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Piagetian Stage 5 in Two Infant Chimpanzees (*Pan troglodytes*): The Development of Permanence of Objects and the Spatialization of Causality

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We investigated the level of cognitive development of two chimpanzee infants, both tested at 14 and 19 months of age, within the Piagetian framework of cognitive development. We administered tasks related to the understanding of object-concept—visible displacement tasks—and the operation of physical causality—the support problem—and observed responses similar to those of human infants. Both subjects reached stage 5 object-concept when they were 19 months of age: only at this time, in fact, were chimpanzees able to find the object wherever it was hidden. Stage 4 errors still characterized infants' performance when they were 14 months old. However, only one of the 19-month-old subjects was able to solve the support problem: she ignored the support when the goal object did not rest on it, showing that she understood the necessity of spatial contact between the target and the intermediary object. On the contrary, the other subject was not proficient in such a task because he drew the support even when the reward was placed beside it. At 19 months of age its level of causality still remained characteristic of the fourth stage.

KEY WORDS: *Pan troglodytes*; Piaget; cognitive development; object-concept; causality.

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INTRODUCTION

According to Piaget (1971), the most interesting aspect of stage 5 of human sensorimotor cognition is the gradual elaboration and objectification of reality in terms of spatiotemporal and causal structures.

In the domain of the object-concept, the developmental advances typical of this stage appear when a child is first capable of searching for vanished objects, taking into account the sequence of object displacements perceived in the visual field. Piaget believes that it is in this behavior pattern that the infant, for the first time, reveals a capacity to conceive of objects as independent and permanent entities, occupying a definite place in space. Such a capacity starts to appear during stage 4, when the infant is first capable of active search for hidden objects. However, the permanence is assumed to remain closely linked to the child's action. In fact, the occurrences of two well-known errors the infant makes while searching for vanished objects reveal the limits concerning stage 4 object-concept: typical reaction and residual reaction. Typical reaction is observable when an object, after having been hidden under a screen A and recovered, is subsequently hidden under a new screen B in full view of the subject. In such a case, the children keep searching for the object under screen A, that is, where their own action was previously successful. Residual reaction, which characterizes the end of stage 4, occurs in more complex situations, for example, when the object undergoes a series of successive displacements or when the initially correct action does not succeed immediately. Overcoming stage 4 errors marks the beginning of stage 5 object-concept.

With the development of the permanence of objects there is a corresponding advance in causality. At this stage, in fact, causality becomes objectified and spatialized since the child is able to recognize the existence of a system of causes that operate independently of its own activity, as well as the need for spatial contact between successive terms in a causal series. Piaget describes a number of meaningful examples that explain the gradual evolution of stage 5 competence. For example, in the behavior pattern of the support, the child gradually learns that the movement of the support influences that of an out-of-reach object but on the condition that the target object rests on it. Piaget showed that the use of the support could be manifested also during the previous stage, but the special relation "placed on" between objects, necessary for the causal connection to work, is not fully understood. In fact, a child will keep drawing the support, even if the object is placed beside it. Thus, causality still remains magicophenomenalistic. Conversely, during stage 5, the same attempts quickly generate an understanding of the contact condition: a child will not pull the support unless the target object is placed upon it.

In the developmental studies of nonhuman primate intelligence from a Piagetian perspective, object-concept has been one of the cognitive categories most extensively investigated. In particular, the achievement of stage 5 has been observed in monkeys (Vaugther *et al.*, 1972; Wise *et al.*, 1974; Mathieu *et al.*, 1976; Parker, 1977; Snyder *et al.*, 1978; Natale, 1989) and apes (Mathieu *et al.*, 1976; Redshaw, 1978; Wood *et al.*, 1980; Mathieu and Bergeron, 1981; Hallock and Woroby, 1984; Natale, 1989). In most of these studies, researchers used standard tests that were devised to investigate sensorimotor sequences in human babies (Uzgiris and Hunt, 1975) and were adapted to the nonhuman species. However, evaluating the accuracy of their results is often difficult because of the absence of any quantitative data on the subjects' behavior (Redshaw, 1978; Mathieu and Bergeron, 1981; Hallock and Woroby, 1984). No details are given of number of trials administered to the subjects and no reference is made to typical or residual reactions. A different problem arises in investigations (Mathieu *et al.*, 1976; Vaugther *et al.*, 1972) that employ formal testing procedures, in which a kind of displacement is repeated at high frequencies. In these cases, correct responses by the subjects can reflect a simple task-specific learning instead of the presence of stage 5 cognitive ability.

With regard to the domain of causality, few students of nonhuman primate cognition, based on the Piagetian paradigm, have investigated the understanding of elementary physical relations governing interactions between objects through the support problem. In a few cases in which this problem has been presented, successful performance has been reported in the species tested. Redshaw (1978) found that her gorilla infants showed the behavior pattern of the support typical of both stage 4 and stage 5. At about 24 weeks of age, her subjects manifested the first success in pulling the support to obtain an out-of-reach object, but only at 31 weeks could they resist pulling a support when the reward was suspended over it. Mathieu *et al.* (1980) simply report that two chimpanzee infants solved the support problems at 26 and 30 months of age, while one of their subjects was unable to solve the problem at 20 months. In both of these studies, results are focused more on performance than on understanding the problem. In fact, in the absence of quantitative data on type and number of trials administered and evaluation criteria, one cannot exclude that correct performance may be based on a "practical rule." Such a rule would develop if the relative positions of support and reward are fixed and very few in number and the trials are repeated many times.

We investigated the level of cognitive development attained by two chimpanzee infants, during their second year of life, in the domain of object concept and in that of causality. In this context, we examined the emergence of some behavioral patterns that the human infant displays at the beginning of the second year of life, which represent developmental advances of stage 5 cognition.

With regard to object concept development, we tested infant chimpanzees' ability to direct their search for hidden objects as a function of a series of visible displacements. This capacity provides evidence for understanding the spatial and objective permanence of the object as detached from the subjects' action.

In the domain of causality we tested the subjects' capacity to understand the condition of spatial contiguity in the use of a support as an intermediary in order to obtain an-out-of reach object through increasing levels of difficulty.

To evaluate whether and to what extent stage 5 competences in the two domains were present in our subjects, we employed a set of experimental tasks previously elaborated in our laboratory and already utilized in studies on nonhuman primate species on the same topics (Natale, 1989; Spinozzi and Potí, 1989). We designed these in order to minimize the development of learning responses, thereby eliminating the ambiguity inherent in the interpretation of results, which characterize previous studies.

OBJECT-CONCEPT

Method

Subjects

Our subjects are two chimpanzee infants (*Pan troglodytes*), a male Fuad (Fu; born February 15, 1989) and a female, Lianne (Li; born February 19, 1989), housed in the Chimpanzee Nursery of TNO Primate Center of Rijswijk. Both infants had been hand-reared since birth by human caretakers. We tested each subject individually at 14 and 19 months of age.

Procedure

The apparatus consisted of a wooden board (70 × 40 cm) and a set of three empty plastic blocks of different colors, open on one side. The side length of the blocks is 9 cm. We selected the blocks randomly for each session, and two or three of them, depending on the experimental conditions, were randomly selected for each trial, so that the same block could not occupy the same position in two successive trials. Rewards were

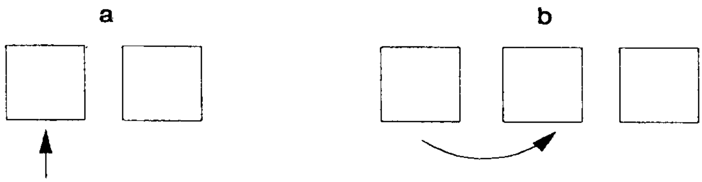

Fig. 1. Diagram of the two conditions used to test for object-concept: (a) between-trials displacements (BTD); (b) within-trials displacements (WTD).

Table I. Responses to the Between-Trials Displacement (BTD) Task by 14-Month Chimpanzees

Subject	Correct	Incorrect	TR[a]
Li-14	48*	9	6/19
Fu-14	42*	2	2/18

[a]Typical reaction. Values are proportions over the total number of possible occurrences.
*Binomial test, $p < .001$.

small pieces of biscuit or fruit. During each trial, we aligned blocks on the wooden board with the open side down.

We utilized two kinds of visible displacement: between-trials displacements (BTD) and within-trials displacements (WTD). Both conditions are diagrammed in Fig. 1. In BTD, we aligned two differently colored blocks on the wooden board. In full view of the subject, we placed a reward under a block and moved the board toward the cage so that the subject could easily reach the blocks and recover the reward. Then we withdrew the apparatus and hid the reward under the same or the other block.

In WTD, we used three differently colored blocks. We hid the reward under a block and them moved it under a second block before the subject was allowed to recover it. The direction of the displacement of the reward and the itinerary it followed in passing under the other blocks were varied systematically.

Two experimenters administered the tests; one manipulated the blocks and the other watched the animal to see if it was following all the steps of the procedure. Trials in which the animal did not pay attention to all the steps of the procedure were interrupted and discarded.

Table II. Responses to Block Shifts by 14-Month Chimpanzees

Subject	Correct	Typical reaction	Total
Li-14	13	6	19
Fu-14	16*	2	18

*Binomial tests, $p < .001$.

Table III. Responses to the Within-Trials Displacement (WTD) Task by Fu-14

Correct	Incorrect	Total
12	9	21

Results

In Table I, we report responses to the BTD task for each subject. At age 14 months both infants gave a significant majority of correct responses (binomial test, $p < .001$), showing that they were able to master the simple visible displacements. However, incorrect responses represented mostly typical reactions. This analysis was effected by considering all couples of consecutive trials in which the position of reward was changed and extracting all cases in which a typical reaction would be manifested. Block shifting performance is shown in Table II.

There were 19 shifts of reward positions across trials for Li-14; it uncovered the block where it had seen the reward being hidden 13 times, while it manifested a typical reaction 6 times. The difference between the two kinds of responses is not significant (one-tailed binomial test, $p = .08$). This result indicates that the active search for vanished object is still governed by some important limitations. In fact, when the reward, after being correctly recovered under the screen A, where it was hidden, was placed under screen B, this infant consistently failed to search for it. Although she had seen the reward disappear under B, she tried to find it in A.

In contrast, the performance of Fu-14 was overwhelmingly correct. Indeed, correct responses predominated over typical reactions ($p < .001$). This seems to suggest that chimpanzee Fu-14 had overcome the difficulties of the stage 4 object concept. To check for this possibility, the WTD task was administered to this subject only. The results are in Table III.

The infant failed to solve the task, with a number of correct responses at chance level. This reveals that when reward displacement to its hiding place becomes more complex, the infant fails to find it. This result could indicate that 14-month-old chimpanzees are still at a full stage 4 object-concept level.

At 19 months, responses to the WTD task were instead overwhelmingly correct (Table IV). Both subjects gave a significant majority of correct responses. Residual reactions were performed by one subject only (Li-19), but their frequencies are extremely low. Since both subjects searched only at the place where the object was last seen, we concluded these 19-month-old chimpanzees had attained stage 5.

CAUSALITY: THE SUPPORT PROBLEM

Method

Subjects

The subjects are Fuad and Lianne.

Procedure

The apparatus consists of a wooden board (70 × 40 cm) and one or two strips of cloth, according to the experimental situation, measuring 10 × 30 cm. When two strips were required, we placed them in parallel 15 cm apart on the wooden board. Rewards were small pieces of biscuit or fruit.

We employed three test situations of different levels of difficulty (Fig. 2). In test 1, we used a single strip and placed the reward in one of the following positions: (a) on the strip at its distal extremity; (b and c) on one of two outer edges of the strip or at its distal extremity. In test 2, we used two strips of the same color and placed the reward as follows: (d and

Table IV. Responses to the Within-Trials Displacement (WTD) Task by 19-Month Chimpanzees

Subject	Correct	Incorrect	RR[a]
Li-19	36*	5	2
Fu-19	25*	3	—

[a]Residual reaction.
*Binomial test, $p < .001$.

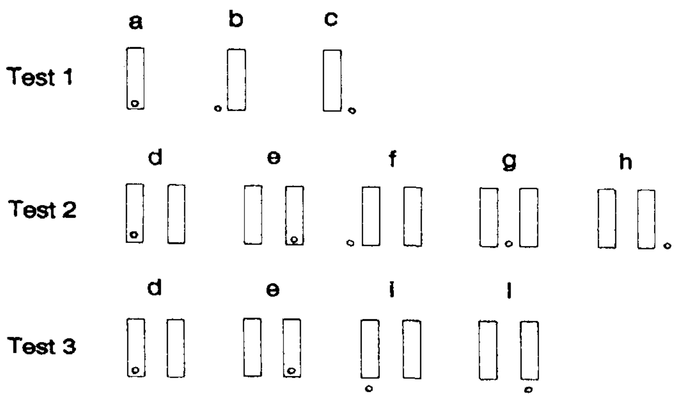

Fig. 2. Diagram of the "outside" and "inside" conditions presented in the support problem tests.

e) on one of the two strips; (f and h) on one of the outer edges of the two strips; or (g) between the two strips. In test 3, we modified the most crucial conditions, f and h, in order to create a situation that was perceptually different from the ones presented in the second test. In these cases, we placed the reward in front of one of the distal extremities of the strips.

We terminated a test session as soon as the subject showed signs of disinterest. Accordingly, the sessions did not have a constant number of trials for each subject.

Results

Table V is a summary of results from test 1 for each subject tested at 14 months. There is a clear difference between the infants. Li-14 did not discriminate between the condition in which the reward was on the support and the condition wherein the reward was outside it. In fact, she kept pulling the support in any condition. On the other hand, the performance of Fu-14 is significantly correct (Fisher exact probability test). However, it is conceivable that he had simply learned to respond appropriately to a specific position of the reward, without understanding the causal relations of spatial contiguity between the support and the reward. We administered test 2, in which we presented two supports and five different reward positions (Fig. 2), to test for such a possibility. The performance of Fu-14 is summarized in Table VI. The results are overwhelmingly negative: Fu-14 drew the support in each condition, as he was manifestly unable to recognize the necessity of spatial contact between the goal object and the intermediary. This evidence strongly suggests that a

Table V. Type and Number of Responses to the Inside (a) and the Outside (b+c) Conditions of Test 1 by 14-Month Chimpanzees

	Inside		Outside		
Subject	Pull	No pull	Pull	No pull	Total
Li-14	8	0	3	3	14
Fu-14*	9	0	3	6	18

*Fisher exact probability test, $p < .001$.

Table VI. Type and Number of Responses to the Inside (d+e) and the Outside (f+g+h) Conditions of Test 2 by Fu-14

Inside		Outside		
Pull	No pull	Pull	No pull	Total
7	0	4	0	11

practical strategy, based on task specific cues, guided the infant's responses in test 1.

We conclude that an efficacy-linked causality still characterizes the cognitive development of chimpanzees at 14 months

But at 19 months, both subjects showed a significantly correct performance in test 2 (Table VII). In order to exclude completely that the problem was being solved by simple discrimination learning, we administered test 3 to both subjects. Test 3 results show a substantial difference in their responses (Table VIII). The performance of Li-14 was completely disrupted by the successive modifications that we introduced into the task: her response pattern was, in fact, quite wrong. Therefore, the correct solution to the problem in test 2 was obtained by this animal by resorting to practical rules, based on specific positions of rewards. Fu-14's responses were still significantly correct. He immediately identified the new outside positions of the reward, which suggests that he understood the elementary physical relations—the spatial relations—governing interactions between the support and the reward.

It is the development of this capacity that characterizes the beginning of the spatialization of causality that typifies stage 5.

Table VII. Type and Number of Responses to the Inside (d+e) and the Outside (f+g+h) Conditions of Task 2 by 19-Month Chimpanzees

	Inside		Outside		
Subject	Pull	No pull	Pull	No pull	Total
Li-19*	30	0	9	21	60
Fu-19*	35	0	12	27	74

*Chi-square, $p < .001$.

Table VIII. Type and Number of Responses to the Inside (d+e) and the Outside (1+m) Conditions of Task 3 by 19-Month Chimpanzees

	Inside		Outside		
Subject	Pull	No pull	Pull	No pull	Total
Li-19	6	0	6	0	12
Fu-19*	12	0	3	9	24

*Fisher exact probability, $p < .005$.

DISCUSSION

The developmental sequences of object-concept and spatialized causality that we followed in the two chimpanzees from stage 4 to stage 5 are closely comparable to the steps of sensorimotor development in human infants.

With regard to the object-concept, our analysis of chimpanzees' responses to vanished objects in different locations shows that, at 14 months, their cognitive skills in this domain are still at a level of stage 4, as indexed by the stage 4 errors. But at 19 months both subjects developed an object-concept level that is typical of stage 5. Indeed, at this age they can find the object wherever it is perceived to be hidden, which indicates that they possess the cognitive competences that a human infant displays at the beginning of her or his second year and that constitute the initial acquisitions of stage 5.

With regard to the development of spatialized and objective causality, the way in which 14-month chimpanzees use a support as a tool is analogous to the behavior described by Piaget (1971) as instances of stage 4 competence. The incorrect responses of Li-14 in test 1 shows that she could not discriminate between the inside and the outside conditions. Fu-14 adopted an empirical strategy to obtain the reward, which was effective only in the simpler task version (test 1). His performance was disrupted by variations that we introduced in test 2. Thus, none of chimpanzees gave evidence of recognizing the relation of spatial contact between the support and the reward. On the other hand, the correct solution of the support problem appeared at 19 months only in Fu-19. In all testing conditions, he ignored the support when the goal did not rest on it and, thus, seemed to understand the elementary causal constraints that govern the operation of support. But Li-19 remained unable to solve the task. The fact that she could not transfer the discrimination performance promptly to a new situation (test 3) strongly suggests that her level of causality was still characteristic of stage 4.

The specific limitation of Li-19 in mastering the use of the support could reflect a slower maturational development in comparison to the other chimpanzee infants; she may evidence spatialization of causality when she is greater than 19 months. However, she appears not to be an exceptional case. Recall that Mathieu *et al.* (1980) found that their two chimpanzees, tested at 28 and 30 months, respectively, could solve the support problem, but one of them failed to do so when it was tested at 22 months. One might suppose that 19 months is the earliest age for emergence of understanding of this elementary problem in chimpanzees.

However, although the developmental sequences from stage 4 to stage 5 in domains of object-concept and causality are very similar in chimpanzees and human infants, at least with regard to the behavioral patterns that we considered, their developmental rates appear to be quite different—the onset age for stage 5 is approximately 19 months in chimpanzees and 11–12 months in humans. Thus, chimpanzees appear to be much slower than human children. Although our sample is limited to two infants, comparative data on cognitive ontogeny of chimpanzees confirm our findings.

Comparing sensorimotor development in great apes, Chevalier-Skolnikoff (1983) found that stages 5 and 6 are prolonged in chimpanzees, as they are in orangutans and gorillas. She observed unskilled stage 5 object-object coordinations in her subjects between 18 and 24 months, while she observed skilled tool use at 4 years only. Wood *et al.* (1980) found that 18-month-old chimpanzees showed stage 5 object-concept abilities, while 30-month-old chimpanzee performance was like that of 24-month-old human infants in tasks related to the invisible displacement of objects. Mathieu *et al.* (1980) demonstrated the attainment of representation in the causality domain with chimpanzees. However, they reported that it was delayed in 2-year-old human-reared chimpanzees.

In view of our results, it seems that a similar pattern of deceleration characterizes the cognitive development of the subjects tested. This pattern of deceleration seems to be the only variable that discriminates chimpanzees from humans, at least with regard to the cognitive capacities underlying the behaviors that we considered.

More than 60 years ago, Kohler (1976) documented that chimpanzees understand the basic conditions that underlie the operation of physical causality by confronting his subjects with various situations in which a desiderable goal was not directly available. Chimpanzees expressed a capacity for object-object spatial relations by immediately discovering and using a rope to obtain food that was linked to its distal extremity and out of reach. Analogously, they showed that they possessed this capacity when, using a stick as tool to rake in out-of-reach objects, they always tried to establish contact between the tool and the goal and when, utilizing a box to reach food that was suspended from the ceiling, they first pushed the it across the floor to a position directly under the incentive.

The correct use of a stick or box as an instrument also involves an understanding of other physical variables that govern interactions among objects to transmit mechanical and dynamic forces through physical contact. In human infants, the capacity for object-object force relations—a typical mark of stage 5 causality—develops between 13 and 16 months, when children succeed in using the stick as a tool or engage in other problem solving behavior. Contrarily, chimpanzees develop this capacity with a strong delay in comparison with humans: their ability to perform the stick test develops at about 3-4 years (Chevalier-Skolnikoff, 1983; Schiller, 1952, 1957; Beck, 1980).

It seems that, in the physical domain, although chimpanzees denote levels of understanding of causality mechanisms that are similar to those of children in stage 5, the development of some competences appears to be retarded strongly, perhaps indicating that a limit is being approached.

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