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THE ASSESSMENT OF COGNITIVE DEVELOPMENT IN HUMAN AND NON-HUMAN PRIMATES

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There is no standard scientific definition of cognition, and even a cursory consideration of the list of processes which one author or another has included in its meaning could easily fill this chapter. Flavell (1977) included cognition among those concepts whose meanings are multiple, ambiguous, imprecise, unstable, arguable, subject to reformulation, redefinition, etc. He noted further, "One is led to ask, what psychological processes can not be described as 'cognitive' in some nontrivial sense, or do not implicate 'cognition' to a significant degree?" (p. 2).

We retreat to the typical dictionary definition which associates cognition with knowledge and the process of knowing. We suggest that reasonable inferences can be made regarding what an animal 'knows' by observing its behavior. The least equivocable demonstrations of such "performance knowledge" are likely to be obtained in controlled laboratory environments, in general, and in learning experiments in particular. (For a useful discussion of "performance knowledge," see Bastian and Bermant 1973.) We do not, however, "beg the question" of whether a subject's demonstrated knowledge was learned during an experiment or prior to the experiment, or even whether it was learned at all. As Hayes and Nissen (1971) said regarding the demonstration of a subject's use of concepts, "We cannot imagine any set of operations applied to any subject, that could detect a concept without at the same time operating to induce its formation" (p. 79). The same might be said of a demonstration of performance knowledge or learning.

With the general purpose of this book and the topic of this chapter in mind, we have elected to emphasize the process of assessing cognition in human and nonhuman primates rather than to emphasize the existing empirical literature. We believe that, in general, the literature sheds little light on the use of nonhuman primates as models for human cognitive growth and development but that the potential for meaningful comparisons (and therefore, perhaps, for modeling) is there. We want to show some possibilities for such comparisons, meanwhile also summarizing some interesting and relevant empirical studies.

The most useful comparisons to date have been done in the context of Piaget's theory. We shall evaluate these data and the methods used to obtain them. While we believe that the Piagetian approach has much to offer, there are serious problems to be overcome in using it with nonhuman animals (its use with children has also been found by some to be fraught with difficulties; see Siegel and Brainerd 1978). In view of this, we shall also discuss the possible use of a 'hierarchy of learning abilities' approach which has not been so used but which might provide a basis for meaningful comparisons of cognitive development in human and nonhuman primates. A point to be remembered as we discuss both the Piagetian and the learning-hierarchy approaches is that both are sufficiently general to embrace the other. That is, virtually any assessment of cognitive development in the past, present, or future could be described in terms of either approach.

Two practices which will be followed here which should be made explicit are (1) hereafter, in the interest of brevity, the word "animals" will refer only to nonhuman animals, and (2) scientific names for species will be provided only when they appeared in the references cited; otherwise, the common name for the species provided in the reference will be used.

THE PIAGETIAN APPROACH

Jean Piaget (1896-1980) published his first paper (one involving naturalistic observations of an albino sparrow) at the age of 11, he published a series of papers on molluscs between the ages of 15 and 18, and he received his Doctor of Philosophy degree in natural science at age 21 (Ginsberg, Opper 1969). After this modest beginning, however, Piaget shifted his interest to the study of the origins of knowledge, a subject that he first approached by observing his own children. His early observations resulted in the publication of his first book in 1923. This was the first of many books and hundreds of articles in which his empirical data grew and his theoretical views evolved. Piaget's theory continued to evolve until his death. In 1970, he wrote, "As a matter of fact, 'Piaget's theory' is not completed at this date and the author of these pages has always considered himself to be one of the chief 'revisionists of Piaget'" (p. 703). Although many would characterize Piaget as a child psychologist (perhaps, the world's foremost), he viewed himself as being a genetic epistemologist. He was concerned with the biological origins of knowledge (e.g., Piaget 1971) and it is consistent with his views that such might be studied in both animals and humans.

However, the application of Piaget's theory and methods to animals has occurred only recently. Apparently, the first published study in this regard was that of Gruber, et al (1971) who investigated the development of the concept of object permanence in kittens. Independently and prior to the publication, Parker (1973) had begun to use Piaget's theory with nonhuman primates. Also apparently independently, Jolly (1972) wrote an influential book which included a chapter advocating the use of Piaget's theory as a framework for the study of the comparative development of cognition. In the 12 years since the Gruber et al article, a number of studies have appeared. After a brief consideration of some of the relevant aspects of Piaget's theory, we shall examine the animal-Piagetian literature.

An Overview of Piaget's Theory

The outline of Piaget's theory here was based primarily on Piaget (1970), Piaget and Inhelder (1969), and Phillips (1975). Piaget did not accept a "naive realist's" view of the world, that is, he did not believe that knowledge, such as the independent and permanent existence of objects, was 'out there' waiting to be acquired. For Piaget, knowledge was constructed by each subject (person or animal) as a result of its interactions with the environment. For example, knowledge of the independent and permanent existence of objects is not self-evident in the human infant. To the contrary, the infant behaves at first as though objects were an extension of itself or its actions; this theory will be illustrated below.

According to Piaget, cognitive development proceeds in four major periods. The first, which covers the time from birth to about 24 months of age, is the Sensorimotor Period. This period is further divided into six stages during which the development of several "schemes" occurs concurrently. Schemes is Piaget's term for repeatable and generalizable operational activities, that is, a kind of performance knowledge indicative of the child's developing notion of such concepts as space, time, causality, and object permanence. Much attention has been given to the study of the development of object permanence in animals.

The second period of cognitive development, the Preoperational Period, occurs in humans from ages 2 to 7 years. Whereas the Sensorimotor Period was relatively restricted to direct interactions with the environment, the Preoperational Period involves the use of symbols which represent the environment.

The third period is the Concrete Operational Period which occurs in humans from ages 7 to 11. According to Phillips (1975):

> Since birth, the dominant mental activities of the child have changed from overt actions (in the Sensorimotor Period) to perceptions (in the Preoperational Period) ....the Concrete Operational child conserves quantity and number, constructs the time and space that he will live with as an adult, and establishes foundations for the kind of thinking that is the identifying feature of the next and final period of his intellectual development, Formal Operations (p. 117).

Several studies (see below) using nonhuman primates have investigated concepts which develop during the Concrete Operations period.

The Formal Operations Period occurs in humans from ages 11 to 15. Whereas, during the Concrete Operations Period, the subject's intellectual operations were inextricably linked to objects and relations among objects, during the Formal Operations Period, the subject becomes capable of reasoning independently of objects. As evidence for Formal Operations, the subject might reason from purely hypothetical content or even, from content which it knows to be untrue. In short, the form of reasoning becomes independent of its content.

Finally, it is important to emphasize that the ages in humans associated with the four major periods of cognitive development are averages or approximations. Nevertheless, according to Piaget, the sequence of development is invariant. Individuals may take more or less time to progress through these periods, but they will progress in the same order.

<u>The sensorimotor period and object permanence</u>. The single, most-studied Piagetian concept in animals has been object permanence. This refers to the subject's ability to perform in a way which suggests that it knows that objects exist independently of itself or its actions. Object permanence is said to develop in six stages. In the later stages of its development, object permanence is assessed by some tasks which examine a subject's reactions to objects which are being moved about and hidden while the subject observes both the movements and the hiding.

For example, in stage 4, if the object is hidden in location A and then moved and hidden in location B, the subject, when permitted, will search for the object in location A. The interpretation of this is that the subject perceives the object as being continuous with as opposed to being independent of its past action of searching successfully for the object in location A. In stage 5, the subject will perform successfully the task failed at stage 4, but now it searches inappropriately if the object is hidden (e.g., covered with a cloth) while it is being moved from location to location, especially if more than two moves are involved (e.g., A to B to C, etc.). Again, the interpretation is that the out-of-sight object can not be followed, because it has lost its continuity with the subject's actions on it (i.e., looking at it while it is moved about); in short, the object is not yet perceived as having an independent, permanent existence. In stage 6, the subject succeeds in finding the object even with hidden moves, and the development of the concept of object permanence is said to be complete.

Assessment procedures used with both humans and animals are often closely related to Piaget's relatively informal procedures, although some investigators use standardized procedures such as those described by Uzgiris and Hunt (1975). Some investigators have criticized strongly the methods used to assess object permanence as well as the interpretations of the results obtained (e.g., Cornell 1978; Thomas 1982). Attention will be given to these criticisms later, but for now, the studies will be summarized noncritically.

Two studies have compared directly the development of object permanence in apes and humans. Redshaw (1978) compared gorilla and human infants on several scales of cognitive development including 14 tasks related to object permanence described by Uzgiris and Hunt (1975). The four gorilla infants were consistently ahead of two human infants, and the gorillas completed the 14th task at a mean age of 43.5 weeks versus the humans' mean of 54 weeks. Wood et al (1980) compared chimpanzee and human infants also using the Uzgiris and Hunt scales except that Wood et al. used a 15th task said to be "the definitive test for the concept of object permanence" (p. 4). Wood et al. used chimpanzees of ages 18 and 30 months and humans of 8, 18, and 24 months. The 18-months chimpanzee and human performed comparably and well but not as well as the oldest chimpanzee and human. The latter two performed equivalently through task 9, but the human performed slightly better on tasks 10-15.

Three additional studies have compared directly at least two species of nonhuman primates. However, these were not developmental studies in that the animals were nearly two years old or older when the studies were done. Mathieu et al (1976) used a chimpanzee (Pan troglodytes), a cebus monkey (Cebus capucinus), and a wooly monkey (Lagothrix flavicauda), and they used tasks indicative of stages 4-6 object permanence. The chimpanzee and cebus monkey were successful on all tasks, but the wooly monkey was only partially successful on the stage 5 task. Snyder et al (1978) compared a gibbon (Hylobates lar), a rhesus monkey (Macaca mulatta), and a cebus monkey (Cebus apella) on three object permanence tasks. All were said to show object permanence, and no differences among them were reported. Natale et al (1983) compared a 22 months old Japanese macaque and a 22 months old gorilla on a series of tests designed to assess the use of representational capacities for object permanence at stage 6. The gorilla was said to show stage 6 object permanence, but the macaque was not. The authors mentioned that earlier data had shown stage 5 in the macaque.

Among single-species studies of object permanence in nonhuman primates, Wise et al (1974) reported that of two rhesus monkeys, one showed the fully developed concept at 92 days of age and the other by 103 days. Parker's (1977) stumptail macaque had succeeded on tests of object permanence through stage 5 at the time of its accidental death at 174 days old. Vaughter et al (1972) studied squirrel monkeys ("Saimiri sciurea") of ages 6, 9, and 12 months together with the latter's mother whose age was not specified. Only the 6-months-old monkey failed the tests of object permanence. Vaughter et al also made the interesting observation that the use of the Wisconsin General Test Apparatus, perhaps the most used apparatus in nonhuman primate learning-cognitive research, assumes the fully developed object concept. Accepting this viewpoint would add a number of species to the list of nonhuman primates for which object permanence has been demonstrated.

Object permanence has also been studied in a number of nonprimate animals. Gruber et al (1971) concluded that "alley cats" do not progress beyond stage 4 and that they attain this by 6 to 7 months. However, Triana and Pasnak (1981) used food as objects and concluded that cats do attain a fully developed concept of object permanence when they are appropriately motivated. Triana and Pasnak also demonstrated object permanence in dogs. Thinus-Blanc and Scardigli (1981) reported evidence to suggest that golden hamsters are capable of stage 4 object permanence. Finally, Etienne (1973; 1976/1977) provided an interesting analysis of object permanence largely based on extrapolations from natural behaviors such as predation and other forms of food-foraging. Additionally, Etienne conducted some laboratory studies with birds. It was suggested that animals vary in the degree of development of the concept of objects and that the fully developed concept may be particularly human.

Before turning to some criticisms of the assessment of object permanence, it is appropriate to reiterate that several investigators have also studied other concepts which are said to develop during the Sensorimotor Period (see especially, Mathieu 1982; Mathieu et al 1980; Parker 1977; Parker, Gibson 1977; Parker, Gibson 1979; Redshaw 1978). Other investigators have considered other developmental processes (social development, pre-language-language development) from the standpoint of the Sensorimotor Period of intellectual development (Chevalier-Skolnikoff 1976; Chevalier-Skolnikoff 1977; Chevalier-Skolnikoff 1981). Finally, for an alternative review of the Sensorimotor Period in human and nonhuman primates, one with a different emphasis, see Vauclair (1982).

Criticisms of the assessment of object permanence. First, as one of us noted earlier (Thomas, 1982) somewhat whimsically but seriously too, object permanence is a philosophical choice which is inseparable from a belief in materialism and, such, is not a matter for empirical demonstration and verification. Most humans believe in a materialistic world (presumably, most assume a materialistic view or choose it naively, but some choose it deliberately). But it is reasonable to question whether animals are capable of knowing the choice, much less making it. We might ponder this issue forever without resolution, so we proceed, as all scientists must, based on the assumption that animals are materialists, that objects are real and independent of their perceivers, and that we can infer from behavior what an animal knows and believes about objects.

Turning to more mundane criticisms of object permanence, Cornell (1978) has recently presented some of the arguments and reviewed some of the evidence which suggests that ineffective search strategies may account for the errors seen in object permanence tasks, rather than that the errors reflect the subject's lack of the concept of object permanence. We will leave most of the details of Cornell's arguments for the reader to pursue in the original account, but among the variables he discussed which might affect a subject's search strategies were the response requirements of the task, attention deficits, memory deficits, and prior reinforcement histories. Related to the latter, Cornell cited the following example which shows that subjects may have extensive histories which suggest the nonpermanence of objects.

> The infant is seated across a table from an adult. The adult has a variety of colorful, odoriferous, multishaped objects of different textures and sizes arranged on a plate. The adult proceeds to pick up some objects and place them in a cavity. The opening of the cavity is then closed and, when reopened, the objects have disappeared. The procedure is repeated until the plate is cleared, and the procedure may be repeated two or three times a day. It seems obvious that the infant is exposed to many such situations in which, in fact, objects are not permanent (1978, pp. 8-9).

An extension of this example which has additional implications for the effect of reinforcement histories on search strategies in the object permanence task involves refilling the child's plate (or the monkey's food bin) with similar appearing objects (e.g., peas, monkey chow biscuits). For the naive animal or infant, this may be a history with objects that seem to appear, disappear, and reappear in the same location. Hiding games such as "Peek-a-boo" or "Where is (ducky)?" add to a child's history with objects which appear, disappear, and reappear in the same location. Additionally with respect to reinforcement history, the object permanence test itself provides the subject with a history of finding objects in location A, before it is expected to search successfully in location B.

Such examples suggest that it should not be too surprising that an inexperienced subject who performs in an object permanence test might search inappropriately at first, and such inappropriate searching may not be related to the subject's having or not having the concept of object permanence. Based on arguments such as these and based on experimental data which he and others have reported, Cornell (1978) suggested:

> the more parsimonious interpretation is that experience results in the coordination of abilities to the contingencies of search, not that, during the course of development the infant comes to differentiate the existence and location of the object and his own previous actions (p. 9).

Turning to another view of the object permanence testing situation, assume that a subject performs appropriately in terms of the usually accepted evidence for the concept of object permanence but that it does not have the concept. How might this be? There are a number of reliable cues for appropriate 'looking behavior' (to be contrasted with 'searching behavior'). The subject might respond to (a) the last location of the hand which moved the object or which moved the material which hid the object during invisible displacement tests, (b) the cover itself, or (c) the endpoint of the movement sequence itself. In this sense, hand, cover, and endpoint-of-movement are confounding cues which may fortuitously guide a subject's looking behavior to a hidden object. Additionally, the number and locations of the hiding places in the typical object permanence test are few and relatively fixed, respectively. Czerny's (1977) study of object permanence in Java monkeys (Macaca fascicularis) suggested their considerable dependence on location per se; successful performances were significantly disrupted by changing the location of the hidden object a mere one inch from its previous location.

In some animal studies, odoriferous objects (food) have been used. Odor as a possible confounding cue has been acknowledged in some cases (but not all), and efforts have been made to control against odor as a cue (see Triana and Pasnak 1981, for a good example). However, despite the acknowledgement of odor as a confounding cue, the other confounding cues discussed here apparently have not been recognized as such. Until the role of these cues has been assessed and, if possible, controlled, the evidence for object permanence will be ambiguous. Theoretically, such cues are troublesome, because they maintain continuity between the subject and the object and, thereby, obscure the necessary evidence for separation of subject and object (see Piaget 1970, p. 704).

Most of the studies, especially those using animals, have used multiple trials, but few have considered this variable in terms of the successful demonstration of object permanence. Such repeated trials should provide subjects with ample opportunities to overcome their ineffective search strategies, if that be the preferred interpretation, and learn to use all the available cues to the object's location. The study of Mathieu et al (1976) is a noteworthy exception in that they discussed the possible effect of repeated trials, an effect which they discounted as far as interpreting their data in favor of the concept of object permanence. However, it should be noted that they provided extensive pretraining on several of the principal components of the task. Harlow (1959) said something relevant here. "If it is assumed that learning is the elimination of all EF's (error factors) operating within a particular problem, it should be possible for animals to learn problems partially by eliminating individual EF's before formal training in the test situation begins (p. 524)."

Natale et al questioned whether several of the studies of object permanence using animals had demonstrated stage 6. Natale et al. noted that most of the studies had not provided evidence to support the use of a representational solution, evidence which they deemed to be necessary for a demonstration of object permanence. Natale et al. compared a gorilla (Gorilla gorilla) and a Japanese macaque (Macaca fuscata) both

22 months old, on a task in which a food reward was hidden under a small block. The small block was then placed under a large block, A. The small block was then moved past large block B to be placed under large block C in a way which surreptitiously left the reward under block A. When allowed, both animals looked appropriately under the small block. The gorilla reliably looked next under block A, but the macaque tended to look under the physically nearer block B, although it had not been involved in the transfer. Natale et al. concluded that the macaque had used a nonrepresentational strategy and had not shown evidence for stage 6 object permanence.

The concrete operational period. First, for the reader who may wonder what happened to the "preoperational period," there are too few nonhuman primate data to permit a proper evaluation. Mathieu (1982) addressed some of the development related to the preoperational period, but her summary account precludes a critical examination. However, several of the concepts which develop during the concrete operational period have been examined in nonhuman primates and it will be useful to consider those. We will begin with the concept of conservation which has been the subject of at least five investigations.

Conservation refers to the subject's realization that certain properties of a system (e.g., length, volume) remain invariant in spite of transformations performed within the system (e.g., changing the shape but not the volume). Of the five animal studies related to conservation, we won't dwell on Czerny and Thomas (1975) or Pasnak (1979) as both dealt explicitly with prerequisities to conservation. We will consider the studies of Muncer, 1983, Thomas and Peay (1976), and Woodruff et al (1978), as they were concerned with conservation per se.

First, it is essential to our analysis to describe the typical conservation task procedure and note some of its critical features. Typically, two quantitatively and perceptually equivalent entities are shown to the subject, for example, two identical jars which contain identical amounts of liquid. Then, while the subject observes, a transformation is performed such that the quantities of liquid are no longer perceptually equivalent but they remain quantitatively equivalent; for example, the liquid from one of the jars is poured into a third jar which differs in size and shape from the first pair of jars. The subject's task is to judge whether the two quantities of liquid following the transformation procedure are equivalent.

The nonconserving subject usually makes errors in judgment owing to having been misled by cues such as the differing heights of liquids following transformation. On the other hand, the subject who judges the post-transformational equivalence correctly may not do so on the basis of the concept of conservation. For example, the subject might merely be a good perceptual "estimator" (see Gelman 1972) of quantitative equivalence even when the entities are not perceptually equivalent.

A conserver should be able to acknowledge the relationship between the pre- and post-transformational states and/or acknowledge the noneffect of the transformation on the quantities. With humans, verbal explanations can be used to clarify the basis for a judgment. However, appropriate explanations require subleties of language which, to the best of our knowledge, have not even been attempted in any of the well known chimpanzee-language projects (e.g., explanations which acknowledge the reversibility between the pre- and post-transformational states of the liquids, compensatory explanations such as the fluid is now shorter but it is wider, or explanations which acknowledge that it is actually the same fluid following transformation as opposed to its merely appearing to be the same).

Thomas and Peay (1976) used a length conservation task as illustrated in Figure 1. The top row shows a typical conservation trial. The bottom three rows show types of control trials. The arrows signify transformations or faked transformation (see next paragraph) of the pre- (left side) and post-transformational (right side) displays. Consider the top row first. The monkeys had been pretrained to respond to a covered food well to the right of the stimulus display if the stimuli were judged to be the "same" and to respond to a similar food well to the left of the display if they were judged to be "different."

As one control procedure, it was necessary to provide and require the alternative of responding "different," so trials as illustrated in the bottom row were given. To insure that the monkeys attended to both the pre- and post-transformational displays, it was necessary to include the possibility of an actual change from the initial display, so procedures represented in rows 2 and 3 were followed. Row 2 shows a pre-

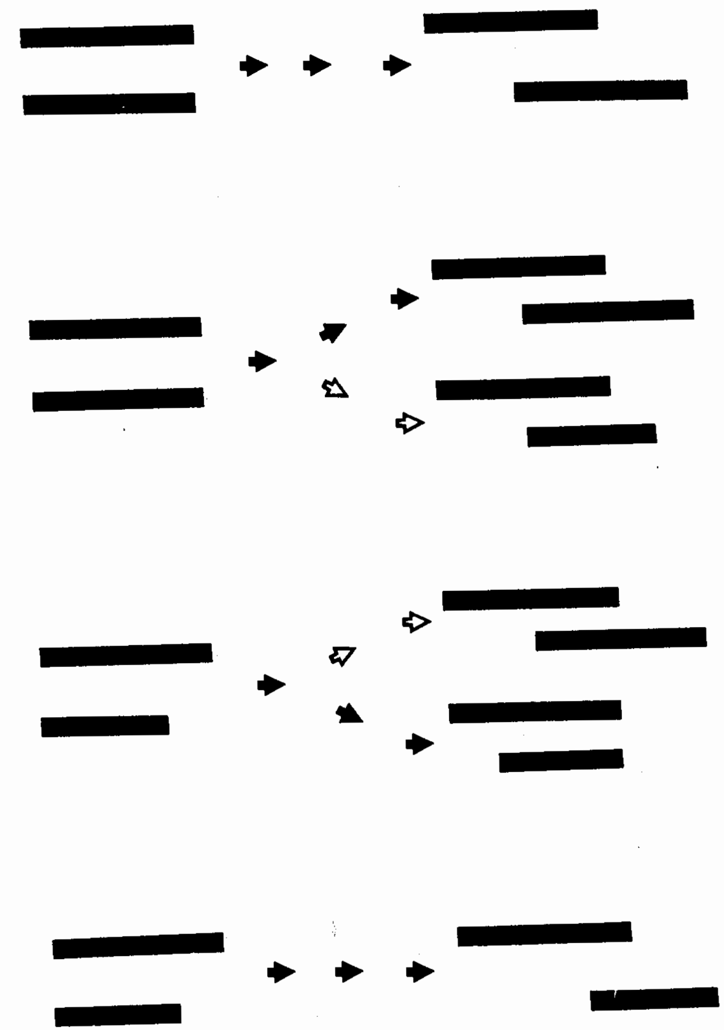

Fig. 1. Illustrative trials in the length conservation task. The top row shows a standard trial and the bottom three rows show control trials (see text for further explication).

transformational "same" display in which the transformation involved an actual switch to a "different" display (the open arrows) or a faked switch (solid arrows) in which the post-transformational display still required a "same" judgment. Row 3 shows a switch from "different" to "same" (open arrows) or a faked switch (solid arrows). The faked switches were necessary to prevent the monkeys from cueing on the object-in-hand or from cueing on the hand action involved in the actual switches.

Following extensive pretraining and stepwise training, two of four monkeys met stringent criteria in a mean of 540 trials on the last stage of training in which all types of trial shown in Figure 1 were presented concurrently in random order. Both showed immediate generalization to a new set of stimuli. Despite the thoroughness of the design, Thomas and Peay (1976) acknowledged that they had no way to be certain that the monkeys had attended to and used the information from the transformation. Thus, it was conceivable that the monkeys had performed successfully by being good estimators of quantitative equivalence despite perceptual nonequivalence rather than that they were necessarily conservers of length.

Woodruff et al (1978) studied liquid and solid conservation using Premack's now famous chimpanzee, Sarah. The procedures and results were similar, so we will confine our discussion to the procedures and results based on liquid quantity. They began with a "Pretest" which consisted of having Sarah make "same" or "different" judgments of liquid in two identical jars; that is, the liquid was of equal heights on the "same" trials and of unequal heights on the "different" trials. She performed significantly better than chance on the pretest indicating that she was a good judge of same and different amounts of liquids when they appeared in identical jars.

The pretest was followed by "Conservation test A" which began with pretransformation trials of either equal or unequal amounts of liquid in two identical jars. The transformation involved pouring the contents from one of the jars into a third jar which differed in size from the first two jars. Sarah's responses were limited to the post-transformational display, and she performed significantly better than chance on both "same" correct and "different" correct trials. To this point, however, there is no compelling reason to argue that the information which might be derived from the transformation process was essential to her performance, that is, she might merely be a good perceptual estimator.

However, Conservation test A was followed by a "Control test" which consisted only of the post-transformation trials of Conservation test A. Her performance on the control test did not differ from chance which indicates that Sarah was not a good perceptual estimator. The difference between Sarah's performance on the post-transformational trials on the control test vs. her performance on Conservation test A was interpreted by Woodruff et al. as evidence that Sarah had taken the transformation into account. We submit that it is favorable circumstantial evidence, but there is an alternative interpretation. It is possible that Sarah's success on Conservation test A was based on her recall of and response to the pre-transformational state of the liquids which she had seen only a few seconds before. Further, it may be recalled that prior to Conservation test A, she had completed a series of trials on the Pretest which were precisely comparable to the pre-transformational trials on Conservation test A. It is conceivable that Sarah considered the transformation to be irrelevant to what she was being asked to judge.

However, it must be noted that Woodruff et al. also conducted a "Conservation test B" which involved initial displays of perceptually and quantitatively equivalent liquids followed by standard transformations on half the trials and by transformations on the other half of the trials which included the overt addition or subtraction of liquids. Sarah performed well on this test which showed that she could discriminate "a relevant from an irrelevant transformation (p. 993)". Interestingly, to Woodruff et al "irrelevant" here refers, presumably, to the standard transformations; this was our point at the end of the preceding paragraph, although, admittedly, we believe that Woodruff and Premack intended a different meaning for "irrelevant."

The results of Conservation test B may strengthen the aforementioned circumstantial evidence that Sarah attended to the transformations, but these results do not preclude the alternative interpretation, since this test was conducted after the others had been completed. Further, speaking strictly, the evidence from Conservation test B only shows that Sarah attended to the transformations on those trials in which liquid was overtly added to or subtracted from the original quantities; the evidence is not conclusive that she attended to the standard transformations.

There are other points which trouble us about Woodruff et als ' study, especially in terms of its replicability. Sarah already knew the concepts of "same" and "different," and, significantly perhaps, these had been acquired without prior experience with sameness-difference judgments of quantity. Had it been necessary to train her on sameness-difference in the context of the experiment, it might have biased her towards being a good perceptual "estimator." As it was, her prior history of making qualitative same-difference judgments, which presumably involved perceptual similarities and differences, may have biased her against making "same" judgments to equivalent quantities when they were perceptually unequivalent. Regardless of her prior history it may have been fortuitous, in terms of the Control test, that she was not a good perceptual "estimator."

Sarah was able to perform 24 trials in succession with no reinforcement other than the phrase, "That's good, Sarah" which was spoken whether or not she performed correctly. The experimenters took care to avoid social cues by leaving the room while Sarah responded. Were they able to disguise and avoid the feedback of expressing any pleasure or disappointment they might have felt about her performance when they said "That's good, Sarah"? Despite these possible objections, one must not lose sight of the cleverness of Woodruff et als.' study. They should be encouraged to continue to study conservation and to seek the means to get Sarah to explain her judgments in terms of reversibility, compensation, and identity. If she can do that, we will be the first to say, "That's good, Sarah!"

Muncer (1983) reported a study using chimpanzees which assessed "overconservation;" that is, instead of transforming equal quantities, Muncer transformed unequal quantities. The main reason for this was to minimize the role of task-related training. Muncer used, as the substances to be transformed, blackcurrant syrup for volume judgements and M&M candies for number judgements. The chimpanzees were allowed to consume their choices, and it was presumed and confirmed that they would choose the larger quantity when they could distinguish it. Regarding the volume study, Muncer acknowledged that his successful chimpanzee might have "succeeded on the conservation trials by not attending to the transformation but attending only to the initial comparison" (p. 5; note that this is one of the criticisms raised earlier about the Woodruff et al study). This possibility was deemed to have been eliminated

in the number study, although Muncer acknowledged some other possible difficulties with that study. As he noted, Piaget has objected explicitly to the use of inequalities to assess conservation. Further, even if one overlooked Piaget's objection, overconservation with its "more" and "less" judgements may be easier conceptually than tests which require evidence for the conservation of equality.

To Muncer's admitted caveats, we add the following. Of his seven tests regarding number overconservation, two involved no transformations. The chance performance on one of these, which involved a row of 7 M&M's and a shorter row of 9 M&M's, was most critical to the evidence that the animal needed the information associated with transformation to perform successfully. The other nontransformation test involved a row of 7 M&M's in one-to-one correspondence with a row of nine M&M's, except for the last two M&M's in the 9 row. The five tests involving transformations included various combinations of adding or subtracting M&M's and lengthening or shortening the rows, but always ending with 7 versus 9 M&M's. Muncer's preferred interpretation is that the information associated with transformation was essential to the chimpanzee's successful choices of the rows with more M&M's. However, it seems possible and not unreasonable that the chimpanzee might have been more attentive per se as opposed to using the information associated with the transformation on the trials where transformations occurred. Success on the nontransformation test with one-to-one correspondence of 7 M&M's in one row and 7 of the 9 M&M's in the second row might be viewed as a 'perceptual given' with respect to which row had the most, while failure on the other nontransformation test might be due to general inattention. We suggest that definitive evidence for conservation must be supported by evidence for the subject's knowledge of the reversibility of the pre- and post-transformational states, compensatory mechanisms, etc. This, in turn, will require methods of communication which have yet to be demonstrated in chimpanzees or other animals.

For our last consideration of cognitive assessment in terms of Piaget's theory, we will examine three studies involving transitivity. Transitivity, or transitive inference, is assessed by tests in which one learns, for example, that A>B and B>C and then responds in a way which shows that one also knows that A>C. Piaget included such measures in his assessments of cognitive development. At least three studies have been done with nonhuman primates on transitivity, although none were developmental studies and none were reported in terms of Piaget's theory.

Menzel (1969) conducted a study using chimpanzees where A,B, and C were large, medium and small disks of banana (reward). In some tests these were not visible, that is, the chimpanzee had to mediate size of banana via cues provided by objects (e.g., object 'a' symbolized reward magnitude 'A', etc.). Menzel concluded that his results provided evidence for a "statistical transitivity" (similar to McGonigle & Chalmers, below) and he regarded it as unlikely that his chimpanzees had used "logical inference of size relationships." McGonigle and Chalmers (1977) based their study of transitivity in squirrel monkeys on and found similar results to an earlier study by Bryant and Trabasso (1971) involving children. However, unlike Bryant and Trabasso who favored an interpretation that the children had used deductive inference, McGonigle and Chalmers favored a "binary (statistical) decision model," a model for which they provided additional experimental tests and confirming results. Essentially, this statistical model suggested that the probability of a correct choice was related to the reinforcement 'history' associated with that choice. They did acknowledge that "it is clear that some kind of 'inference' necessary to produce the appropriate 'inferred' set or absent referent is used by monkeys in tests of transitivity such as those described here" (p. 696).

Gillan (1981) recently published a study of transitivity in chimpanzees, and he favored a deductive inference interpretation over McGonigle and Chalmer's statistical interpretation. However, it is not clear that he applied their arguments appropriately to his data. Furthermore, a question to be considered about both Gillan's and McGonigle and Chalmer's studies is that of not using an ordered series of stimuli to establish the transitive series. Whereas, Menzel had used three sizes of food reward, McGonigle and Chalmer's pairs of stimuli (for a given comparison) were always "light" or "heavy" where light always meant an empty tin and heavy meant a tin weighted with lead shot. Gillan's pairs were distinguished by the presence versus the absence of a food reward. In both cases the containers were differentially colored and the animals were to learn a "series" according to color. However,

in doing so, their direct sensory experience associated with the stimuli was counter to the notion of a series. For example, red might be 1 and light versus blue being 2 and heavy. Next, it would be the same blue, still 2 but now light, versus green, 3 and heavy, and so on. Since the animals performed consistently with a transitivity interpretation, it appears that they overcame this discrepancy between a 'concrete' series based on sensory experience and an 'abstract' or symbolic series based on learned associations, but it would seem more appropriate in terms of transitivity to have had the learned associations be consistent with the sensory experience. On the other hand, as McGonigle has informed us (personal communication) the choice of an 'abstract' series was deliberate and is well supported in the transitivity literature (e.g., Thayer, Collyer 1978; Breslow 1981, Chalmers, McGonigle in press). Space limitations preclude further discussion, but it seems to us that the question of using an 'abstract' versus a 'concrete' series of stimuli has not been resolved.

Concluding remarks. Obviously, we have been strongly critical (some might say excessively) of the animal-Piagetian literature on cognition. We find much of it to be questionable methodologically and, therefore, the interpretations which followed the use of those methods to be unconvincing. We are most convinced by those studies which have used standardized assessment methods, such as but not limited to the scales of Uzgiris and Hunt, and by those studies which have taken extra steps to identify or control for alternative interpretations (e.g., McGonigle, Chalmers 1977; Natale et al 1983; Triana, Pasnak 1981).

We hasten to add that our concern is based more on the use of Piaget's theory than on the theory and its concepts. One of us (Czerny, Thomas 1975; Thomas, Peay 1976) has tried to use the theory with animals and the other (ELW) is now using it in a study of seriation in squirrel monkeys. We continue to believe in the utility of Piaget's theory, and we encourage other investigators to continue using it. On the other hand, we believe that certain concepts in Piaget's theory, most notably, conservation, are unlikely to yield themselves to conclusive demonstrations in animals (see earlier arguments here regarding conservation and essential supporting evidence in terms of the animal's awareness of reversibility, compensatory 'explanations' etc.). Unfortunately, in terms of the assessment of cognitive development beyond the Sensorimotor Period, conservation is a central concept. This means that unless the methodological issues associated with conservation in animals can be overcome, Piaget's theory will have limited use. In view of this, we now turn to the brief consideration of an alternative approach to cognitive development, one which should be especially useful at the more advanced stages of cognitive development, particularly in nonhuman primates.

A LEARNING HIERARCHY APPROACH

The learning hierarchy to be summarized here has been described elsewhere in the context of the comparative assessment of intelligence (Thomas 1980; Thomas 1982). It is suggested here that the learning hierarchy should be equally useful for the comparative assessment of cognitive development. The hierarchy begins with the simplest type of learning, habituation, which has been shown to be among the capacities of invertebrates and, perhaps, even protozoa. The hierarchy culminates with the most complex types of learning imaginable; for example, the upper two levels may be expanded systematically and, theoretically, infinitely (see Thomas 1980). In short, if as is contended here, the learning hierarchy can address any and all forms of learning, then it should be a useful device to assess cognitive development.

The learning hierarchy (shown in Table 1) is based on Gagné's (e.g., 1970) hierarchy of types of learning and a hierarchy of concept learning which has been described in the human concept learning literature (e.g., Bourne 1970; Haygood, Bourne 1966; Millward 1971). Thomas (1980) added habituation at the bottom of Gagné's hierarchy, as it is a recognized type of learning (e.g., Thompson, Spencer 1966) which Gagné did not include. Thomas also suggested the particular use of the terms "Relational Concepts," "Class Concepts," and the categories "Absolute" and "Relative" class concepts as shown below. The numbers are included for possible use as indices to reflect how far up the hierarchy a subject was able to perform. Although not shown here, it may be noted that it is possible to increase the precision of measurement at levels 4 through 8, in which case indices such as 4.1, 4.2, etc. might be used. The indices are intended to reflect only the measurement on an ordinal scale.

TABLE 1
THE LEARNING HIERARCHY

		Relational Concepts	
8		Biconditional	
7	Conjunctive	Disjunctive	Conditional
6		Class Concepts (Affirmative)	
	Absolute		Relative
5		Concurrent Discrimination	
4		Chaining	
3		Stimulus-Response Learning	
2		Signal Learning	
1		Habituation	

Briefly, habituation (level 1) refers to decrements in responding to a stimulus which has no consequences for the subject. Signal learning (level 2) is synonymous with simple Pavlovian conditioning. Stimulus-response learning (level 3) is synonymous with simple instrumental, operant, or Thorndikian learning. Chaining (level 4) refers to the ability to learn in a sequentially connected fashion more than one simple stimulus-respone learning "unit." Concurrent discrimination (level 5) refers to the ability to learn more than one simple discrimination problem at the same time (e.g., learning to discriminate between a triangle and a circle while learning to discriminate between a square and a star, while learning the difference between a pentagon and an octagon, etc). Levels 6 through 8 which involve concept learning will be discussed below.

To compare the cognitive development of human and nonhuman primates, one might start with same-age, human and nonhuman primate infants and with measures of habituation and determine the ages at which each subject was able to provide evidence for the ability to perform habituation and each of the succeeding types of learning task. One should not, of course, compare rates of learning (trials to criterion, errors, etc.) within a task, as these might be affected by relatively noncognitive variables (e.g., sensory capacities, motivation, etc.).

Furthermore, the tasks at each level should be adapted appropriately to each species (i.e., in terms of sensory and response requirements, motivating conditions, etc.). Assuming the means of assessment is appropriate for each subject, one should merely assess the presence or the absence of the cognitive capacity suggested by the particular type of learning being examined. Upon reaching level 4, if members of two or more species were capable of chaining but not concurrent discrimination (level 5), then the length of the chains which each species could learn as an indication of its cognitive capacity at that time might be compared. Similarly, if the animals performed concurrent discriminations but not class concepts (level 6), then one might compare the number of concurrent discrimination problems that they could learn.

Level 6 is the beginning of concept learning. Concept, like cognition, is a variably defined term. Central to our view of what any definition of concept learning must include is recognition that the likelihood of specific learning has been precluded. For example, consider the oddity concept, a concept which has been studied in both children and nonhuman primates. Typically, an oddity problem consists of three stimuli, two of which are identical and different from the third (the odd stimulus). If the same three stimuli were administered repeatedly, nonconceptual bases for correct choices are possible. There are three basic configurations for such a problem (assuming a linear array): ABB, BAB, BBA. The subject might learn to respond to the odd one owing to use of the oddity concept, but it might respond on the basis of A's specific properties or on the basis of having learned the relationship of the reward in terms of the three specific configurations. The optimal way to assess a subject's use of a concept is to use new stimuli, either on each trial or in a generalization test with new stimuli following training on the first set of stimuli.

The hierarchy of concept learning shown at levels 6 through 8 is based on the use of the basic logical operations: affirmation, conjunction, disjunction, conditional, and biconditional. Their complementary operations (e.g., negation for affirmation) are equally applicable, but they

will not be considered further here. By definition, affirmation and negation are the sole operations associated with the specification of class concepts. The remaining operations determine explicit relationships among class concepts or among class concepts and specific stimuli. For this reason, the logical operations at levels 7 and 8 have been said to determine relational concepts. (See Thomas (1982) for a discussion of ambiguities in nomenclature associated with the specification of types of concepts and how the approach used there and here might be useful.)

Class concepts are divided into absolute and relative. With absolute class concepts, the properties which identify a specific stimulus as being a member of a particular class concept are inherent in the specific stimulus. For example, each specific tree possesses the properties which identify it as a member of the class "tree," but the properties which identify a stimulus as a member of the class "oddity" are not inherent in the stimulus but are relative properties among the stimulus choices. There is abundant literature to show that adult members of several species of nonhuman primates are capable of using both absolute and relative class concepts; however, systematic developmental data are lacking.

To illustrate the possibilities for comparisons of human and nonhuman primates within the framework of the learning hierarchy, consider the oddity concept. First, it should be noted that the oddity concept can be assessed at two general levels of difficulty. At one level, the nonodd stimuli are identical. At another level, the nonodd stimuli are not identical, but they share more properties with each other than they do with the odd stimulus. Oddity is the term used when the nonodd stimuli are identical, and dimension-abstracted oddity (DAO) is used when the nonodd objects are not identical. Additionally, tasks within each of these two levels may be varied in difficulty (logically at least, although supporting empirical evidence for varying difficulty is generally lacking; see, however, Thomas, Frost (1983). For example, the odd stimulus might differ in all dimensions (e.g., color, form, size) from the nonodd stimuli or on fewer dimensions; some properties might be held constant among all stimuli, and on DAO tasks some properties might be ambiguous, that is, vary in a noninformative way. Both oddity and DAO tasks have been used to assess cognitive development in children; e.g., Lipsett, Serunian (1963);

Lubker, Small (1969); Sugimura (1981); Vaughter (1975). Both types of tasks have also been used with nonhuman primates (e.g., Bernstein, 1961; Strong, Hedges, 1966; Strong, et al 1968; Thomas, Frost, 1983), although these usually were not developmental studies.

Strong et al (1968) did include children (from 4 years, 0 months to 6 years, 11 months as well as a group of 12 years old), college students, and persons described as "senile" together with their rhesus monkeys and chimpanzees in a study involving one of the more difficult types of DAO tasks. In addition to the variations among types of subjects, another variable was whether the subjects had prior experience on more basic oddity tasks. Generally, the "experienced" subjects performed better than the "naive" subjects. For example, 3 of 3 experienced versus zero of 6 naive rhesus monkeys met criterion on the DAO task. Also, 3 of 3 experienced chimpanzees met criterion (no naive chimpanzees were tested). Only 8 (3 naive and 5 experienced) of 40 of the 4-0 to 6-11 children met criterion, while 16 (6 of 10 naive) of 20 of the 12 years old subjects met criterion. All college students met criterion on the DAO task whether or not they had prior oddity experience, but only 1 of 29 (a member of the naive group) of the senile human subjects met criterion. In addition to suggesting the general utility of oddity and DAO for the comparative assessment of cognition in human and nonhuman primates, the Strong et al study reminds us that, despite the emphasis in this chapter on early development, it may be useful and meaningful to compare cognitive development (and changes) over the entire life-span. Oddity, DAO, and the learning hierarchy approach, in general, should prove to be very useful in this regard.

There are also data which show that adult members of several species of nonhuman primates are capable of performing concepts at level 7, although there is uncertainty whether the concepts were conjunctive or conditional. Most of these studies (e.g., Thomas, Kerr 1976; Thomas, Ingram, 1979) were done in the context of the "conditional discrimination" paradigm (see French 1965) which involves judgments which may be described in the conditional form ('if A, then B' where A or B or both are class concepts). However, conclusive evidence for the use of the conditional requires tests of aspects of the truth-functional analysis of the conditional which have not been done. Nevertheless, even if the claims for use of the conditional are questionable, the same studies can be said to have at least provided evidence for the use of conjunctive concepts which are also at level 7. Apparently, there have been no attempts to study the use of biconditional concepts in animals, but it is suggested that such a demonstration may be feasible.

CONCLUDING REMARKS

As noted early in this chapter, both the Piagetian and the learning hierarchy approaches are sufficiently general to embrace the other, at least until one encounters concepts which require the use of language. Additionally, it is possible to use either or both approaches to examine retrospectively virtually all studies which have attempted to assess cognitive development or cognition per se in human and nonhuman primates. In this regard, then, both approaches may be used to analyze past research as well as to provide a framework for future research. What is needed now is more systematic empirical research which compares the cognitive development of Primates and which determines the utility of nonhuman primate models pertinent to the study of human cognitive development.

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