurring around 3 to 4 years follows a more fundamental transformation, that is, the emergence of new knowledge systems. To understand this transition going from constituted systems to systems in elaboration, it is first necessary to take into consideration the nature and the role played by constituted knowledge systems. These systems, which I call *perceptuomotor*, are characterized by whole representations. They determine behaviors that integrate numerous dimensions of the encountered situations. The emergence of new knowledge systems defines, therefore, an inverse shift to the one observed between 5 to 7 years, going from behaviors determined by whole representations (those of the constituted knowledge systems) to behaviors determined by partial representations (those of the new systems in elaboration). Consequently, in order to understand the transition from 5 to 7 years, it is necessary then to consider the complex relationships between the new systems in elaboration and the previous, constituted ones.

From that perspective it is possible to conciliate the various contradictory claims concerning, in particular, children from 3 to 5. Thus when a 5-year-old child is described as centered on a single aspect of a situation, it is possible to assume that his or her behavior is determined by a new knowledge system in elaboration (or that the child's behavior is controlled by an attentional or conscious supervisory system and not by an automatized one). Nonconservative responses in the classical conservation tasks are good examples of this type of organization. In this connection, it is necessary to consider nonconservative judgments as resulting from a new construction, from an elaboration that initially forces the child to focus on a single dimension. Simultaneously, in a different context the same 5-year-old child could display behaviors that reveal his or her abilities to grasp the whole set of relevant dimensions for a situation more or less similar to the classical conservation tasks, as is the case in Donaldson (1978), for instance. This time the child's behaviors could be determined by an achieved and sedimented knowledge system that operates in an automatized way.

In this chapter I start by illustrating the complex relationships between the two categories of knowledge systems (achieved and in elaboration) by means of an experiment carried out on the construction of simple instruments by children 4 to 9 years old (Mounoud, 1968, 1970). More particularly, I characterize the shift from a conception of instruments as juxtaposed segments or fragments supposed to perform successively various functions (the construction and the corrections consist in adding or subtracting segments at the extremity of the instrument) to a more global conception of instruments, which perform a global transformation (a translation, for example) taking simultaneously into consideration the various functions to be fulfilled (the corrections tend to modify the relationship between the different parts of the instrument in correspondence with the constraints of the task). I explain how this change in the

conception of the instrument in children 4 to 9 years old is initially framed or directed by an already constructed knowledge system called perceptuomotor. I then show how this system is later on controlled and integrated by the new conceptual knowledge system in elaboration.

Then I present more extensively a developmental model of the emergence of new skills as resulting from new conceptualizations (owing to new knowledge systems). I will also show how these new conceptualizations are initially directed or framed by the practical forms and automatized behaviors determined by previous systems. The new systems initially reveal themselves as conscious or explicit conceptualizations before transforming themselves into practical or procedural forms of knowledge, more or less automatized, and elaborative processes, which are no longer accessible to consciousness (Mounoud, 1990b).

To conclude, I present the experiments recently conducted by Wilkening and his collaborators (Krist, Fieberg, & Wilkening, 1993) in order to compare competences in intuitive physics in children 5 to 6 years old with those in children 9 to 10 years old as well as those in adults such as expressed through their actions and their judgments.

Construction of Instruments

Before illustrating my point of view, I present these few methodological comments. Some experimental situations are better than others in order to reveal the transformations in children's knowledge during the developmental course and, in particular, to understand the role of experience in this process. The best experimental situations are those that make it possible for children to evaluate their performances in terms of success or failure and to complete or correct them, in other words, to regulate them so as to modify their representations of the task. Practical problem solving is ideal for such an objective. However, most of the situations utilized to evaluate the cognitive abilities of the child do not have such characteristics, as, for example, conservation or classification tasks and all the situations requesting only verbal responses. For these reasons, I became interested a long time ago in tasks requesting the construction of simple instruments in order to solve practical problems. These tasks have been extensively used to study the origins of intelligence and to compare the respective abilities of children and monkeys as well as the transition between so-called practical intelligence and representative intelligence (e.g., Guillaume & Meyerson, 1930, 1931, 1934, 1937; Koehler, 1917/1927). By means of these types of tasks, I consider it possible to understand the modifications in the way children conceive objects, as much from the point of view of their intension (the set of features that define it) as from the point of view of their extension (the set of situations to which the instrument can be applied) and

the relations of equivalence between various objects (the set of instruments adapted to solve a given task). This method could be an indirect way to study concept formation or the development of categories. I did not initiate my research for such a purpose. Nevertheless, instruments constitute a special category of objects, intermediary between the subject's actions and the situations to which they apply. This is what I briefly consider.

I had suggested calling an instrument any object the individual associates with his or her actions to execute a task. The instrument constitutes a kind of intermediary world between the person and the object in the sense that it is associated with the individual's actions, which it transmits to other objects, in the sense that it substitutes itself for some of the person's actions for which it then fulfills the functions, and in the sense that it has complementary relationships with the objects to which it applies.

In addition to its static features such as its shape, length, and so forth, the instrument can be characterized by dynamic properties such as the forces that it produces or transmits. In this matter, we have to deal with the problem of the transmission power attributed to the instrument. The instruments also involve causal means-ends relationships that do not exist in the spatial nor logico-mathematical structuration of objects.

I had distinguished two major categories of instruments, those that transmit the individual's actions without transforming them and those that transform them (inversion, demultiplication, etc.). Those instruments I have studied belong to the first category.

Moreover, it is important to make the distinction between the utilization and the construction of instruments. I have been more concerned with their construction.

Finally, among the instruments that transmit actions without transforming them, three different kinds can be described:

1. The simple modification of an object (as, for example, bending a wire to make a hook).
2. The assembly of elements where the meaning of the whole is identical to that of the parts (such as the assembly of small hooks that still constitute a hook).
3. The assembly of elements where the meaning of the whole differs from that of the parts (for example, fitting sticks together in order to construct an instrument that makes it possible to get around obstacles).

Despite the fact that instruments constitute a particular category of objects (which, as we have analyzed, necessitate a causal and physical structuration as

well as a physical and logical one), I nevertheless consider the process by which children construct them as revealing some basic aspects related to general developmental mechanisms. More precisely, I hope to discover how children understand, define, and categorize objects at the “concrete” level and to capture directly the transformations of their conceptions by recording their corrections, regulations, and verbal commentaries.

The Experiment

One of the experiments was the following: Children were asked to move a little cube located beside an obstacle by means of an instrument that made a detour. That is a situation belonging to the family of “detour behaviors.”

As we know, getting around obstacles can be accomplished in various ways. In infants, for example, it is usual to distinguish the reaching detour (performed with the arm) from the locomotor one (performed with the whole body) (Lockman & Ashmead, 1983). Moreover, the reaching detour can be executed with or without a stick to extend the arm (Guillaume & Meyerson, 1930). Reaching detour studies have been repeated recently by Diamond (1988) and Diamond and Gilbert (1989) under the label of “object retrieval.”

The device used was a box without a cover (see Figure 5.1). The rectangular base measured 25 cm \times 30 cm and was 4 cm high. An opening of 5 cm was made in the lateral wall of the box, and two partitions labeled *v* and *h* were placed inside, making a little entryway. Three squares of different colors (*C*₁, *C*₂, *C*₃) were glued to the bottom of the box. A small wooden cube could be placed in four different locations (*P*₁, *P*₂, *P*₃, *P*₄). The task was to move the cube from one of these starting positions to a new position (*C*₁, *C*₂, *C*₃), by means of an instrument previously constructed by the subject. Four situations were then possible: moving from *P*₁ to *C*₁ (Situation I); from *P*₂ to *C*₂ (Situ-

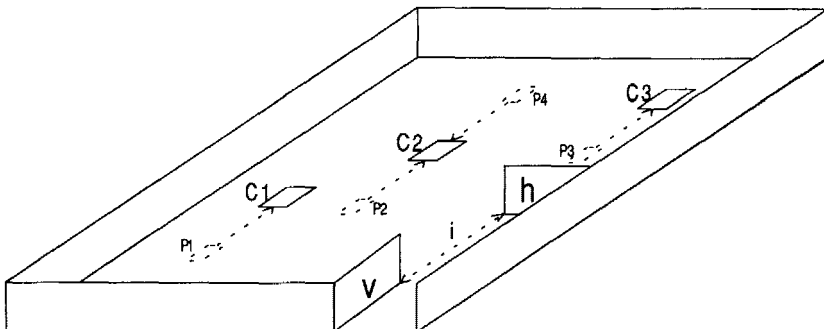


Figure 5.1 Experimental device. Letters *v* and *h* represent the partitions of the box separated by the interval *i*. *P*₁ to *P*₄ stand for the starting positions of the cube. *C*₁ to *C*₃ correspond to the final positions of the cube.

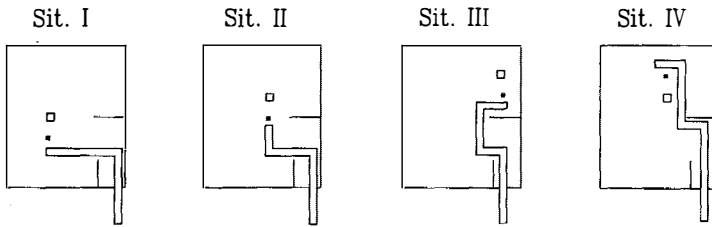


Figure 5.2 Instruments allowing to solve each situation.

ation II); from P3 to C3 (Situation III); and from P4 to C2 (Situation IV). These different displacements could be carried out using instruments such as curved sticks, which could be operated from outside through the lateral opening after the instrument was placed in the box. The amplitude of these displacements was always the same and was slightly smaller than the separating interval between v and h ; the variable dimensions were the direction and the kind of detour necessary to reach the cube. It should be noted that the turns made to reach the cube are not necessarily adequate to permit its displacement.

The instruments were constructed with identical rectangular 16 mm \times 64 mm plastic pieces called *Legos*, which can interlock with one another, therefore lengthening a part or making a 90° angle. The simplest instruments that were used in order to solve the four situations are shown in Figure 5.2.

After having the child describe the material, the experimenter indicated that the cube had to be pushed onto the square from outside of the box. Then, as an anticipation, the child was asked what would be needed to perform this action; a pencil and a ruler were suggested without letting him or her try. Next, the child was asked to use the Legos to construct "something" that would permit him or her to execute the task.

Once the instrument was placed into the box, the child was asked to move it from outside, without going over the partitions. To make it easier for the younger children to understand, a transparent cover was put on the game once the instrument was introduced. In order to better grasp the degree and type of organization the children were capable of, we asked them the reasons for their errors and the corrections they made.

Children 4 to 9 years old were tested and retested after 4 to 10 months. The children were split into four age groups: 4:6 (4 years 6 months) to 4:11 years ($N = 12$), 5:0 to 5:11 years ($N = 35$), 6:0 to 6:11 years ($N = 20$), and 7:0 to 9:3 years ($N = 16$).

Construction Behavior

Four types of behavior can be characterized on the basis of the children's constructions and corrections. Each of these types is predominant at a given age.

Type I

Type I behavior is predominant among the 4:6- to 4:11-year-old children (90% of the constructions).

It includes two subtypes. The most rudimentary constructions (Type Ia) are simple rectilinear segments (“I need something long”) to which children impart rotary motions in order to get around the obstacles. The children often attribute the failures to their own actions. Corrections consist in adding or subtracting elements for lengthening or shortening the instrument at its distal part. (N.B.: To modify the instrument exclusively at its distal part by adding or subtracting elements is related to a very peculiar conception that diverges as we will see later on from the modification of its various segments or of their relationships.) Then bended constructions (Type Ib) can be observed (“I need something to get around it”) of which different segments are successively added one to the other after successive trials. Consequently the instrument is constructed step-by-step. Corrections consist again in adding or subtracting segments at the extremity of the instrument.

Type II

Type II behavior is predominant among the 5:0- to 5:11-year-old children (50% of the constructions).

As for Type I, these are bended constructions made step-by-step after successive trials; but all constructions are ended by a vertical segment aimed at pushing the cube in the desired direction (“It can push,” say the children). So each segment has a precise role: to lengthen, to get around, to reach, to push, and so forth. The children’s conception of the instrument is in a way piecemeal or fragmented; corrections are always made at the extremity of their constructions. Several children entirely destroyed their construction to restart it again. One child restarted his construction four times. At each attempt he produced the same unsatisfactory result!

Type III

Type III behavior is predominant among the 6:0- to 6:11-year-old children (80% of the constructions).

Again, we have two subtypes. The instrument is initially constructed as a whole (without the ultimate segment assigned to push). “I take the instrument, then it turns and then I push,” said one child. “It turns around and I can push,” said another. Corrections concern initially (Type IIIa) the length of the various segments considered as responsible for the failures, most often paradoxically the length of the first segment (the “handle” is estimated as being too long). Sometimes corrections are produced by adding or subtracting one

element to the junction point between the first and the second segment. Children search for a precise location when seeking the cause of the impossibility of moving the instrument. The problem is still conceived in terms of segment length or of distance and not yet in terms of relationships between segments or between parts of the device. Then the corrections do progressively take into consideration the relationships between the parts of the instrument and of the device (Type IIIb) without adding or subtracting elements; children try to modify the relative positions between two parts of the instrument (see Figure 5.3).

Type IV

Type IV behavior is predominant among the 7:0-year-old and older children (60% of the constructions).

As for Type III, the instrument is constructed as a whole without any previous trial. No correction is done on the first segment (or the "handle" of the instrument); its lengthening is recognized as having no effect on the mobility of the instrument. The children anticipate the precise location of the instrument in the experimental device in order to move it. They are also able to justify the equivalence between two instruments having different shapes (see Figure 5.4).

Interpretation of Construction Behavior

Schematically the general developmental trend can be characterized by two major steps.

In the *first step*, typical for children 4 and 5 years old (behavior Types I and II), one can observe the following:

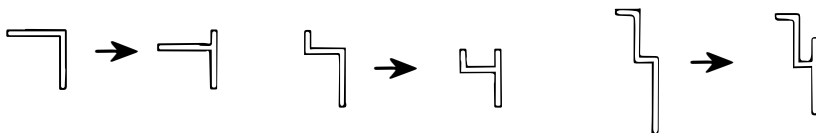
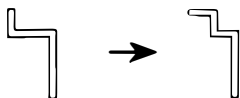


Figure 5.3 Examples of typical Type III corrections.

For sit. II



For sit. IV

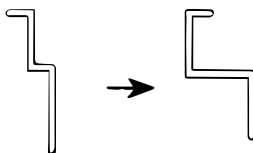


Figure 5.4 Examples of equivalent instruments.

1. How children progressively give up the idea of being able to transmit directly all their actions to the instrument, the instrument being a simple extension of their arm (absolute transmission).
2. How children discover (conceive, become aware of) the functions fulfilled by their actions (lengthening, turning around, pushing), which are then attributed to the instrument that is substituted for the action. In a certain way the instrument is endowed with power. It could be said that it is "lengthening," "passing or turning around," "pushing," and so forth; children discover these various aspects step-by-step while performing the task.

In the *second step*, typical for children 6 to 9 years old, which summarizes the two last behavioral types (Types III and IV), the instrument acquires a global meaning and loses its fragmentary character. It is conceived as a whole. But initially the function of displacing (or moving) transmitted by the instrument is referred to the length of one of its segments before being correctly related to the relationships between the various parts of the instrument and of the experimental device.

In summary, during the first step the instrument progressively loses its initial absolute transmission power in so far as it substitutes itself for the child's actions that it "performs." On the contrary, in the second step, the instrument "recuperates" its relative transmission power, in the sense that the child becomes able to dissociate and to take into account the object's characteristics and those of the action transmitted.

It is now time to express more explicitly my interpretation. At 3 or 4 years of age it is obvious that children are able to solve detour problems in action, the so-called reaching or locomotor detour. They do it by means of a constituted knowledge system that I call perceptuomotor. When the solution is no longer possible in action but requires the use of an intermediary object, 4-year-old children are progressively able, thanks to new capacities, to conceive objects that not only transmit their actions but also substitute themselves for them in order to fulfill various specific functions. Confronted by such situations, children demonstrate the capacity to select, to abstract, and to conceive (to elaborate conceptually) some partial and fragmentary characteristics related to the experimental situation or to their actions. These behaviors illustrate for me the construction of a new knowledge system, the successive construction steps of which I have tried to describe: the progressive discovery of the various "*local*" functions taken up by the action and of the various local aspects of the situation. We are then confronted by a first "realistic" conception of the instrument, conceived by means of representations that can be qualified as partial and fragmentary because they refer only to some local functions or aspects.

The instruments are endowed with power corresponding to these various functions; their particularity is their fragmented nature, as the functions are juxtaposed and not integrated. The major transition, which precisely defines the 5 to 7 year shift, is the transition from a *fragmented conception* of the object as juxtaposed functions, local meanings, or collection of characteristics to a *unified conception* of the instrument as the basic realization of a global function (or transformation) or as the possession of a whole stable meaning. This is in fact a necessary condition (a precondition) for its structuration, for the progressive mastery of the relations between its parts. (Similarly, children must succeed in identifying the objects in a stable way in order to master thereafter the relationships between their dimensions or between various objects concerning one single dimension.)

Finally, I consider the crucial problem of the relationships between knowledge systems. On that topic I do not consider that new cognitive systems are representative redescriptions of previous systems as stated by Karmiloff-Smith (1991), nor abstractions and transpositions from previous systems (Piaget, 1967, 1977; Mounoud, 1979, 1986a), but new original constructions initially framed by previously constituted systems that control the automatized complex exchanges with the encountered situations (Mounoud, 1993b).

By means of new partial (constructed) representations (the new declarative knowledge, the new fragmentary knowledge), subjects can directly assimilate (in a realistic way) some aspects of the situations or of objects encountered.

These partial representations or fragmentary knowledge will be integrated or coordinated into whole representations, owing to or consecutive to the transformation of the central mechanisms on the one hand and to the coherence introduced by the functioning of the previous constituted knowledge systems (which have framed or guided the initial interactions between subjects and environment) on the other hand.

Following this illustration, I now present the general theoretical model I propose to account for the emergence of new skills.

Relationships Between Knowledge Systems: Short Introduction to a Model

In all individuals involved in a learning or developmental process there are simultaneously *two knowledge systems* that 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. These two systems maintain *hierarchical and fairly complex relations* that 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. Such a formulation leads us to a brief comment about the practical-conceptual opposition.

Researchers in human sciences have introduced at least from the beginning of the 20th century an opposition between two types of intelligence or knowledge most often termed “*practical*” or “*sensorimotor*” intelligence (or situational intelligence) and “*conceptual*” or “*representative*” intelligence (or discursive or verbal intelligence). This opposition has been used to distinguish *levels of development* (for more details, see Mounoud, 1993a).

This opposition between practical and conceptual knowledge remains present in cognitive psychology under various labels more or less related to the initial ones, for example, between *procedural* and *declarative* knowledge, between *know-how* and *knowledge*, between *symbolic* and *nonsymbolic* processing levels, between knowledge *accessible* to consciousness or *not accessible*, or finally between *implicit* or *explicit* memories.

These oppositions have most often been used in the past to characterize non-contemporaneous *levels* and systems of knowledge; currently, they are used to confront contemporaneous systems of knowledge that are usually considered to be different in *nature* and clearly dissociated.

Ever since 1970 (Mounoud), I have strongly questioned the possibility of using the opposition between “practical” and “conceptual” knowledge in order to differentiate the nature or between the levels of *knowledge systems* (as did Piaget (1936) and Wallon (1945), 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 labeled “*conceptual*”) and “*formal*.” Each one of these systems (different in nature) can appear under two different forms, that is, conceptual and practical.

It is possible to state the following:

1. The practical forms of a given knowledge system result (ontogenetically or phylogenetically) from the previous conceptual forms of the same system that have become sedimented (or encapsulated) and consequently are no longer accessible to consciousness (no longer explicit).
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. The conceptual forms of a given knowledge system do not improve without involving the practical forms of an already elaborated knowledge system.

4. If cognitive development in humans proceeds through stages, differences between two successive stages cannot be reduced to the opposition between practical and conceptual.

Every behavior of an individual involved in a developmental or learning process, and especially that of children from 3 to 4 years of age and on, can be described as determined simultaneously by *two different knowledge systems* (each system being constituted by representations coupled with procedures).

On the one hand, there is a first knowledge system (called “perceptual” system in 3 to 4-year-olds) composed of *constituted and “sedimented” representations* (to which inputs have a direct access) merged with automatized action procedures. This first knowledge system is expressed in practical forms.

On the other hand, there is a second knowledge system (called “concrete” system in 3 to 4-year-olds) 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 a current process of conscious construction, bringing accessible representations into play. The transformation I defined to characterize the 5 to 7 year shift constitutes one of this second system’s elaboration steps (the “concrete” system).

In summary, these two contemporaneous representational systems express themselves under two different forms that correspond to the “practical” (or implicit knowledge) and “conceptual” (or explicit knowledge) 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). It is also 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, as well as with the two systems of automatic processing and attentional control defined by Posner and Rothbart (1991).

The capacity to produce new behaviors, that is, to elaborate new representations as well as new procedures, is due in children to the fact that new structures or new centers are brought into action (I have previously called these 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 may 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

subsamples 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 results precisely from the selection operated by the new centers with regard to the previous ones. These representations are characteristic in 4 to 5-year-olds.

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, or to a single dimension or idea. These new procedures progressively replace, 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, a new set of global representations at the origin of a new complex behavior (as, for instance, the appearance, around 6 years of age, of a conception in which instruments are seen as a whole and in which the diverse functions relevant vis-à-vis a given situation are selected and integrated as a whole; or the ability to integrate diverse dimensions such as height and distance in judgments about ball throwing; cf. "Ball Throwing: Actions and Judgments" section). This is precisely the transition from partial to global representations, that is the main characteristic of the 5 to 7 year shift. Whole representations, when constituted, have to go through a complex process of analysis and decomposition in order to elaborate the relationships between their elements or dimensions.

On the basis of these statements, it is now possible to define what I call the *process of conceptualization* (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 individual consciously selects or samples information that is relevant regarding the pursued goal, by means of the new knowledge system, which brings this new information into representation. *The simultaneous existence of two knowledge systems in parallel* constitutes 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 individual 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 explicit, at least partly.

As a matter of fact, this process would not function in a satisfactory way if the activities of the subject were not initially controlled by *previous knowledge*

(resulting themselves of course from a previous developmental process). Without this initial control the explanation of the origin of new behaviors should be sought in randomly produced behaviors. To quote Piaget: "The results (of experience), most of them being fortuitous, acquire nevertheless meanings by means of *hidden but acting schemes* [italics added] that enlighten them" (Piaget, 1937, p. 350). These "hidden schemes" correspond to what one calls sedimented or modularized knowledge.

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, the previous procedures are going to be replaced by these new ones, which have an inhibitory action before taking the old ones under control and integrating or incorporating them.

Putting so much emphasis on 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) and Nelson (1983) 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.

To conclude this presentation, we need to examine what hypotheses can be advanced about the emergence of new behaviors. Four different hypotheses, among others, can be considered:

1. The emergence of new behaviors is preformed; development is only the outcome of progressive maturation of the knowledge systems. Spelke's (1991) position could correspond to this first hypothesis.
2. The emergence of new behaviors comes from a *redescription*, a *transposition*, or an *abstraction* of already organized systems (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 (e.g., Mounoud, 1979, 1986b).
3. The emergence of new behaviors basically comes from the structure of the situations with which the individual is confronted (with no major role played by the organization of previous systems or of previous knowledge). This hypothesis could correspond to Harnad's model (1987) or Edelman's model (1987).
4. The emergence of new behaviors comes from new processing of experiences done by the individual in his or her different environments but *during activities determined by previously organized knowledge*

systems. It is what I call the indirect link. This hypothesis corresponds to the position I have developed in this chapter and has some similarities with the model published by Morton and Johnson (1991) related to the development of face recognition.

Having described the first illustration borrowed from my previous researches and having briefly presented the theoretical model, I now present more recent studies carried out in order to understand the relationships between children's knowledge such as revealed by their actions and their judgments. These are situations of ball throwing.

Ball Throwing: Actions and Judgments

Wilkening and coworkers (Fieberg, 1992; Krist et al., 1993; Loskill, 1992; Wilkening & Anderson, 1991) conducted several studies aimed at comparing children's and adults' intuitive physics abilities, as revealed in their actions and judgments. To perform their studies, they used a situation of ball throwing in which they varied target distance (on a landing area) and height of throwing (from a horizontal throwing board). Thus, they studied intuitive knowledge about projectile motion. (The authors have written about "throwing speed" ("speed of release"); I consider the term *throwing force* more appropriate.)

Children were tested in two experimental conditions, called action conditions and judgment conditions, respectively. In the action condition, aimed at assessing their perceptuomotor abilities, the children had to throw a ball by varying their movement speed (or force). In the judgment condition, aimed at assessing their cognitive (or judgment) abilities, the children had to turn the knob of an apparatus that was first calibrated for them so they would understand that it estimated throwing speed. The experimenter demonstrated three release speeds (minimum, medium, and maximum) and their corresponding knob position on the apparatus. The goal of the experiment was to understand which aspects of the situation were taken into account by the children in order to adjust their throwing speeds (actual throwing as well as speed rating on the apparatus); in other words, which implicit laws were used to regulate speed (force). Actually, throwing speeds were not recorded; they were computed afterward, on the basis of the landing impacts of the ball.

Five- to 6-year-old kindergartners (mean age 5:11), 10-year-old fourth graders (mean age 10:3), and adults were tested (40 people in each group). In the action condition, all three age groups did behave according to physical laws (to the normative structure) that determine optimal speeds as a function of target distance and height of release. However, mean speed values were far from optimal values; only relative variations were adequate (following physical laws). On the other hand, in the judgment condition, about half the kindergartners did

not consistently vary their speed ratings; the other half of the youngest children did vary their speed ratings according to one dimension only: target distance (16 subjects, 40%) or release height (4 subjects, 10%). When evaluating the mean value for the whole group, only target distance was significantly taken into account by the 5- to 6-year-olds. As to the other age groups, twenty-six 9- to 10-year-olds (65%) and eleven adults (28%) took only target distance into account. Now, fourteen 9- to 10-year-olds (35%) and twenty-nine adults (72%) simultaneously took both target distance and release height into consideration.

In the judgment condition, development thus goes from centering on one single dimension to integrating multiple dimensions, whereas in the action condition, all subjects managed a qualitative integration of multiple dimensions (target distance and release height). A control experiment showed that there was no learning effect.

The author's interpretations were inspired by the Piagetian framework; they argued that their subjects' abilities as revealed by their actions and judgments depended upon two kinds of knowledge representation: implicit and explicit knowledge. The authors also seem to have followed Piaget when considering that the cognitive representations are derived from the sensorimotor representations by reflexive abstraction. However, they did not comment on this complex mechanism. On the other hand, actions (i.e., sensorimotor representations) and judgments (i.e., cognitive representations) were said to be independent. Judgments were seen as derived from (or abstracted from) actions, but not as necessarily having an effect back on actions. Their results seem to show an equivalence between the actions produced by children 5 to 6 years old, 9 to 10 years old, and adults. Thus, according to them, there are two parallel knowledge systems, one derived from the other without acting back on it. This interpretation leads to a number of problems.

The first problem has to do with the nature of the so-called sensorimotor abilities revealed by the individuals' actions. Some psychologists call them know-how or procedural knowledge (I call them skills determined by a constituted knowledge system that express themselves in a procedural form). Obviously, these abilities go through a genesis. A study conducted by Fieberg (1992), one of Wilkening's coworkers, showed that it is not before 4 years of age that children manage to take both dimensions (height and distance) into account, in an integrated way, when regulating their actions (ball throwing). These skills are the result of a construction, mainly taking place during the third and fourth years of life. In a similar way, we have demonstrated (Mounoud et al., 1983) how children 3 to 5 years old, when manually tracking a visual target moving periodically, become progressively able to consider first the target's movement amplitude only, and next the target's movement time only, and finally to manage to produce movements that simultaneously take amplitude and movement time into account (without being able, however, to strictly syn-

chronize their own movement with that of the target; these abilities might not only suppose implicit knowledge).

Thus, in direct ball throwing as well as in manual tracking, children go through stages in which they first take only one dimension into account (at about 3 years of age), and later become able to integrate multiple dimensions (around 4 or 5 years of age). This genesis is comparable to the genesis revealed by "judgments," showing a decalage of a few years: The first genesis takes place between 2 and 4 to 5 years, and the second one between 5 and 9 years. What is the reason why one should talk about implicit knowledge in the first case and about explicit knowledge in the second? Is it related to language abilities? This does not seem to be the case, as the judgments do not involve language but only actions. Is it because only the judgments involve symbolic processes? Probably not, as 3- and 4-year-olds are perfectly able to use symbolic processes: Why would they not use symbolizations in regulating their actions? Piaget considered that sensorimotor intelligence or sensorimotor abilities are the result of grasps of consciousness and analytical reasoning that allow babies to *objectivate* the world; in this process, there is already an "explicitation" or a transition from an implicit to an explicit kind of knowledge. In both cases, it seems that the subject does an explication (or objectivation) job that not only involves grasps of consciousness but also declarative and not only procedural forms of knowledge (Mounoud, 1990b).

The second major problem is to understand why explicit knowledge, which, according to Krist et al. (1993), is revealed by the judgments about speed release, does not seem to be involved in the throwing action control. At this point, I wonder whether the individuals' actions are really not influenced by their explicit knowledge, that is, by the kind of knowledge revealed by their judgments. For instance, among 10-year-olds, 65% take only distance into consideration in their judgments. Do they act differently from the 35% who are able to integrate height and distance? Or do those making up the 40% of the 5- to 6-year-olds who consider distance act differently from the 50% of the 5- to 6-year-olds who do not systematically vary their judgments? It does not seem as though the authors tried any of these analyses. Considering other variables might also be necessary to reveal probable differences. As long as such analyses are not done, it seems difficult to claim that the results obtained by the diverse groups in the action condition are equivalent, as the actions themselves were not analyzed. A total independence of judgments vis-à-vis actions would raise important epistemological and pedagogical problems. All the motor abilities I have been studying do transform after 5 years of age: lifting objects that vary in weight (Forssberg, Eliasson, Kinoshita, Johansson, & Westling, 1991; Gachoud, Mounoud, Hauert, & Viviani, 1983), visuo-manual tracking and target pointing (Badan, 1993; Hauert, Zazone, & Mounoud, 1990; Mounoud, Viviani, Hauert, & Guyon, 1985; Zanone, 1990), drawing and writing activities

(Vinter & Mounoud, 1991; Zesiger, 1992; Zesiger, Mounoud, & Hauert, 1993), to mention a few of them. It would be surprising if ball throwing does not transform between 5 to 6 years and 9 to 10 years of age.

In some ways, the experiment presented by Krist et al. (1993) can be considered close to my work on the construction of instruments. In both situations, 4-year-olds did possess an elaborate perceptuomotor knowledge system to solve the task. In both experiments, when individuals were asked to solve the task, not in a direct way, but through an instrument or an apparatus, they had to reelaborate the situation on the conceptual plane (they had to reconceptualize the situation); this led to the appearance of partial and fragmentary solutions, which revealed new knowledge elaboration. In both cases, there was a transition from centering on one single dimension to integration of relevant dimensions. While new conceptual knowledge elaboration does transform the way individuals act in the detour situation drastically, it does not look like ball-throwing behaviors are affected by the explicit knowledge that is revealed by the judgments. But then again, I maintain the hypothesis that a direct analysis of the throwing actions (by contrast to a simple computation of speed based on the landing impact) should reveal changes. Finally, studying age groups in between 6 and 9 years is necessary. In most of our studies, the developmental trends are not monotonic in this age range.

The third problem, certainly the most important of all, is to determine whether the explicit knowledge revealed by the children's judgments is really derived from the knowledge revealed by their actions, as claimed by authors after Piaget. If this is the case, in which way?

Again, I do not consider that the children's new knowledge revealed in their judgments is directly derived from the perceptuomotor knowledge revealed by their actions. There is no representative redescription, nor transposition or complex abstraction of perceptuomotor or procedural knowledge. Conceptual knowledge also does not emerge from the child's simple confrontation with new situations, through simple abstraction of the events or situations, properties, or structure, without an intervention of previous knowledge or structures. Any purely inductive explanation should be rejected. Finally, new knowledge is also not the outcome of the maturation of the child's internal structures. Maturation only makes it possible for new knowledge to be constructed. There is a real reconstruction, an original reconceptualization of the encountered situations, which is elaborated during the child's exchanges with the situations. These exchanges are made possible or determined by the existence of previous constituted knowledge, which is sedimented and is thus not accessible to consciousness anymore (this knowledge became implicit after it had been explicit). In the same way, the action procedures have been automatized to diverse degrees.

In addition, I have to specify that for me new knowledge does not maintain

itself in a purely conceptual or declarative form; it also generates new practical or procedural knowledge. This new procedural knowledge is thus also local, partial, and juxtaposed, as is the declarative knowledge that generates it. The new knowledge system in elaboration has progressively an inhibitory action on the previous system.

In summary, there are no practical or procedural knowledge systems, nor conceptual or declarative knowledge systems, but rather knowledge systems that express themselves in a practical or conceptual way. For any given system, the transformation goes from conceptual forms toward practical forms but, again, is initially framed by the practical forms of the previous knowledge system (for more details, see Mounoud, 1993a).

The reflexive abstraction hypothesis is only one of the two main hypotheses formulated by Piaget in order to explain the construction of logical operations based on the sensorimotor coordinations. Reflexive abstraction, as is well known, involves a change in representation level or plane. According to this hypothesis, logico-mathematical operations are defined as the internalization of the general coordinations of actions (see Mounoud, 1992, for a commentary on the other Piagetian hypothesis [Piaget, 1942] to account for the connection between the actions and the operations).

Conclusion

In this chapter I hope I have succeeded in explicating what constitutes for me the major transition of children's behavior between 5 and 7 years and which is supposed to result from the transformation of central cognitive mechanisms. This transition can be viewed as the capacity to integrate or to coordinate in a whole the new partial and fragmentary knowledge about objects constructed by children 4 and 5 years old by means of new knowledge systems. Once they become able to characterize—(re)reconceptualize—objects as stable entities, to conceptually identify them as independent of their actions, children between 6 and 10 years of age still have to elaborate the relations between the dimensions that coexist in the object, as well as the relations between objects related to a given dimension. The critical point is therefore the capacity for grouping or chunking these meaningful juxtaposed units in totalities or the capacity to coordinate or integrate isolated cognitive components, what has sometimes been called the "cognitive chunking" or the "perceptual grouping." The shift going from successive to simultaneous processing could be considered a consequence of this major change. In a recent article (Mounoud, 1993a), I developed the same model but illustrated and concretized at the sensorimotor period. In that article, I took a critical position with regard to Mandler's model (1988), in which she postulated the existence, from birth, of a double represen-

tational system (procedural and conceptual systems developing simultaneously and in parallel).

From an experimental point of view, the radical theoretical change I have tried to make consists in looking at the consequences of the new conceptualizations on motoric behaviors instead of studying the conceptualizations for themselves, which has already been extensively done. My project has been to study the restructuring of behaviors, as resulting from new conceptualizations. This is the perspective in which I studied motor development to approach cognitive development from another point of view. It is true that Wilkening's results could constitute a complete denial of my perspective. Nevertheless, changes of behaviors in the construction of instruments as well as in all the other situations I have studied support my perspective. What has to be done in the future is to simultaneously study the respective transformations of the new conceptual and practical knowledge within the same subjects, which is what I have started to do in the studies on the construction of instruments.

To conclude this chapter and as far as it is still necessary I explicate my position on the central question raised by Sameroff and Haith (at least for the nonsedimented parts of my knowledge!). For me it is obvious that the behaviors of 7-year-olds differ from those of 5-year-olds. Originally, the differences are qualitative in nature, but they necessarily generate quantitative differences. Conceiving an instrument in a unified way (as a unity, as a whole) instead of as a constellation of functions constitutes a notorious qualitative change. The corrections brought to the constructions reveal consecutive quantitative changes: Adding a supplementary segment to the construction instead of modifying the relationships between segments is a good illustration. Similarly, taking the various dimensions of a situation into account in a separated or integrated way constitutes qualitative as well as quantitative changes at the same time. This is the case in the genesis of number conservation regarding length and density of collections. These changes result from the emergence of new behaviors, partly dependent on prior behaviors. Eventually, prior behaviors will be controlled by the new ones.

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