

# Infancy and Epistemology:

An Evaluation of  
Piaget's Theory

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## 8 Representation and Sensorimotor Development

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(TRANSLATED BY RUTH BARNARD)

### Statement of the Problem

*Some problems raised by the notion of representation.*

The notion of representation typically serves as a linking concept between several disciplines. Touched on by sciences such as mathematics, logic, and cybernetics, it assumes particular importance in the 'life sciences', like biology and physiology, ethology, linguistics and psychology. In each of these areas, the notion of representation is put forward to answer specific problems.

A foremost problem concerns mediation between subject and object. Some psychological theories depict the subject-object relation as direct and immediate; others suggest intermediaries between the individual and his environment. A second category of problems relates to those of meaning, of translation (or coding), and these are connected. We may ask, for example, if it is necessary to invoke the notion of representation to account for the specific responses of the subject (or of any other living thing) towards the particular form of his environment. In ethology, the works of Tinbergen and Lorenz show that the animal is born with the translation of certain directly meaningful external realities already established and these trigger a more or less stereotyped series of behaviours. In molecular biology, the existence of information exchanges between molecules based on the use of a precise genetic code has been demonstrated. The concept of representation could be introduced here to explain the efficient and straight forward linkage between a pre-established organization of activity in the animal or molecule and certain dimensions of the environment. The problem of constructing symbols and of conserving experiences also raises questions pertinent to representation. In the latter case, the links between representation and memory are studied.

*Representation and mediation*

Representation is a central notion in psychology whether one adopts a synchronic or diachronic<sup>1</sup> point of view towards the subject's conduct.

From the synchronic point of view, the notion of representation raises the problem of mediation in the relations of the subject to his environment. Bower (1976) sees development in terms of the specification and differentiation of representations which are at first abstract and he postulates the constant existence of mediations in the relation between the child and his environment. Some psychoanalytic theories like those of Klein, Heimann, Isaacs and Rivière (1966) conceive the link between the individual and his environment as always mediated by representations. In contrast classical behaviourist theories assert that it is pointless to resort to internal mediation, to representations in the broad sense, in order to understand the activity displayed by the individual in his environment. This principle of economy, frequently erected as a methodological principle, nonetheless reveals the general theoretical assumption that the subject's relation to the external world is direct. The contingencies of reinforcement present in the situation suffice to determine the organism's behaviour. Let us stress that this position is no longer characteristic of behaviourist theories as a whole, which allow—at least in an adult, and perhaps in the child—the necessity of introducing intervening variables between the stimuli provided by the environment (internal or external) and the activity of the subject.

There are, in psychology, theories which deny the existence of pure representation in the sensorimotor period. Wallon, for example, supports a contrast between 'situational intelligence' as in the sensorimotor period and 'discursive intelligence' by basing this contrast on absence of the capacity for representation in the sensorimotor stage, this appearing only towards the age of two years. Similarly, for Piaget, sensorimotor intelligence is characterized by the absence of the capacity for pure representation, which arises around eighteen months with the appearance of the semiotic function and constitutes a new representative form of intelligence. The break introduced between two forms of intelligence leads each of these authors to pose the problem of the relationship between thought and action, a problem discussed elsewhere (Mounoud, 1979; Mounoud and Hauert, 1981).

*Representation and meaning*

From the diachronic viewpoint, the notion of representation raises the problem of changes in the meaning which the individual attri-

butes to his actions and to objects during development. Genetic psychology furnishes examples of this evolution, which we can illustrate with work carried out by one of us (Mounoud, 1970) on the child's construction and use of tools. One of the experimental situations consisted in extracting a plug surmounted by a ring from inside a narrow-necked bowl, with the aid of various instruments. The manner in which children justify their failures or successes shows how they progressively build different meanings relative to their action and to the tools. Children of four years retain only—as the sole pertinent property of the instrument—its length, to which they attribute the success or failure of the action. Towards five years the grasping aspects of instrument and action become significant. At six years the child exhibits a unified conception of the instrument and its intrinsic properties but does not fully understand the relationships which obtain between its different parts relating to the grasping situation, these relational properties will be elaborated between six and nine years.

The problem of constructing meanings necessarily leads back to that of elaborating representations which allow the translation, by means of a chosen code, of the properties of objects with which the subject is confronted, and of the characteristics of the actions he initiates. By code, we mean any transformation (or system of transformations) which allows the establishment of correspondences between the elements of two wholes. These transformations can vary greatly according to the properties of the elements they concern and the nature of the relations between the two wholes. By coding, we mean a particular use of the code. The activities of coding consist in sampling, analysis, organization of information, or in establishing relationships between coded information inputs. It is quite clear that no system can function without using a code which allows it to establish a correspondence between certain dimensions of the internal or external environments (and their variations), and certain internal states of the system. This type of function is particularly carried out by the sensory receptors, which have long been called analysers, and which function as signalling systems. It is through coding that the child (or the adult) manages to sample information about the world in order to give direction to his action. The coherence, completeness and objectivity of such information are proportionate to the degree to which representations have been established. Numerous questions arise here: how are these representations built up? Does the child elaborate several systems of meanings? If so, do the meaning systems carry out codings of the object which are compatible with each other or mutually exclusive?

We will approach these problems chiefly through the study of the sensorimotor period.

*Representation and memory*

The notion of representation considered from a diachronic viewpoint also raises the problem of the relationship between representation, memory and the conservation of experience. By memory, we mean any internal organization of content (or system of internal organizations of content) which act as internal models by reference to which realities acquire meaning for the subject. One might call a particular organization of a certain content a memory trace. It seems very difficult to understand the functioning of the individual without postulating the enduring existence of certain data which are relative both to perceptual input and motor input.

The problem of the relation between representation and memory leads one to ask whether recall of experience and the recognition of objects presuppose the existence of a system of traces, the trace being understood as an internal translation of external reality. Writers like Janet (1928), Bartlett (1932) and de Schonen (1974) have defended the thesis of memory based essentially, if not exclusively, on an activity of reconstruction, thus relegating any system of traces to a subsidiary or even non-existent role. Such a conception is tantamount either to denying the existence of memory as a mechanism for conserving experiences, or to assimilating memory to a system of rules for reconstruction (or coding) devoid of figurative elements. By contrast, a writer like Wulf (1922) reduces memory to a system of traces whose conservation may or may not lead to distortions in recall (Mounoud, 1977).

As far as the sensorimotor period is concerned, Watson (1981) distinguishes three types of memory: regenerative memory, which consists in transforming a current experience so that it shows characteristics in common with a past experience (this is almost an evocation); reactive memory, which allows recognition of a past in a current experience (this is close to a memory of recognition); and associative memory, which allows association between two or more experiences. Each of these is divided into short- and long-term memory. For Watson, regenerative memory presupposes representation (we might also wonder if the other forms of memory don't also presuppose this).

It is now a matter of enquiring into the relationships which exist between representation, coding and memory. Can the notion of representation be assimilated to that of coding? If this is the case the role of representation would be to provide an interface between the

perceptual and motor systems. In this view, memory consists in reconstruction since only the activities of information coding are pertinent to an account of how the interaction between subject and environment proceeds: formed representations of memory traces do not intervene as determinants of the subject's behaviour.

To give to representation the status of an interface between the afferential (perceptual) system, and the efferential (motor) system appears to be an original point of view in psychology, though this position is widely accepted in cybernetics. Most writers who study perception in psychology do not concern themselves with the use or integration of perception in the motor behaviours of a subject, and, conversely, writers concerned with the study of motor behaviour are largely uninterested in perception. Research carried out on prehension in the infant provides good examples of this: errors in grasping are attributed either to a defect in the motor system, or to a perceptual problem, but the coding relations between perceptions and actions are rarely investigated.

Another way of looking at the relations between representation, coding and memory is to enquire whether the systems of traces, or formed representations, must also play a part in coding the environment which the individual carries out in order to sift information from it. In this view, memory is no longer conceived of as essentially a reconstructing activity; the traces themselves, as the coded contents of reality, would also play a part in the memory processes.

### *Representation and programmes of action*

In order not to dissociate the study of perception from that of action one must define processes which interconnect the two levels. Arbib (1980) adopts a theoretical orientation inspired by cybernetics, defining perception as a 'potential action' and he is necessarily led to postulate the existence of mediations, or intermediaries, 'perception of an object (activating appropriate perceptual schemas) involves gaining access to routines for interaction with it (motor schemas) . . . .'. The introduction of the notion of routine as a mediator of relations between perception and action, a commonplace idea in cybernetics, is interesting. It is comparable in some ways to a programme of action, defined elsewhere (Mounoud, 1981; Hauert, 1978). As we know, a routine does not operate directly on the information provided by the programmer (data external to the machine); translations of such data in the machine language necessarily intervene. These play the part of representations or codings on which the functioning of the routine is based. In the same way, anticipation and execution of a programme of action depends

on the nature of the representation which the subject possesses of the objects, with which the programme is concerned. Thus programmes of action and representation are related notions.

In a cybernetic machine, any treatment of data is carried out by means of a double coding procedure: the first is related to the language of communication with the outside (the programme), the second consists of the machine language (or internal communication). We shall try to show how this 'double coding' is equally appropriate from the psychological viewpoint, and how it permits us to raise the problem of differentiation between the subject and the environment in the sensorimotor period which interests us here.

The aim of this chapter is on the one hand to show the pertinence of the notion of representation to understanding sensorimotor development; and on the other, to present a model for the development of representation. The first of these objectives requires a discussion of Piaget's theory of representation and of his concept of the relation between reference and referent. We will show how Piaget had difficulty with the problem of representation largely because he refused to consider the existence of intermediaries in the relations which unite the baby to the environment. This will be discussed in the next part of the chapter, then having considered Piaget's position from a theoretical point of view, we will see in the third section how the analysis of behaviours displayed from birth also brings some fundamental empirical data to our conception of the problem. Finally, in the fourth section, we will show how the development of representation takes place during the sensorimotor period.

### Some Aspects of the Piagetian Concept of Representation

The notion of representation does not appear central to Piaget's work; on the contrary, Piaget has always tried to have little recourse to it, in order to concentrate on the transformations or operations which the subject performs on reality. Paradoxically, it is nonetheless one of the first concepts, along with those of assimilation, accommodation and co-ordination (Piaget, 1936, 1937, 1946) which he elaborated theoretically.

In *La naissance de L'intelligence chez l'enfant* (*The Origins of Intelligence in Children*) (1936) and *La construction du réel chez l'enfant* (*The Construction of Reality in the Child*) (1937), Piaget tried to show how the child manages, through his actions, to be placed in an organized world, where different spatial, causal and temporal relationships obtain between different objects. Sensorimotor constructions lead to establishment of invariants such as the permanence of the object and the 'group' structure of movements.



The former develops through six stages, the last being characterized by the child's ability to master an object's unseen movements.

Piaget, who, for the first five stages, had kept the notion of representation out of his explanatory theory, felt it necessary to introduce this idea to account for the new achievement of following the movements of an object which are not subject to direct perception. The infant must have constructed a mental representation to account for the permanence of the invisibly moving object. Thus, only in retrospect did Piaget trace the possible origin of representation in the development of imitation.

### *Differentiated signifiers*

Piaget distinguishes between representation in the broad sense, assimilated to thought, and representation in the restricted sense, conceived of as 'the symbolic evocation of absent realities'.

In the restricted sense, representation of past events or absent objects is assured by the mental image, the symbol or the verbal sign. These devices of notation are the instruments of a memory of evocation, which appears around eighteen months according to Piaget. The substitutes or representatives have the status of signifiers.<sup>2</sup> The contents or structural forms which give them meanings have the status of signified.<sup>3</sup>

Piaget called the signifiers (with which it will be appropriate to integrate perceptual signs) 'figurative instruments', incumbent on knowledge of states-of-affairs. That is to say they carry out translations of certain dimensions of reality. Figurative instruments depend strictly upon operative instruments (schemes, operations . . .) which in turn deal with transformations and account precisely for the change from one state to another. They permit relationships to be established both between objects and their properties and between positions of the body and those of its parts.

Piaget has tried to trace the origin of these differentiated signifiers in the development of imitation. The status he accords to imitation in relation to representation always remains ambiguous as Bronckart and Ventouras-Spycher (1979) note: sometimes, imitation 'marks the junction of the sensorimotor and the representative' (Piaget, 1946) and 'is one of the possible terms between sensorimotor behaviours and representative behaviours' (*Ibid.*), at other times 'imitative accommodation accounts for the formation of signifiers necessary to representative activity' (*Ibid.*) Imitation develops in parallel with sensorimotor behaviours: the linked notions of co-ordination between schemes and of differentiation between assimila-

tion and accommodation are invoked to explain the genesis of imitation. Deferred imitation will be considered as a valid indicator for judging the internalization of accommodation movements and thence the building of an internal image. If the development of imitation is described in relation to sensorimotor schematization, representation is conceived as a sort of 'picture-memory' which seems to represent states of reality.

It is not satisfactory to resort to imitation as a possible origin of the processes which lead to representation. In the first place, we will see that the infant is capable of imitation at a very early stage. So how can it be argued that imitation is constitutive of representation, although, as we shall stress, early imitation does not have the same status as later imitations? We take the opposite point of view from Piaget, that the presence of representation must necessarily precede imitation: how could one otherwise explain the isomorphism which the subject introduces between the behaviour of the model and his own? Though we do not think it to be through imitation that the child constructs his representative ability seen as a coding process, we nonetheless believe that imitation of the self or others plays an important part insofar as the construction and organization of the content of representations is concerned.

### *Perceptual indices*

Representation in the broad sense can be assimilated to thought, whose essential function, for Piaget, concerns knowledge of reality, that is to say, the attribution of meanings. During the sensorimotor stage, meanings are constructed through perception and action of the subject; they are taken from sensorimotor schematism. For Piaget, the signifiers of the sensorimotor stage are essentially perceptual indices. 'We call *index* any sensory impression or directly perceived quality whose meaning [the referent] is a sensorimotor scheme or object' (Piaget, 1936).

Indices provide knowledge of the object's qualities, that is to say of its particular properties, but in a direct manner, whilst this knowledge, obtained by means of differentiated signifiers, is mediated by representations. Indices show general characteristics of being undifferentiated from the signified, that is to say of constituting an aspect of the object or scheme and of only being actualizable in the presence of the object or the action.

It does not seem acceptable to us to argue that these indices form part of the object; they are translations which are necessarily internal to the subject, otherwise there would be no point in calling them signifiers. As we shall see, this position partly arises from the

confusion Piaget introduces into the definition of the 'signified'; moreover it contradicts his thesis on the 'reading' of experience. The indices' second characteristic, to be triggered only in the presence of the object or through the course of action, means that one acknowledges the existence only of a recognition memory in the sensorimotor period, memory of evocation appearing with the semi-otic function. We mentioned in the introduction that Watson distinguished three types of sensorimotor memory: reactive, regenerative and associative memory. Regenerative memory is defined by the child's ability to modify a current experience in such a way that it presents characteristics in common or even identical with a past experience. As Watson stresses, this closely resembles a memory of evocation (and not of '*ressurgence*' as Piaget (1981), would like to believe, the more so as we have difficulty in understanding the meaning of this term!). He interprets the vocal imitations of the infant of five to eight months in this way and the eight-month-old child's searching to find an object which has momentarily disappeared from his field of vision. There would thus exist, well before the age of eighteen months, facts which provide evidence for a memory of evocation. The characteristics of perceptual indices which Piaget lists (and whose pertinence we debate), together permit him to deny the existence of representation in the strict sense during the sensorimotor period, and to describe the infant as having a direct relation to his environment.

To understand the way in which Piaget manages to have little recourse to representation in the sensorimotor stage, it is necessary to remember one of his fundamental postulates. This is that the function of a scheme of action is to tend to incorporate the whole of reality. The baby tries to exercise action schemes on the whole collection of objects furnished by the environment. The properties of objects encountered will bring about modifications in the form of the infant's actions. Reciprocally, these differentiated forms of actions will reveal the different properties of objects. The same object will be able to give rise to different perceptual indices as a result of its assimilation to different motor schemes. By the reciprocal co-ordination of the schemes, these different indices of the same object will refer one to the other thanks to the infant's inferential activities. Thus the object acquires a more and more autonomous existence from the subject's point of view and parts of the object become sufficient to trigger a behaviour (or a scheme of assimilation). For some time the object's meaning remains dependent on the application of the assimilation scheme to that object: from a part, the infant does not reconstitute the whole. When from an index (or from

several indices), the child reconstitutes the whole object, a first form of object permanence will appear (Piaget's stage four). A first form of permanence, but still lacking representation because the object seems to lose its existence when it is no longer directly visible. Finally, when the presence of indices is no longer necessary for the child to believe in the object's existence, Piaget will say that the child has constructed a representation of the object.

We, however, believe it is impossible to have scant recourse to the notion of representation in explaining sensorimotor development. For an index to trigger an assimilation scheme, it seems necessary that that index be attached to a particular meaning, and the representations which are at the infant's disposal provide this meaning.

### *The signified*

The most debatable aspect of the Piagetian concept of representation lies in his manner of defining the signified. The signified may indicate the scheme of action itself, an event, an object (present or absent) or a concept. To allow that the signified can be defined equally by the object as by the scheme or by the concept raises very different epistemological options whose confusion shows the difficulty of transposing these linguistic ideas to the field of psychology.

We can try to illustrate with examples that show it is impossible to define the signified by the object. How does one manage to say 'this is a table' when we see a table? The signifier corresponds to an internal translation of this object-table. If we say that the signified is the table itself, this object-table possesses all the meanings we know about it (for example, it has weight, a colour, it serves different uses, we can work or eat at the table). Thus, all these meanings belong to the table and are not dependent on a subject who uses or sees the table.

Let us take another example, of a person who interprets a footprint in the snow as an indication of an individual's passage. How does the person manage to elaborate this meaning? The signifier is elaborated from the indentation in the snow, it corresponds to an internal translation of this object-footprint. All signifiers result from the subject's internal elaborations but some can be externalized or materialized (for example, drawings, words) which confers a special status on them. To see an individual as an object possibly signified by the indentation in the snow is to recognize that the signified object possesses the particular property of leaving footprints. Again the object signified would exist independently of any subject who perceived or acted upon it.

Now we all know that this realist, materialist position is contrary to Piaget's fundamental epistemological stance. A possible alterna-

tive to this first solution is to assert the internal nature of the signified and thus assimilate it to systems of relations or processing of reality. Piaget adopts this viewpoint when he accords to the scheme or the concept the status of signified, conceived as processing instruments, insofar as they organize themselves in whole structures. Piaget's thinking still seems slightly uncertain for he defined the scheme 'as a completed whole of perceptions and movements' (Piaget, 1936), that is to say as an instrument of exchange or relation between the subject and the environment and no longer as a structure of the subject's action defined independently of the contents on which the action bears. Nonetheless it cannot be denied that the signified, from this viewpoint, is confused with [the] cognitive structures or processing instruments at the subject's disposal. This option, which considers that the object has no existence of its own outside the system of structuring that the subject applied to it, belongs to an idealist thesis which has also been criticized, though perhaps less strongly, by Piaget. When Piaget defines the signified in this way, he tends to confuse the instrument of representation itself with the result of applying this instrument to a given reality. In other words, he does not distinguish the figurative instruments themselves from the results of their application in the form of particular representation. Of the signified, he only retains a structure whose function is to allow the attribution of meaning.

These notions of signifier/signified were proposed by de Saussure (1916) who attempted to establish a definition of the verbal sign. When Piaget took up these notions, he simplified them considerably (Bronckart and Ventouras-Spycher, 1979). According to de Saussure, two types of material reality have to be processed by the subject to establish a verbal sign: on the one hand, an acoustic substance; on the other, a material substance which corresponds to the content to be expressed. These two realities give rise to two images, the auditory image and the concept, which arise from individual constructions; they are not to be confused with the signifier/signified pair. Language constitutes the signifier and signified by establishing a system of relationships and differences between signifiers on the one hand and signified on the other. For de Saussure, signifiers and signified are reducible to forms constructed on the basis of relationships and of differences established between themselves.

Though for de Saussure as for Piaget, the signifier is assimilated to a form, Piaget does not distinguish levels equivalent to those of substances (acoustic or material), images (the acoustic image or concept) and meanings (signifier and signified). Piaget does not declare himself on the link between the signified and the substances

or contents, except when, in a far too realist manner, he defines the signified as the object itself, which as we have just seen is incompatible with his epistemological position. On the other hand, Piaget introduces these two levels of form and content into the signifier/signified pair itself: in some way the signifier becomes a substance with regard to the signified, a conception which differs radically from de Saussure's. However, when Piaget studies signifiers as mental images, he doesn't treat them at all as organizations of contents, but once again as figurative instruments. Now, we think it is particularly important to link these notions with the contents of reality with which individuals are presented. Piaget has studied the development of representation from the angle of the construction of a code, but he has never concerned himself with the representations built up from applying this code to various realities.

One of the writers of this paper has proposed defining signifiers by means of the sensory messages and different levels of elaboration which they can reach, and signified by the internal organizations capable of interpreting them (Mounoud, 1976). Defined like this, it is clear that signifiers and signified are two inseparable aspects of any representation. In the fourth part of this chapter we shall propose a model for the development of representation without further attention to this distinction between signifiers and signified, which in many ways is arbitrary. We shall nonetheless show how the three levels distinguished by de Saussure in the constitution of a verbal sign can be related to the stages in the construction of a representation.

### **The Initial Organisation of the Infant's Behaviour**

Before setting out in detail our own model of the construction of representation, we intend to describe and analyse two types of activity shown by the baby very early in life; namely behaviours that illustrate the capacity for auditory-visual co-ordination and precocious imitation.

Psychology, in recent years, has been marked by a considerable change in position on the infant. Certain empirical facts clearly point to a contradiction in the conception, at one time generally widespread, of an immature infant without any real capacity to organize his relations with his environment. Most psychologists now regard the neonate as possessing complex abilities for handling information. These abilities should not be compared with those of the adult in terms of greater or lesser complexity. The neonate, just like the adult, carries out performances that presuppose extremely complex and sophisticated handling of a vast amount of data.

The abilities that the neonate exhibits are quite varied: ability to

discriminate visually (Fantz, 1964; Bower, 1974; Carpenter 1973) olfactory and taste discrimination (Lipsitt, Engen and Kagan 1963), and auditory discrimination (Wertheimer, 1961; Eimas, 1975; Hammond, 1970). The ability to co-ordinate seems even more astonishing: co-ordination of vision and reaching (Bower, Broughton and Moore, 1970a), audio-visual co-ordination (Aronson and Rosenbloom, 1971; MacGurk and Lewis, 1974), audiomotor system co-ordination (Wertheimer, 1961; Butterworth and Castillo, 1976; Alegria and Noïrot, 1978) and visuo-motor co-ordination, as research on early imitation shows.

We shall concentrate particularly on two types of co-ordination that still give rise to certain controversies: audio-visual co-ordination and early imitation. At the outset, we should like to stress the scant regard generally paid by writers to the ages of the infants they are studying. It is not unusual to find that results obtained from infants a few days old are directly compared with those obtained from infants aged two to three months. Such an attitude denotes a failure, that we strongly criticize, to take into account developmental hypotheses. We consider that only a developmental model permits understanding of some apparent contradictions thrown up by experimental research.

#### *The initial state of audio-visual co-ordination*

Research on the problem of audio-visual co-ordination raises three main types of question about our knowledge of the sensorimotor period: do there exist, from birth, initial co-ordination among sensory systems and between sensory systems and motor systems. If they exist, do these co-ordinations imply a plurimodal representation of the object? And finally, how do we reconcile the existence of early representations with the idea that the neonate is subjectively undifferentiated from its environment?

Wertheimer (1961) has shown that a few minutes after birth a neonate produces a preponderance of ipsilateral eye movements when a sound arises in its environment. He interprets this data in terms of an initial co-ordination between auditory and visuo-motor space in the neonate, which he believes arises from a reflex function. Replication of this research has revealed more precisely the conditions under which these co-ordinations can be demonstrated (Turkewitz, Birch, Moreau, Levy and Cornwell, 1966).

Butterworth and Castillo (1976) have recorded spatially co-ordinated eye movements in infants a few days old in response to a tone which followed a series of 'clicks'. Sounds were presented at random to left and right of the subject or in blocks of trials to the left

or right. When the sounds had a fixed origin, they noted eye movements contralateral to the direction of the sound. They therefore infer the presence of an innate audio-visual co-ordination, but as Butterworth (1981) later stressed, this hypothesis is not sufficient to account for the development of subsequent forms of co-ordination. Following Jones and Kabanoff (1975), he suggests that the eye movements might coincide with the stabilization of an auditory memory relating to the position of the sound.

The research of Alegria and Noiro (1978) is concerned with infants of six days old. From three loudspeakers situated respectively opposite, on the left, and on the right of the infant, the word 'baby' was emitted once every two seconds for a total of twenty trials. The infants in the experimental group turned their heads in the direction of the loudspeaker, with their eyes open, often vocalizing, much more frequently than the infants in the control group. The findings of Alegria and Noiro permit two conclusions: on the one hand they affirm the ability of the neonate to refer an auditory input to a spatially oriented motor programme, on the other this may imply an ability to locate a sound in space.

In fact, neither Wertheimer (1961) nor Butterworth and Castillo (1976) arrive at such a conclusion, which poses problems about the abilities of the neonate. The possibility of locating a sound in space necessarily implies the definition of two spaces in relation to each other, the space occupied by the subject's body and the space from which the sound originates. What is more, the latter is presumed to be organized according to a geometry calculable by the subject, so that the infant manages to determine the orientation of his head with respect to the spatial co-ordinates of the point from which the sound issues.

Butterworth adopts a position opposed to the one developed by Alegria and Noiro when he doubts that neonates 'expect that a sight be accompanied by a sound', even if spatially organized connections between the oculomotor system and the auditory system exist. One would have to show that the neonate reacted with surprise towards unexpected or surprising placings of the sound. Here we can refer to research by Aronson and Rosenbloom (1971), McGurk and Lewis (1974), and Lewis and Hurowitz (1977) although this evidence must be treated carefully, since it was undertaken with infants older than those already discussed.

Aronson and Rosenbloom (1971) tested seven infants aged between thirty and fifty-five days in two types of situation: a normal one where the mother's voice was spatially congruent with her face, and an audio-visually discordant one where this spatial congruence



did not exist. Infants of thirty days appear perturbed by the audio-visual discordance; they react to it by increasing the frequency of tongue protrusions and mouth movements. According to Aronson and Rosenbloom these reactions show the infant's ability to perceive stimuli across several modalities in combination.

McGurk and Lewis (1974) tried to replicate this research, with some methodological controls (in particular the order of presentation of the tasks and subject sampling). They show that at four and seven months, the number of head movements in the direction of the sound increases significantly in the discordant situation, a tendency which also appears in infants aged one month. The writers consider that 'these data, therefore, afford no support for the hypothesis that the very young human infant lives in a perceptually unified audio-visual world', given that no reaction of surprise or distress arises during the experiment. They conclude, however, that at these ages the ability to locate a sound is relatively efficient. Such conclusions seem contradictory to us; as we have already stressed, locating a sound in space necessarily implies a pluralist representation of the sound's source.

Lewis and Hurowitz (1978) suggest another interpretation of head movements shown by infants in situations characterized by audio-visual spatial dissociation: these could be exploratory reactions provoked by a situation which 'violates' the 'integrated audio-visual person schema', this being an intersensory organization already present at birth. In their study infants aged between one and four months were tested. The frequency of lateral head movements increased significantly in situations where the voice was displaced from the face, and where the voice and face were not matched (for example, the mother's face with a stranger's voice). The authors believe the results support their hypothesis, since the greatest frequency of head movements was found in discordant situations. However, their data are difficult to interpret because, firstly, age groups are not separated and secondly, no distinction is drawn between conditions with the mother or with a stranger, nor between control conditions.

Even if they seem contradictory in some respects, taken as a whole, the above mentioned pieces of research help to show the existence of initial sensorimotor co-ordinations (co-ordination of the auditory and motor systems). The demonstration of these initial co-ordinations raises questions concerning the Piagetian conception of the infant's initial state. For Piaget, the sensory and motor systems would initially define heterogeneous or non-co-ordinated spaces, functioning in isolation. The infant's perceptions would thus consist

of different 'perceptual tableaux without substantial substratum' (Piaget, 1947) which would trigger each other in the course of the infant's activity. The spaces would only come to co-ordinate with each other subsequently, depending on the construction of mobile and differentiated sensorimotor schemes. The existence of early co-ordinations, to which *we* accord the status of adaptive behaviour showing a certain level of elaboration of reality, gives by contrast an important empirical basis to the conception of a neonate characterised by a complex, co-ordinated sensorimotor organization.

Aronson and Rosenbloom's experiment, and the other experiments mentioned, could be interpreted in terms of the existence of very early audio-visual intersensory co-ordinations, as if hearing a sound implied the expectation of seeing an object. The research of Bower, Broughton and Moore, (1970a) on reaching for virtual objects by neonates could, in the same way, lend support to the presence of an intersensory sight-touch co-ordination. As far as the infant is concerned it is a matter of asking whether this bimodal specification belongs to an external object or whether it is determined by the functioning of the infant's sensory systems. In the first case the infant will be said to possess perceptual representations of the external objects from which he would then be partially differentiated. The experiments mentioned could thus be interpreted as evidence for perceptual anticipation: the detection of an auditory input would be sufficient for the infant to anticipate the presence of an object in his vicinity. With such a conception it becomes difficult, not to say impossible, to maintain simultaneously the idea of an initial unitary framework. Butterworth on the other hand opts for the second alternative. According to him, the different pieces of research prove the existence:

of an innate functional relationship between audition and vision that provides a unitary spatial framework in relation to which patterned information can be detected [but] this is not the same as an ability to anticipate visual consequences on auditory stimulation. (1981 p.54).

Even though we also do not think that the neonate possesses objectified perceptual representations of his universe, we would nonetheless like to modify Butterworth's point of view. We propose to describe the infant's aforementioned performances in terms of sensory anticipation. It is then possible to conceive of these performances as illustrating 'an ability to anticipate visual consequences on auditory stimulation'. This anticipation is determined and controlled by intersensory motor co-ordinations and not at all, as will

subsequently be the case, by an ability in the infant to make inferences. Inference necessarily presupposes a distinction between premise and conclusion, which is translated, in our example of audio-visual co-ordinations, by a subject-object differentiation. On the contrary, a visual anticipation (an expectancy of the visual system) may exist without the subject having in any way constructed a representation of the object as an object to be seen. One might nevertheless say that the organism 'carries out' an inference of this nature. Such a position leads us naturally to modify the notion of undifferentiation: one can only assert the existence of an initially undifferentiated state relative to the perceptual elaborations of reality that the infant subsequently carries out. It will also be said that the child of about two years lives simultaneously in a dualist position as regards his ability for perceptuo-motor experience of reality and in an adualist position as regards his new abilities (of a conceptual nature) for interaction with his environment. From our point of view, the notion of adualism is not pertinent when one considers the neonate in terms of its initial abilities for handling information, which we assume to be based on intersensorimotor co-ordinations. By contrast, it becomes pertinent as soon as the infant's new coding abilities, of a perceptuomotor nature, appear.

### *Early Imitation*

The theoretical propositions on which we have based our review of research on auditory-visual co-ordination suggests the existence of distinct levels of translation of reality by the new-born and by the baby of several months. At birth the baby would possess representations of a different kind than those constructed by the baby several months old. We will qualify the first group as 'sensory' and the second as 'perceptual' representations.

We must now ask about the nature of these initial representations. In particular, if representations of external objects exist, does it mean that the infant also possesses representations of his own body? Do such initial representations give rise to reconstructions? Research work on early imitation provides a substantial empirical basis for enquiring into the existence of initial representations.

Recently an important controversy has developed about the presence of imitative abilities in the neonate. Some writers (Maratos, 1973; Meltzoff, 1976; Meltzoff and Moore, 1977; Dunkeld, 1979), have argued in favour of the existence of imitation other writers (Lewis and Hurowitz' 1977; Hayes and Watson, 1979; Jacobson and Kagan, 1979) attempt to show that the phenomena observed can be explained by experimental artifacts of various kinds.

We shall try to centre this review around the following problems. Does the presence of early imitation necessarily imply representation of the self's body and that of others? More generally, does representation precede imitation? We have already seen which solution calls Piagetian theory into question. How do we account for these imitations if they exist? Do they spring from a reflex function or from an innate schema of recognition of the 'fixed action pattern' type, do they result from a social apprenticeship or from contingent reinforcements, or do they depend upon the child's cognitive development? Finally, we will have to enquire into the status of early imitation in the development of the child's imitative abilities and into the links between early and subsequent imitation.

Maratos (1973) carried out a longitudinal study of twelve infants aged one to six months, tested every fifteen days and centred her research around two hypotheses. The first concerns the genesis of imitative abilities. Maratos subscribes to the developmental model elaborated by Mounoud (1970, 1976) that postulates the existence of initial sensorimotor co-ordinations that are subsequently dissociated and reconstructed. In this view the infant of a few weeks would show imitative abilities, which would then temporarily disappear whilst the baby was developing. The second hypothesis concerns the status of the models the infant can imitate. According to Maratos, the only models imitated by the very young infant involve parts of the body with which he would have experimented during the intra-uterine and perinatal periods. She presented infants three types of model: visual, kinesthetic and auditory. At one month the only models imitated are tongue protrusions and mouth movements (visual models), and these imitations then disappear. In a general sense Maratos' hypotheses are confirmed by these results.

Meltzoff (1981, this volume Ch4) describes several experiments on early imitation, trying to introduce the necessary methodological controls (particularly regarding control of the 'arousal effect' and coding of the infant's behaviours). He studied immediate and deferred imitation (with or without a lapse of time between presentation of the model and occurrence of the response) and carried out an analysis which allowed differentiation between qualitatively distinct degrees of imitation. Models included tongue and lip protrusion, opening the mouth, and sequential movements of the fingers. Between two and three weeks the infants showed themselves capable of imitation, even when imitation was deferred. Meltzoff and Moore (1977) conclude 'infants have the ability to act on the basis of a centrally stored internal 'model' or representation of a perceptually absent gesture to-be-imitated'. What we find interesting

in this conclusion is that it associates the presence of representations with that of a memory trace.

Each of Dunkeld's (1979) pieces of research aims to test one of Piaget's (1946) hypotheses on the age-level at which various imitative abilities appear. It is not easy to compare Dunkeld's data with those already mentioned, because she groups infants of quite different ages (three and thirteen weeks for example). She presented a large variety of models and used criteria for judging imitative behaviour similar to Meltzoff and Moore's and she also demonstrated that three-week-old infants imitate tongue protrusions, though these behaviours subsequently undergo a regression (around eight to eleven weeks). From six to seven weeks, the infant imitates mouth opening movements (three weeks in Meltzoff), but imitation of finger movements is not apparent. Dunkeld discusses her data (regarding imitating and smiling) in relation to alternative theories (Piaget, Watson, Trevarthen, Bower) and offers the following explanation: 'Early imitation may be an epiphenomenon of social intercourse, but it may develop into a real vehicle of learning, through social reinforcement'. For Dunkeld therefore, the development of imitation would have no relationship with that of representation.

The controversy that has recently surrounded the question of early imitation places the debate essentially on a methodological level. Lewis (1979), Lewis and Hurowitz (1977) and Hayes and Watson (1979), have attempted to show that Meltzoff's methodological controls are inadequate. Lewis (1979) attempts to define the act of imitation and to specify the parameters pertinent to it (the degree of similarity of actions between the model and the subject, the temporal parameters, the nature of the actions to be imitated . . .). He insists, as do others, on the necessity for controls over arousal and the baseline response level. Lewis' and Hurowitz, and (1977) experiment, undertaken with infants aged one, three and six months, respected these controls. Whatever the age of the infants, they found that tongue-protrusion occurred whether the model was a tongue-protrusion or a movement of the fingers, or even some other model. It is surprising that these authors found no evidence for imitation between one and six months. This contradicts many other studies (including Piaget's own) and cannot be due to anything other than faults in experimental procedure.

The criticism of Meltzoff' and Moore's research put forward by Hayes and Watson (1979) concerns the use of the pacifier control in deferred imitation (see Meltzoff, 1981, this volume page 96). According to these writers, imitations were a 'function of the ex-

perimeter's unintentional monitoring of the infant's mouthing activities on a pacifier immediately before the response period, rather than of the model presented to the infant'. That is, Meltzoff was said to have presented the 'tongue protrusion' model immediately after he had unconsciously observed the infant make mouthing movements.

They suggested two situations in which tongue protrusions could be experimental artifacts. In the first, the experimenter withdraws the pacifier from the infant's mouth when the infant sucks on it with his tongue; in the second the experimenter takes out the pacifier when the infant shows no sucking or pushing activity. Naturally the number of tongue protrusions is shown to be significantly higher in the first situation than in the second. It must be stressed that this criticism, if it is acceptable, is only applicable to part of Meltzoff's researches and is not applicable to those of Maratos and Dunkeld. The interpretation of early imitation proposed by Watson (1966) is formulated in terms of contingent reinforcement. The child may detect a contingency between his action and the appreciative reinforcement behaviours of the mother (or of the experimenter).

Jacobson and Kagan's (1979) criticisms of Meltzoff' and Moore's work are more theoretical. They show that tongue protrusion responses can also be released by inanimate stimuli (a pen, a golf ball); they are not specific, selective imitations of the model. We refer the reader to the article by Meltzoff and Moore (1979) for their reply to these criticisms.

At first sight, demonstrations like these might cast doubt upon the scientific value of research showing neonatal imitation. But however convinced we are of the pertinence of arousal and baseline controls, the last two criticisms mentioned reveal a vital flaw. Unlike Maratos, Meltzoff or Dunkeld, these researchers seem to have carried out no qualitative analysis of responses. It seems evident to us that a tongue-protrusion imitation is qualitatively different from a spontaneous protrusion and the confusion of these two categories of response would be enough to explain the results of Hurowitz and Lewis, and of Hayes and Watson. In spite of these controversies, we think that research shows with consistency, the existence of early imitation, particularly with respect to the face. Only Meltzoff seems to have put forward evidence for imitation of finger movements.

These early imitations give rise to a double paradox. The first concerns the differentiated aspect of the infant's behaviours: how does one explain the infant's ability to differentiate tongue-protrusions from, for example, mouth-opening movements, when at the same time his imitative abilities seem limited to a few models? But

the existence of this paradox is not quite proven. None of the research mentioned has really investigated the neonate's imitative ability with parts of the body like the hands, the arms or the legs. In any case, several hypotheses could be advanced to explain the limitations discovered in the infant's imitative abilities. For example, different speeds of maturation of proximal and distal parts of the body could be responsible. Thus the neuron circuits leading to the proximal parts (like the mouth) could be mobilized more rapidly than those which end in the distal parts (such as the arms or legs). A second hypothesis concerns intrauterine experience (see, for example, Maratos). The infant may only be performing movements analogous to those already exercised so that various mouth movements could effectively give rise to more intense responses than those of the arms or hands.

The second paradox raises more interesting issues. It arises from putting together data on imitation with research on the discrimination of facial expressions. Gibson (1969) showed that the ability to discriminate facial expressions is limited in the infant and Spitz' (1952) findings also have a bearing upon this question. The mouth is only distinguished as a feature of the face quite late, around four to five months yet the infant appears able to discriminate at three weeks between a tongue protrusion and an opening of the mouth. We believe that to resolve this paradox, reference must be made to different, previously ordered levels of coding of reality. The three-week-old infant carries out a coding procedure of a qualitatively different type from that carried out by the infant of several months. We have called the first sensory and the second perceptual coding.

Various other attempts have been made to explain early imitation. Watson (1966), for example, introduces the notion of contingent reinforcement but we do not believe this can account for the isomorphism between the model's behaviours and those of the subject. How, by detecting a contingency, does the infant manage to match his movements to those of the model? What is more this cannot explain the decrease in imitative abilities observed by Maratos or Dunkeld.

Eiblsteldt (1979) proposes that imitation could be considered a fixed action pattern. The model would trigger a more or less stereotyped response in the infant. Several facts seem to us to run counter to this explanation including the temporary disappearance of certain imitation behaviours after birth (see also Meltzoff 1981 this volume Ch4).

Dunkeld rejects the notion of a link between the development of imitation and representation. If they evolve in parallel how does one

explain why the child first imitates the movements of non-visible parts of the body (tongue-protrusions) and then the movements of visible parts (hands), when, in the Piagetian theory, the 'representation' of visible parts of the body precedes that of non-visible parts? We feel that this question is wrongly formulated; it takes no account of different levels of understanding reality; early imitations are not directly comparable with later imitations. Piaget described the development of imitation during the sensorimotor period and omitted early imitations, just as in his description of the development of sensorimotor co-ordinations, he neglected initial co-ordinations.

We are more inclined towards the proposition of Trevarthen, Hubley and Sheeran (1975) or Meltzoff (1976) according to which the neonate would possess an innate body schema which would authorize matchings between parts of his own body and corresponding parts of others' bodies. Only the presence of a representation of the body of the self, which we have termed sensory, can explain early imitation. Thus we believe the presence of representation to be necessary in order for the child to be able to imitate, for otherwise it is impossible to account for the isomorphism which the subject introduces between his own movements and those of the model.

Imitation at birth and later imitation translates different levels of understanding reality. We therefore refuse to consider early imitation as pseudo-imitation (Piaget) or as pre-behaviours, unrelated to later behaviours. The link between these two types of imitation poses the problem of the relation between different levels of representation: are we to believe, for example, that perceptuomotor representations are built up from sensorimotor representations? Would there be an integration of the lower-level coding in the higher or a control of the first by the second? Or would the different types of coding which the child possesses co-exist with no relation to each other? Hauert (1978), discussing the relationship between conceptual and perceptual representation (or coding) defends the hypothesis that perceptual representations would be progressively modified by conceptual representations whilst the latter were being built up; however, transformed perceptual representations can still be evoked as such, under certain conditions.

### **Towards a Model of the Development of Representation**

The study of auditory-visual co-ordination and early imitation have shown (in our view), the necessity of the notion of representation to explain the sensorimotor period. Each of these behaviours undergoes a momentary disappearance to reappear later, around three to four months in the case of audio-visual co-ordination, and eight to nine



months for the imitation of tongue-protrusions. We have proposed that by introducing different levels of coding of reality (internal or external), these two sets of co-ordinations (the first present at birth, the second appearing later) can be accounted for. It is now a question of deciding on the later genesis of these initial intersensorimotor co-ordinations, that is to say on the development of representations established by the subject. The problem of the origin of representations can only be suitably posed within a global conception of behaviour considered as transactions between an organism and its surroundings. From this viewpoint, the development of grasping visually perceived objects is one of the best ways of illustrating stages in the construction of new representations.

### *General considerations*

The notion of representation has strict links with the notions of code and memory for which we gave very general definitions in the introduction. It can be considered from its two aspects. First, representation as internal organization of contents, or traces, or memory. Whether these are formed or in process of formation, they bring about mediations or interfaces between the subject's perceptions and actions. Second representation as a coding process, a translation operating between internal realities or between internal and external realities, by means of coding instruments. This latter approach enables full consideration to be taken of the transactions which occur between the subject and environment. It seems clear that any separation of these two aspects of representation must be partially arbitrary. A memory carries out a certain codification of experience; it is therefore not independent of the codes at the subject's disposal. On the contrary, it seems important to us to distinguish carefully between instruments of representation (or coding) and representations which are formed or in process of construction and which result from applying these instruments to various realities. As we have already seen, Piaget is only interested in the *development* of instruments of representation (figurative instruments) without distinguishing the development (if it does occur) from the results of applying these instruments. For our part, we postulate the preformation of coding instruments: at birth, around eighteen months, and towards nine to ten years the child acquires new coding abilities in a programmed manner. The results of applying these new abilities, or representations, gives rise to new development. Representations are constructed through transactions which take place between the subject and his environment.

The distinction established between the two aspects of represen-

tation acquires particular importance when the notion of representation is related to that of programmes of action. Whilst he is developing, the child constructs different programmes of action which govern the modalities of his transactions with the environment. We consider the programming of a behaviour to be directly related to the degree of elaboration of the properties of both organism and environment. Thus, one can study how the infant manages to adapt his actions to such physical properties of the object as for example its weight (Mounoud, 1973). The programme will be satisfactory when the infant has built up complete representations of the object concerned. The activity of coding, or sampling information, predominates the more these representations (as organizations of content) are still partial or incomplete. Conversely, it is reduced to an absolute minimum when complete, global representations are available.

In such a view, representations cannot be understood as static configurations of reality states. In fact, apart from their close connections with programmes of action, it would be more correct to talk of the building of a perceptuo-motor organization (integrating representations and programmes of action) during the sensorimotor period from an initial sensorimotor organization, than of the development of perceptual representations from initial sensory representations.

Representations are built up within programmes of action (or strategies). Already formed representations, which play a support role from which new meanings can be elaborated, intervene in the building up of new representations. The nature of the translations or codings of his environment or of his own body which the infant carries out, must also be taken into consideration when characterizing the construction of representations. We distinguish four types of code: sensory, perceptual, conceptual, and semiotic code; which correspond to four successive levels in this construction:

- (i) the sensory level, correlated with the perinatal period;
- (ii) the perceptual level, reached around eighteen months;
- (iii) the conceptual level; which gives rise to
- (iv) the semiotic level around nine to ten years.

During development the child reorganizes his transactions with the surrounding world several times; these upheavals mark phases or stages of development, just as they take place within a single stage. Each of these stages begins with a homogeneous organization of

behaviours which contains within it the programme for subsequent reorganizations (Mounoud, 1976).

Having made these general points, we can attempt to trace the manner in which representations develop during a given stage, in this case the sensorimotor stage.

*The initial organization of the infant's behaviour*

The infant's activity at birth is governed by a set of reflexes which will determine his reactions to stimuli which reach him. These reflexes are neither isolated nor heterogeneous but define an organized comprehensive structure, within which they appear differentiated and co-ordinated.

Audio-visual co-ordination and early imitations provide good examples of the complexity of the organization which connects the infant to his environment. At this level the problem of intentionality in the infant's behaviours does not arise, as we have already indicated. The infant is connected to the environment by an intersensorimotor organization internal or external which determines that certain actions follow certain stimuli. The organism is able to programme particular behaviours when particular configurations of stimuli present themselves. It reveals a completely anticipatory functioning; the behaviours could be described as triggered, or needing no active organization on the subject's part. With the example of audio-visual co-ordination we saw an illustration of the organism's anticipatory abilities; on hearing a sound the visual system expects and prepares itself to receive visual stimulation. The organism's abilities for control seem on the other hand to be minimal. At birth we can identify an elementary form of control which consists simply in registering the result of carrying out an action as a failure or success, an all-or-nothing classification. If the action has succeeded, it is not useful to initiate it again; if not, a new action is programmed. But the infant cannot make use of the information provided by carrying out a first action (by taking account of the transformation process or of the divergence (between the target and the effect achieved) in order to carry out the second. If, for example, he fails to take hold of an object, he will have no extra chances of success when he makes the second attempt. Thus, contrary to what is generally agreed in psychology, we consider that the neonate initially possesses a memory of evocation, built up by the repertory of his actions and of their consequences, and that this permits him to anticipate his behaviours, but that he does not have a recognition memory which would allow him to correct his behaviours on the basis of previously initiated behaviours. This could be expressed by saying that the

neonate functions like an open loop, with minimal retroaction.

The grasping behaviours of the neonate illustrate this description well. The findings of Bower (1970a, 1970b) show that, during the first days of life, the infant is capable of a very surprising type of prehension: he can stretch out his arm in the direction of a moving object, opening his hand while so doing, and in some instances closing it around the object. The infant's grasping behaviours show that account is taken of certain categories of information, relative to his situation (distance, orientation), to his actions (scope, speed . . .), and to the objects (speed). These dimensions are specified by the intersensorimotor organization with which the infant is equipped at birth, owing to formed sensory representations. It is these which establish the links between complex configurations of sensory messages (giving information on the distance, size, shape . . . of the object) and motor programmes (specifying the action with regard to direction, scope, speed . . .). They permit an explanation of how the infant can exhibit complex grasping movements triggered by visual information when these are not accompanied by visual control. Remarkable co-ordinations are thus present between visuo-motor, tactuo-motor and postural activities.

The complexity of initial co-ordinations is further borne out by the fact that they involve a set of parts of the body or a set of infant's postures. For example, following something visually does not merely involve moving the eyes and the head, but also necessitates finely orchestrated postural modifications of the trunk, arms and legs (Bullinger, 1981 this volume Ch7). One might say that at birth everything varies in relation to everything else. Development can be described as a progressive selection of certain initial sensorimotor liaisons.

The particular mode of transaction that exists between the infant and his environment is brought about by biunivocal linkages based on sensory translations of internal and external realities. If the neonate reacts well to visual, tactile stimulations etc., these still do not have meanings comparable to those built up by the infant of some months who will be able to refer them to perceptible external objects. The existence of initial intersensorimotor co-ordinations confirms that of representations of totalities, where a distinction between representations of the body of the self and representations of external objects is difficult, or even impossible, to establish. Initial representations are necessary to the functioning of early co-ordinations that indeed require the construction of mediations between perceptions and motor behaviours. We term these representations sensory, in order to distinguish them from others, of a different

type, established subsequently by the infant. As we have already stressed, these internal initial representations cannot be referred to a universe of objects. There is a strict correspondence between the internal status and transformations of the subject and the external status and transformations of the environment, but none of the neonate's internal states or transformations can be referred, attributed or connected by him to anything which might be an element of reality or a part of himself.

The sensorimotor dependencies or connections which the sensorimotor organization exhibits are not under the infant's active control. Development can be seen as the infant's progressively taking control of his behaviours. We distinguish different forms of control of behaviours in the course of the development of representations.

Initial representations are the result of phylogenesis (on this level, it would be possible to draw analogies with fixed action patterns) just as they arise from the infant's intrauterine experience. In our view, it is not admissible to describe the infant's initial behaviours as exhibiting knowledge in the strict sense. They only constitute one of the necessary conditions for the establishment of knowledge. Another necessary condition is provided by the human being's capacity for building new internal representations that can be referred to a universe of objects. New representations concern the respective states of the organism and of the environment as well as the transformations that allow the change from one state to another. We speak of knowledge in the strict sense when these representations are constructed. What status should be accorded then to the infant's initial behaviours? They show knowledge or meanings which are only experienced or actualized by the organism and constitute the matter and substance which form the basis for objectivization, for the developing awareness of reality and of the self (that is to say the construction of a new system of meanings).

The new born's acquisition of a new coding ability will permit new representations to be established. It will overturn the initial relationship in comparison with which he will find himself in an adualist position. Adualism arises from the infant's inability to pick out in an interaction that which arises from his own action, from that which arises from other physical or social objects. In our view, the construction of a distinction between the self and others (subject-object) is made possible by the infant's double coding of realities: sensory coding and perceptual coding. The problem of consciousness, and of the subject's intentionality will spring from the initial existence of an internal duality, which allows the progressive establishment of the subject-object duality.

*The construction of partial or multiple representations*

How will the system constituted by the infant and his environment be modified? By means of the perceptual code the infant will bring about a new sampling, a new analysis of sensory messages relative both to his actions and to objects. Whilst the meanings of these messages were initially determined by sensory representations, they will be progressively redefined by means of the perceptual code and give rise to perceptual representations. Certain initial sensorimotor connections will thus be re-established; they escape from the control of the initial sensorimotor organization which then appears dissociated.

Reaching behaviour undergoes a considerable change between the fourth and eighth weeks. The tactuo-motor and visuo-motor activities of the arm and hand become progressively dissociated. The phases of approach and seizure are now only partially co-ordinated. At birth the grasping reflex correlates synergic flexions of the elbow, wrist and fingers with tactile and proprioceptive information from the hand and arm (Twitchell, 1965, 1970). Some tactile information provided by the hand thus forms the subject of a new coding and gives birth to partial perceptual representation. These establish relationships between certain tactile information and the flexing movements of the fingers. During this stage we are thus witnessing the selection of this sensorimotor connection, and its re-establishment on the perceptual level. As for proprioceptive information, this is always coupled with synergic flexions of the wrist and elbow, just as the activities of the head and eyes are coupled with those of the arm and hand (tonic neck reflex). These sensorimotor connexions as a whole remain determined by the initial sensory representations. As the perceptual coding is applied to the sensorimotor information, sensory representations are thus rendered inoperative. Other tactile information is then coupled with other movements, with the help of perceptual representations in process of construction. Thus movements of opening and closing the hand, initially controlled by sensory representations, find themselves redefined by perceptual representations. The infant thus builds a representation of his hand as a reaching instrument.

The phase of approach to the object also undergoes a reorganization on the perceptual level and appears momentarily dissociated from the phase of capture. Between nine and twelve weeks, White, Castle and Held (1964) describe a 'swiping' response which consists in projecting the closed hand towards the visually perceived object. This response is later (around thirteen to sixteen weeks) changed to a 'raising' response, where the infant stretches his arm to the object by

a target controlled visually and tactually the nearer it gets. Among other things, each of these reactions shows how the infant manages to integrate the 'distance from the object' dimension into his new perceptual representation, in order to initiate his movement. Field (1976a, 1976b, 1977) has studied how infants progressively take distance from the object into consideration in their reaching behaviour. Visuo-motor activities, initially determined by sensory representations, will also undergo new coding. White, Castle and Held (1964) show how the change comes about from 'peripheral following', where information inputs trigger following movements only when they reach the periphery of the retina, to a so-called 'central following', where the peripheral and foveal parts of the retina are co-ordinated, which thus allows the visuo-motor subsystem to anticipate the successive positions of moving objects.

The infant thus builds up, principally during the first three months, partial perceptual representations both of his own body and of external objects. Some dimensions of internal and external reality are objectified by the infant, and he can then act on them in a controlled manner. We have termed this type of representation 'multiple representations' (Mounoud and Guyon-Vinter, 1979), in order to make clear that, from the infant's point of view, they do not refer to an object endowed simultaneously with a set of properties. In a way, understanding an object through one of its properties makes it a new object each time for the infant. For example, the object which the infant follows visually cannot seem to him the same as the one which he grasps.

As he has not built up representations of the whole (of himself or of the external world) the infant's anticipatory ability now proves itself restricted. He must attain control step by step and recognition memory is gradually established. At this stage we can say that the infant's functional world is of the 'respondent' type (Mayer, 1978). We should add that the sensorimotor connections which have still not undergone a re-establishment on the perceptual level, remain under the control of the sensorimotor organization. Thus, a state of partial co-ordination remains.

#### *The construction of total or unique representations*

During the second stage, ranging between three to four months and seven to eight months, representations previously broken up form new co-ordinations and give birth to global, 'total representations'.

For the infant, objects, like his actions, are singularized or individualized. In the same way, the infant can comprehend himself as one object among others. The identification of the object (or of

others) is only carried out when it appears with the whole of the properties the infant has been able to objectify. Any divergence from this rigid pattern breaks the identity. At this stage, representations are of the 'unique' type. Sensorimotor connections, objectified during the preceding stage, become once again co-ordinated with each other. At this level, perceptuo-motor organization, in constitution, has completely supplanted sensorimotor organization as the control-centre for the infant's behaviours. The child's behaviours simultaneously take into consideration the object's various properties (size, distance, weight . . .).'

At this stage, reaching behaviours are once again well defined with regard to the distance, direction, speed and size of the objects. The whole of the reaching behaviour (approach and capture) is carried out in a rapid and direct movement. The arm and hand are stretched in the object's direction without being visually controlled. Thus the trajectory has been anticipated, as has been the opening and closing of the hand. The movement is pre-programmed before it is carried out, whereas it was formally elaborated step by step, during the preceding stage. The advance organization of actions is made possible by the existence of these total representations which furnish *a priori*, relatively strict definitions of the properties of the object with which the infant is interacting. The infant's functioning corresponds to an 'operant' functioning, which can anticipate, but is rigid and adapts with great difficulty to variations in situations. At this level the child's behaviours always show limited possibilities for correction or control. These limitations are direct consequences of the nature of the perceptual representations available at this stage of development.

These representations are rigid and cannot be broken down or analysed. We might talk here of representation-stimulation. Indeed there is a one-for-one correspondence between the information acquired by the subject about his actions or about objects, and the representations built up about his actions or those objects. The object loses its identity if it is transformed, the action cannot be modified whilst it is being executed. The control present at this level consists in carrying out the action, then evaluating the difference between the state-of-affairs expected and the state-of-affairs achieved so that a correction can be introduced in the organization of the subsequent action.

#### *The construction of synthetic or typical representations*

The first two stages in the construction of representations mark the end of a first phase which brings about unique representations. This



first phase will be succeeded by a second phase during which these representations can be modulated or broken down. Between six to nine months and sixteen to eighteen months, the infant will construct representations which will allow his activity to be modulated or adapted as a function of the variations in the characteristics of the objects he encounters. The new coding of information received from objects or actions consists in establishing relationships between parts of the action or between parts of the action and situational variations, or between parts of the object, or between different objects. This phase can thus be described as a period of establishing the relational properties of the object and the action. The infant will be able to master the variation in an object's dimensions as well as the variations which obtain in the relations between it and other objects. In the Piagetian sense, the object becomes permanent: its momentary disappearance is attributed to the establishment of a new system of relations (spatial, temporal or causal) between the subject and the object. Representations which characterise this phase are called 'typical', that is to say, adaptable to a class of objects, situations or actions.

At the level of action, the infant will take into consideration the particular values of the dimensions of the object to which they apply. Such a functioning, called 'mixed', entails both a pre-programming of initial parameters of action, and an adaptation of these, by external control, to the current data of the situations. Corrections will be introduced in the course of executing the actions.

Many experimental findings bear witness to the reorganization of reaching behaviour around seven to eight months. We must first recall the important break which Halverson (1931) noticed between behaviours prior and subsequent to thirty-two weeks. For him, it is as if during a first stage, the hand was passively moved towards the objects, whereas from thirty-two weeks it is the movements of the hand which determine the complex articulations (finger movements and reaching) of the arm. Results obtained by McDonnel (1975) on the behaviour of reaching for objects visually perceived through prisms with infants aged from sixteen to forty-three weeks, also show a split on thirty weeks. From sixteen to thirty weeks, infants succeed in grasping the object in the same proportion of attempts, with or without a prism; on the other hand, between thirty and forty-three weeks, successes are proportionately more frequent without the prism.

Finally, mention should be made of work carried out by Wishart, Bower and Dunkeld (1978) on the comparative evolution of reaching for objects perceived either visually or auditorily in infants

aged seventeen to fifty-two weeks. For objects perceived auditorily, there is a marked improvement in performance from seventeen to twenty-two weeks, then a fall-off up to thirty-nine weeks, which then picks up again from forty-three to fifty-two weeks, without, however, achieving again the level of performance reached at twenty-two weeks. The evolution of these performances for visually perceived objects is the same in general terms, but much less marked. We consider that these results emphatically confirm the reconstruction which reaching behaviours undergo during the second half of the first year, and which is a consequence of the different stages in the establishment of perceptual representations.

### *Conclusion*

In the second section of this chapter we mentioned the possibility of establishing relationships between the concept of development and representation which we have put forward, and that of de Saussure regarding the constitution of a verbal sign. Initial sensorimotor connections bring about 'substances', the contents from which the system of perceptual meanings will be built. 'Unique' representations constitute 'images', translations of these initial connections in a new code. Finally, 'typical' representations provide a new system of meanings, called perceptual meanings. They result from the establishment of various relational systems (intra- and inter-object) issuing from 'unique' representations. But from our genetic perspective, we must modify this point of view: the initial substances can be seen as a system of meanings (sensory meanings), in the same way as the system of perceptual meanings provides the substances from which the system of conceptual meanings will be elaborated.

In this article we have tried to interpret sensorimotor development through the construction of internal representations (or memory) conceived of as structuring or organization of content. The appearance of new coding abilities makes the establishment of new representations possible. This is subject to a genetic regulation and it would thus depend very little upon particular interactions which take place between the child and his environment, unless interactions were meant in a very broad, non-specific sense. Formed representations are directly dependent on the experiments which the child has been able to carry out (specific role of the environment).

## Notes

1 These terms contrast contemporaneous or 'steady states' (synchronic) with changing or evolving (diachronic) processes in development (Editor's Note).

2 The French *signifiant/signifié* is sometimes translated by the words 'term/referent' or 'term/meaning' (Editor's Note).

3 See Note 2 above.

4 The phrase 'reading of experience' corresponds to the Piagetian expression *lecture de l'expérience*. This is a difficult concept to translate succinctly but it implies that the subject *necessarily* requires appropriate cognitive structures to understand reality. Properties of objects in and of themselves are insufficient to explain children's difficulties in comprehension. (Editor's Note).

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