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Sensorimotor Intelligence in Human and Non-human Primates

Characteristics of object manipulation are discussed for the sensorimotor intelligence of human and non-human primates. The generality of the concept of object permanence, as well as the complex level of spatial relations realized by non-human primates, requires a separation between these behaviors and social acquisitions like imitation and combinatorial play. The human specificity of complex object manipulation is recognized and assessed by comparing differences in functioning of the maturing brain of human infants with other primates. Other peculiarities of the human environment and training which act upon the social and cognitive development of the infant are also identified. It is hypothesized that these maturational characteristics play a major role in the emergence, stabilization and differentiation of the forms of object manipulations. This paper advocates that complex manipulative behaviors be considered in the assessment of similarities and differences between man and other primates.

1. Introduction

During the last decade, many studies were devoted to the investigation of linguistic capacities in apes, notable among which are Gardner & Gardner (1971), Premack (1976) and Rumbaugh (1977). Recently, new trends have developed which focus on some other human-like behaviors such as intentionality (Premack & Woodruff, 1978) and symbolic communication (Savage-Rumbaugh *et al.*, 1978). This paper complements these approaches and emphasizes the importance of object manipulation in the assessment of similarities and differences between man and other primates.

2. Object Permanence

The capacity to retrieve an object which has been hidden under a screen progresses through different developmental stages in human infants (Piaget, 1954, orig. publ. 1937) from birth to approximately 18 months of age. Object permanence is considered by Piaget to be one of the most important achievements of intelligence because the object is the invariant in many aspects of the infant's cognitive acquisitions, as, for example, in the organization of space, time and causality (e.g., means-end relations).

The test of object permanence also provides an important tool for comparative studies in non-human primates and has been widely used. The attainment of object permanence has, thus, been demonstrated both in apes and in monkeys (Mathieu *et al.*, 1976; Parker, 1977; Redshaw, 1978; Vaughter & Smotherman, 1972; Wise *et al.*, 1974; Wood *et al.*, 1980).

For the purposes of the present discussion, three remarks are in order. First, object permanence has not been described for primates exclusively, but also for cats and dogs (Gruber *et al.*, 1971; Triana & Pasnak, 1981) and, to some extent, for birds (Etienne, 1973). Second, the data which have been collected in non-human primates show that object permanence is acquired much earlier in these species than in human infants; for example, see Parker (1977) for data on macaques. Similarly, in a comparative study of human and gorilla infants, Redshaw (1978) found that the gorilla led the human by more

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than 14 weeks in retrieving an object completely covered by a screen. Third, it is important to stress that *in human infants, object permanence is contemporary with several other developments, namely, spatial and functional organization among objects.* These developments seem to be lacking in non-human primates. Redshaw (1978), for example, notes in her discussion, "There are two areas of behaviour in which the gorillas are deficient when compared with the humans. The first is that of constructive play; here the gorillas seem unwilling to combine objects in an organized way. Thus they fail on the use of a rake as an implement and in the tower-building task. This deficit also shows up in their slowness to replace objects in a container . . ." (p. 140). Such a lack of correspondence between the behavior of human infants and apes was stated many years ago by Kellog (1933), when he discussed the play behavior of Gua, a human-raised chimpanzee, when compared to that of his son, Donald: "Although the play of the chimpanzee was thus in many respects strikingly childlike, there was one aspect in which it differed significantly from that of Donald. This concerns the *exploration and manipulation* of new objects with which the subject may come in contact, or, if you will, with his curiosity over and tendency to examine things for their own sake" (pp. 132–133, italics from the author).

The relation between precocious locomotion and the capacity to locate an object is quite obvious; one can expect a subject that is able to move around will have to consider objective and spatial relations among objects. This is not to be expected for a human infant, who will remain in a more or less stable relation to the objects around him/her until approximately ten months of age. This issue of locomotion has become important in studying the infant's understanding of spatial relations for object permanence. Some recent papers have shown that the typical error of Stage IV (searching at a previous location A after displacement of the object from A to B) can be overcome when the child is passively moved around the locations of the hidden object (Bremner, 1978) or after an active movement of crawling or walking (Benson & Uzgiris, 1981).

While a young macaque may spend much of its time practising new locomotor patterns, the situation is somewhat different for the human infant who, for at least nine months, is in a state of helplessness with regard to mobility. During this period of dependency, the human baby will be exposed to many environmental stimuli of a social nature, including language. This period of perceptual learning enhances the practice of motor patterns, particularly those of the hands and mouth used in exploration of objects.

3. The Contexts of Object Manipulation

It is important to consider the various contexts of object manipulation in primates, particularly in apes and humans. Based on field observations, McGrew (1977) stated that young chimpanzees spend as much as 75 % of the observation time (368 hours) manipulating objects. Such a percentage may seem high when compared with other observations in which few cases of object manipulation are reported (i.e., Kummer, 1968, for baboons; Schaller, 1963, for gorillas). It is, therefore, of interest to examine the type of objects manipulated by chimpanzees. According to McGrew (1977), "the vast majority of objects in the physical environment which were manipulated comprised one category: 62 % of observation minutes included handling of living and flexible, but attached (*in situ*) vegetation. These included the trunks, branches, twigs, leaves, flowers, fruits, bark, etc." (p. 271). Among the few detachable objects which the chimpanzees manipulate are solid food (palms, nuts), leaves, sticks, stones and, occasionally, artificial objects (cloth, paper).

One can distinguish two main contexts of object use in non-human primates, the first of which is social and the second is in the realm of food-gathering and nest-building. The social context is represented by the use of objects in agonistic situations, in which there is intimidation of a conspecific, predator or intruder; see examples involving the use of stones by baboons (Hamilton *et al.*, 1975) or the use of branches by chimpanzees (van Lawick-Goodall, 1968). Another social situation involves the use of objects in social play. Some striking examples of this, such as "leaf grooming" or "running away with an object", are displayed by wild infant chimpanzees in order to gain attention from their mothers (Plooij, 1978).

The second context of object manipulation refers to feeding strategies. Some well known examples were reported by van Lawick-Goodall (1968) involving the use of twigs by chimpanzees to dip for ants or to "fish" for termites. It should be noted that this behavior is not peculiar to apes, since baboons also use sticks to extract hard-to-get food, such as bulbs (Beck, 1980; Oyen, 1979). The construction of sleeping platforms and shelters by apes also belongs to the second category.

Regarding the use of objects by humans, it should be noted that a general feature of objects used by man is that the majority are discrete and movable. Hence, they are susceptible to various combinations and arrangements. The human infant investigates objects in order to discover their properties (weight, texture, form). These elaborations can be very precocious in infants, as demonstrated by their ability to adapt their prehension to apparent changes in the weight of objects (Mounoud & Bower, 1974).

Objects also support the complex coordination of actions, including classification and one-to-one correspondence. This important process takes place in the cognitive development of infants by the end of the first year. Piaget (1953, orig. publ. 1936) has called this process the *tertiary* circular reaction, and defines it as the trial-and-error manipulation of objects in relation to other objects. According to Piaget, the *first* circular reaction concerns all behaviors related to the baby's own body (e.g., repeated thumb-sucking), whereas the *secondary* circular reaction describes the repetition of movements or actions in relation to the environment (e.g., shaking an object in order to repeat an interesting sound). Such tertiary reactions are almost systematic or experimental variations performed by the infant and are seen when he/she tries to vary the frequency, intensity and/or orientation of the behaviors directed to the objects. Among the many examples provided by Piaget is the repeated dropping of objects by the child while in a highchair, while watching the effects of varying their height, target and position. Another striking example is the repetitive placing and removing of objects in and out of containers. These latter behaviors become more and more complex and at approximately 18 months of age develop into other behaviors such as categorizing objects.

The progressive elaboration of internal relations among objects in the second year has been documented in detail for some types of object manipulation. For example, Forman (1975) described the developmental sequence of early manual actions leading to an equivalence between two objects in which $A = A^1$, but A is not A^1. A prefiguration of the equivalence concept can be found in the actions of children manipulating blocks by considering the symmetrical action of the two hands. "First, the child generally picks up one object with his right hand, transfers it to his left, and then searches for the equivalent object with his right hand. Upon grasping the second object, he bangs the two together at the midline (age $1\frac{1}{2}$ to 2 years old). Of thirty cases observed of the midline banging, twenty-nine involved two equivalent blocks (same form and size) even though many other

non-equivalent blocks were available. Equivalence was expressed by fitting A in one hand, A^1 in the other hand, and then alternatively touching and separating them at the midline" (Forman, 1975, p. 4).

From the few reports on primates (Antinucci *et al.*, 1980; Knobloch & Pasamanick, 1959; Parker, 1977; Redshaw, 1978), it appears that the species which have been studied (macaque and gorilla) do not manifest either the secondary or the tertiary circular reaction in the manner of human infants. Attempts to elicit in the macaque the secondary circular reaction by demonstrating the effects produced by different objects (e.g., mechanical toys) failed repeatedly. "The macaque would notice the result, but would never try to reproduce the schema that originally produces it. If one has in mind the typical human infant of stage III repeatedly manipulating such objects, one cannot avoid being struck by this difference" (Antinucci *et al.*, 1980, p. 14). Similarly, actions bringing two or more objects in contact with each other (such as hitting, stacking, etc.) never appeared in the macaque. As the macaque behavior appears to be far removed from that of the human infant, one may wonder whether the chimpanzee expresses these same differences. Few studies have dealt with this problem, although many reports have described the complex use of tools in obtaining an object (Chevalier-Skolnikoff, 1977; Koehler, 1927; van Lawick-Goodall, 1968). Even though some papers have mentioned the spontaneous manifestation of the "in" scheme (Parker & Gibson, 1979; Premack, 1976), to date there are no complete studies of manipulations of objects *per se* by the chimpanzee. We are presently conducting, in collaboration with S. Savage-Rumbaugh, a comparative study on the development of object manipulation in humans and two species of chimpanzee, *Pan troglodytes* (common chimpanzee) and *Pan paniscus* (pygmy chimpanzee), within the context of mother-infant communication.

4. Brain Maturation and Complex Object Manipulation

It is attractive to search for a neurological factor which would correlate with the infant behaviors described above. The features of the object-object relations which develop into differentiated and integrated forms through ontogeny imply a neural process which will change as the child develops.

The human brain has acquired approximately 40 % of its maturity at birth, compared with about 70 % for other primates (Limber, 1980), and its maturation period significantly exceeds the postnatal maturation of the chimpanzee. It is not unlikely that in humans, this long period of postnatal development and exposure to numerous influences from the social and physical environment play an important role in the progressive elaboration of behaviors related to object manipulation.

Recent concepts in developmental neurobiology concerning language acquisition (Walker, 1981) may also apply to object manipulation. While initially the wiring of the cortex is genetically determined, ultimately it is likely that many connections are modified by interactions with the environment in which the infant matures.

Summarizing the differences observed between the stumptail macaque and the human in terms of circular reactions, Gibson (1977) concluded, "The variable form of the repeated actions implies frontal association cortex functioning. The ability to focus on object-object interactions is based on the capacity to note simultaneous and sequential relationships between objects; these are parietal and temporal association area capacities. The

existence of the tertiary circular reaction in the human infant as compared to the macaque seems, therefore, to denote differential frontal, parietal, and temporal association area functioning in the infants of the two species" (p. 152).

5. Social Communication and Object Manipulation

Scarr-Salapatek (1976) argues that the sequence of development in the human infant during the sensorimotor period is basically the same as in related species and that the normal development of sensorimotor intelligence requires only the opportunity for exploration and learning without specific instruction from the parents or caretakers. Such a provocative model implies that human communication has only a slight effect on the development of the infant. This position might explain the reports of the relatively widespread manifestation of object permanence in primates. However, this view fails to account for the uniqueness of complex manipulations and other sensorimotor functions, such as imitation, in human infants.

Relevant to this discussion are the studies of Bates (1979) on the emergence of symbolization in infants between 9–13 months of age. Bates found that neither object permanence nor spatial relations are good predictors of communicative development. On the contrary, it is the more social sensorimotor functions (i.e., imitation, tool use, combinatorial play) that are good predictors of language, and the highest rate of correlation was between combinatorial play and language.

The distinction proposed by Bates (1979) between non-social and social sensorimotor measures is of heuristic value in the estimation of the cognitive behaviors of non-human primates. On one hand, this distinction minimizes the impact of object permanence, confirming the position that was presented here earlier. On the other hand, it permits an understanding of the elaborated knowledge of spatial relations demonstrated by animals (see, for example, the work of Menzel, 1973, on chimpanzee spatial organization and memory) without implying a strict parallel with human behavior.

Recognizing the importance of play and mastery of object-object relations leads to the emphasis of the role of action and its structure for the acquisition of language (Bates, 1977; Inhelder *et al.*, 1972; Sinclair, 1971). Bruner (1975) considered the structure of language and action to be isomorphic in the discussion of universal categories such as agent, action, object of action, recipient of action, etc.

The development of object manipulation, as well as language, emerges from the social and interactive context of communication between the mother and infant. Many examples of the intricacies of early mother-infant interactions are found in the recent literature. Mothers interacting with their babies at around five months of age (Trevarthen, 1979) incorporate toys in their attempts at play. Newson (1980) reported situations in which the mothers imitated the manipulations of their 8–10 month old infants. During interactions, mothers follow their infant's gaze at objects and, thereafter, establish concordant visual behavior, referred to as "deictic gaze" by Collis (1980). Moreover, the mother adapts to the infant's gaze, points to objects, and names the objects when they appear in the infant's visual field(Kaye, 1980).

Therefore, the behaviors of shaping, monitoring or imitating can be expected to be the main determinants of the infant's investment in the object, in the discovery of its properties, and in its conventional or logical uses.

Reconsidering the circular reaction, it can be speculated that its repetitive nature, stemming from what Piaget calls its "interesting effect", results from social reinforcement; parents, caregivers, etc., respond to the infant's behavior with objects. Thus, the social environment determines which objects, and their uses, are acceptable for manipulation.

The characteristics of human communicative behavior with its object-oriented dimension are, therefore, of crucial importance for the comparative perspective. Hinde (1971) pointed out that mothers of non-human primates do not seem to teach their infants. Clearly, this characteristic does not preclude the possibility of the infant learning from the mother, mostly through observation.

Thus, the very early social human interaction can be characterized by intense and mutual eye-to-eye contact, which quickly becomes focused on objects and is accompanied by imitation and language. It appears that the situation is rather different for other primates. For example, in chimpanzees, distal communication signals (such as glancing or visual exchanges) were rarely observed between mothers and their babies in the first three months of life (Plooij, 1980). It is assumed that the type of early mother-infant interaction strongly influences the infant's cognitive development. The fact that chimpanzee mothers do not seem to actively direct their babies' attention toward objects could, therefore, be a major factor in their lack of complex manipulations.

In conclusion, the present paper proposes that the entire range of human infant behaviors should be considered in cross-species comparisons of primates. The most widely used Piagetian task of object permanence covers only a part of all cognitive acquisitions realized by human infants. Moreover, the fact that the primates which have been tested show object permanence does not imply that its ecological and individual significance is the same in all species.

Human infant intelligence is characterized by a unique complex of object-related behaviors. This complex must be considered within the context of its social and neurobiological determinants in order to be useful in a comparative approach.

It is expected that an attempt such as the one outlined above will eventually provide a better definition of the uniqueness of the human species as well as that of non-human primates.

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