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A REVIEW OF SOME PIAGETIAN CONCEPTS*

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CHAPTER CONTENTS

OVERVIEW

Our task was to examine Piagetian concepts in light of recent research and theory on cognitive development. This breathtaking assignment was made somewhat easier by the fact that elsewhere in the *Handbook* there are discussions of the first (sensorimotor intelligence) and last (formal operations) of Piaget's proposed stages of development. This allowed us to focus on Piaget's two intermediary stages of development, those of preoperational and concrete-operational thought. But we still had to make choices. In the end, we tried to put together a review that would reflect the impact of Piagetian theory as well as our own views on the current status of the theory. The result is a review that is critical, yet in agreement with some of the fundamental tenets of the theory. Thus, we accept the position that there is much to be learned about cognitive development by studying the acquisition of such concepts as number, space, time, and causality. We also have no quarrel with the idea that cognition involves structures that assimilate and accommodate to the environment; indeed, we do not see how it could be otherwise. However, we do question the notion of there being broad stages of development, each characterized by qualitatively distinct structures. As we will see, the experimental evidence available today no longer supports the hypothesis of a major qualitative shift from preoperational to concrete-operational thought. Instead, we argue for domain-specific descriptions of the nature as well as the development of cognitive abilities.

Our review of Piagetian concepts starts with matters of *structure* and ends with matters of *function*, or development proper. That is, we take up first the

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what and then the *how* of cognitive development. We begin by examining some of Piaget's ideas about the nature of preoperational and concrete-operational thought. We then review in some detail the research that has been conducted in several cognitive domains, including numerical and quantitative reasoning and classification. In the final section, we examine Piaget's ideas about the sources of cognitive structures and the processes—assimilation, accommodation, equilibration, and so on—that account for their development.

ASSESSMENT OF THE CHARACTERIZATION OF CONCRETE OPERATIONS

When tested on the standard Piagetian tasks in the standard way, preschool children typically err in their responses. Thus, when asked whether a bouquet composed of six roses and four tulips contains more roses or more flowers, they quite invariably answer more roses. Similarly, when presented with two even rows of chips and asked, after watching the experimenter spread one row, whether the two rows still contain the same number of chips, preschoolers typically respond that the longer row has more.

No one seriously questions the reliability of these (and other similar) observations, which have all been widely replicated. What is very much at issue, however, is how preschoolers' failure on the standard Piagetian tasks should be interpreted. The fact that children less than 6 years of age typically fail these tasks and that children 6 years of age and older typically succeed on these tasks suggests that there are important differences in their cognitive capacities. The question is, How should these differences be characterized?

Piaget's account of the differences involved granting the older child reversible structures, or operations, while limiting the younger child to irreversible structures: hence the use of the terms operational and preoperational to describe the cognitive capacities of the older and the younger child respectively. Piaget believed that children's (at first concrete and later formal) operations are organized into well-integrated sets, or structured wholes, and he and his colleagues developed logicomathematical models to characterize these wholes. (The reader who is not familiar with these models is referred to Flavell, 1963; Gruber and Vonèche, 1977; and Piaget, 1942, 1957).

Evaluation of the theory of concrete operations has proceeded along several lines. One has been to assess whether success on different Piagetian tasks (e.g., conservation, classification, seriation, perspective taking) is indeed related. Another has been to explore the preschool child's alleged intellectual incompetence relative to the older child. Still another line of evaluation, closely related to the third, has been to devise training studies that might bring to the fore unsuspected competencies. In the next sections, we review some of the work that has been done along each of these lines.

Are There Structures d'Ensemble?

Do Multiple Correlations Obtain?

Many studies have been conducted to compare children's ability to classify, seriate, conserve, measure, give predictions and explanations, assume another's visual or social perspective, and so on. Most such studies have failed to show high intercorrelations between the various abilities tested (e.g., Berzonsky, 1971; Dimitrovsky & Almy, 1975; Jamison, 1977; Tomlinson-Keasey, Eisert, Kahle, Hardy-Brown, & Keasey, 1979; Tuddenham, 1971). Such findings are not really inconsistent with Piagetian theory. Piaget never really claimed (1) that all concrete-operational abilities are based on, or are derived from, a single underlying structure; or (2) that all concrete-operational abilities emerge in a strictly parallel, perfectly synchronous fashion (Vyuk, 1981). To the contrary, Piaget's writings are filled with theoretical claims concerning the order of emergence within each developmental stage of distinct cognitive abilities, with the earlier abilities viewed as precursors of, or as prerequisites for, the later abilities. For example, Piaget (1952a) argued that numerical reasoning is the product of the joint development of the child's classification and seriation abilities. In addition, Piaget often noted in his empirical writings that cognitive abilities, once acquired, are not always applied uniformly in all contexts. Instead, cognitive abilities are frequently applied in one context at a time, with considerable décalages between successive applications. Thus, Piaget (1962) reported that children do not conserve number before the age of 6 or 7; mass, before the age of 8; weight, before the age of 10; and so on.

All of these theoretical and empirical claims obviously mitigate against the possibility of anyone finding high correlations between children's performance on many or all of the concrete-operational tasks. Contrary to what is sometimes held to be the case, investigators' repeated failure to find high correlations across tasks does *not* constitute definite evidence against the notion of a concrete-operational mentality in the (relatively diffuse) sense intended by the theory. Still, such consistently negative results do raise difficulties when it comes to the interpretation of certain studies. Psychologists and educators often attempt to relate children's performance on a given task to their level of cognitive development (e.g., preoperational, concrete-operational) as assessed by any of the standard Piagetian tasks. Were it the case that performance on all standard Piagetian tasks was highly correlated, then, obviously, any task would be as good as any other as a test of children's mastery of concrete-operational thought. But as we just saw, that is far from the case. For this reason, studies that report relationships between, say, children's ability to use metamemorial strategies and children's ability to conserve (taken to demonstrate their entry into the concrete-operational stage) are difficult, if not impossible, to interpret vis-à-vis Piagetian theory.

Are Sequences as Predicted?

The studies we discussed in the previous section tested for the synchronous emergence of different abilities during the concrete-operational period. Other studies have tested whether the order in which abilities develop within that period is as predicted by Piagetian theory. Several investigators have focused on the development of numerical reasoning in the child. As mentioned earlier, Piaget (1952a) maintained that the concept of number develops from the coordination of classification and seriation structures. According to Piaget (1952a), the construction of number

> consists in the equating of differences, i.e., in writing in a single operation the class and the symmetrical relationship. The elements in question are then both equivalent to one another, thus participating of the class, and different from one another by their position in the enumeration, thus participating of the asymmetrical relationship. (p. 95)

Piagetian theory generally assumes that success on standard number-conservation tasks indexes a true understanding of number and that success on standard class-inclusion tasks indexes a true understanding of classification. If Piaget's (1952a) account of the development of the concept of number was correct, one should not find children who pass standard number-conservation tasks well before they pass standard class-inclusion tasks. As Brainerd (1978a) recently pointed out, however, exactly the oppostie sequence obtains. The vast majority of children conserve number by age 6 or 7; but it is not until age 9 or 10 that they truly understand the principle of class inclusion (see also Markman, 1978; Winer, 1980). Such facts clearly call into question the claim that numerical reasoning is the product of the joint development of classification and seriation abilities. Additional evidence against this claim comes from a study by Hamel (1974).

Hamel (1974) analyzed Piaget's (1952a) account of number and concluded that it predicts a strong relationship between: (1) number conservation; (2) provoked correspondence; (3) spontaneous, that is, unprovoked correspondence; (4) seriation; (5) cardination-ordination; and (6) class inclusion. The correlations between the various number tests were significant and quite high (.50 to .80). Likewise, correlations between the multiple-classification tasks and the various number subtasks were also significant, ranging from .45 to .66. However, there were no significant relationships between the class-inclusion task and *any of the other tasks*. Dodwell (1962) reported similar results.

There are other studies that fail to observe some of the between-task predictions derived from the theory (e.g., Brainerd, 1978a; Kofsky, 1966; Little, 1972). There are even studies that fail to observe the same sequence of development across children—whether or not the sequence is predicted by the theory. For example, in a longitudinal study, Tomlinson-Keasey, et al. (1979) found that 13 of 38 subjects passed a class-inclusion task before they conserved amount, 12 passed it after, and 13 passed it at the same time.

What should we make of investigators' failure to confirm the between-tasks sequences predicted by the theory? Should we take it to suggest that Piaget was wrong in claiming that the concrete-operational stage is characterized by the coordinated emergence of superficially disparate but structurally related cognitive abilities? Not necessarily. It could be argued that to do so would be to confuse the issue of whether or not specific abilities develop in the order predicted by Piagetian theory with the more general issue of whether or not abilities from different cognitive domains develop in a well-integrated, coordinated fashion. Piagetian theory could be right in supporting the general issue and still be wrong in any of its specific predictions. Piaget's (1952a) account of the development of the child's understanding of number could be wrong—and as we will see, Piaget (1975a, 1977) himself later abandoned his earlier account—but the general hypothesis that development in other domains contributes to the emergence of the child's concept of number could still be right.

There obviously is no rebuttal to this argument. As the saying goes, the proof is in the pudding. What

Piagetian theory must provide is a satisfactory account of numerical (or causal, or spatial, or logical, etc.) development that posits real, nontrivial interactions between domains. To the extent that such an account can be provided, then to the same extent will the notion of a stage of concrete operations be reinforced. (As we will see below, however, the trend in recent years has been to move away from stage-like, across-the-cognitive-board accounts of development. More and more, investigators appear to focus on the possibility of parallel, domain-specific lines of development.)

Test of the Logicomathematical Model

It is sometimes argued that the reason why investigators have failed to find high correlations between various concrete-operational abilities or have failed to confirm the order in which their abilities develop has to do with the way in which abilities are measured (see Flavell, 1972; Jamison & Dansky, 1979; Tuddenham, 1971). Different investigators use different tasks. Further, it is not always clear whether the tasks used provide a good test of the abilities under study. In addition, there are statistical nightmares. How does one estimate measurement error? Is it constant across tasks? And what if one finds only one child whose performance contradicts the expected pattern—should the theory be rejected?

One way to get around some of these difficulties is to work directly from the logicomathematical model of concrete operations Piaget and his collaborators proposed. Osherson (1974), for instance, used Grize's (1963) axiomatization of these operations. The choice of this axiomatization was based in large part on Piaget's (1967) endorsement of it. Further, Grize's axioms are easily interpreted into statements about classes and relations.

To start, Osherson (1974) derived a set of theorems that followed from Grize's (1963) axioms. He then translated a subset of the theorems into a set of length-inclusion and class-inclusion tasks designed to embody the derived theorems and, thus, provide a test of children's ability to use them. Finally, he made predictions about the patterns of successes and failures that should obtain. That is, he specified which tasks children should pass or fail, given that they had passed or failed certain other tasks. The predictions were based on the analysis of which and how many axioms a particular theorem was derived from. To illustrate, assume Theorems 1 and 2 were derived from Axioms 1 and 2, respectively and Theorem 7 was derived from Axioms 1 and 2. The child who passed the task designed to test for Theorem 7 should likewise have passed the tasks designed to test Theorems 1 and 2 by themselves.

Osherson (1974) found that despite an overall comparable success rate on the length-inclusion and class-inclusion tasks, the patterns of errors made in the two sets of tasks were *not* comparable. These findings suggest that the logicomathematical structures proposed by Piaget and his collaborators are not appropriate for modeling performance in these two task domains. Indeed, one might take these results to call into question the idea that the *same* structures underlie children's ability to solve length-inclusion and class-inclusion problems.

At this point, however, one might point out that Osherson's findings need no longer be taken into account as there have been changes in the formal theory of concrete-operational thought, as well as further developments in the efforts to axiomatize the theory (Piaget, 1977; Wermus, 1971). In addition, one could argue (as before) that even if Piagetian theory, in spite of its recent revisions, still fails to provide an adequate formal description for the logicomathematical structures underlying concrete operations, one need not conclude that no such structures exist: perhaps one has not yet succeeded in finding their proper characterization.

Whether or not the revised Piagetian model serves as a better model has yet to be determined. But as Sheppard (1978) pointed out, it is not clear that the more recent axiomatizations are all that different from the original ones.

Are Within-Domain Relations as Predicted?

Investigators' repeated failure to verify the developmental sequences described by Piagetian theory has led many authors to doubt the claim that cognitive abilities emerge in a coordinated, orderly fashion across domains. Perhaps for this reason, some authors have sought to test the developmental sequences predicted by the theory *within* domains rather than *across* domains. If one interprets Piagetian theory to mean that performance within each domain is based on operations that are organized into a well-integrated, reversible structure, then one might expect to find relatively high correlations between tasks testing abilities assumed to be derived from that same structure. However, attempts to verify this particular hypothesis have not faired well.

Consider, for instance, the work of Hooper, Sipple, Goldman, and Swinton (1979) and Kofsky (1966), who tested Inhelder and Piaget's (1964) description of the development of classification abilities. Kofsky (1966) found that although she could discern a rank order of difficulty for her different classification tasks, only 27% of her subjects fit this pattern. Hooper and his colleagues (1979) later replicated Kofsky's overall developmental sequence.

Some of their findings also led them to doubt that this sequence represented the development of only one common classificatory structure. For instance, Hooper et al. found that the ability to multiply classes as assessed in a cross-class matrix task does *not* predict the ability to solve class-inclusion problems. Indeed, they, like many others (e.g., Brainerd, 1978a; Dimitrovsky & Almy, 1975; Dodwell, 1962; Hamel, 1974; Kofsky, 1966; Tuddenham, 1971; Winer, 1980) found that class-inclusion tasks are much more difficult—and are accordingly solved much later—than are other concrete-operational tasks. They concluded that some four separate factors contribute to the development of classificatory abilities.

Studies that examined the development of ordering abilities have yielded comparable results (Dimitrovsky & Almy, 1975; Tuddenham, 1971). Tuddenham reported a .28 (nonsignificant) correlation between the ability to seriate and solve a transitive inference task. Dimitrovsky and Almy compared children's ability to seriate and reorder, that is, place back in order stimuli that are mixed up before them. Of the 408 children tested, 134 passed the seriation task; in contrast, only 41 passed the reordering task.

Attempts to confirm Piaget's (1952a, 1975a, 1977) prediction that the ability to compensate precedes or co-occurs with the ability to conserve have also been unsuccessful. According to Piaget, the child who truly understands that the amount of liquid in a glass is conserved when it is poured into a container of different dimensions also understands the principle of compensation: "conservation . . . involves quantities that are not perceptive, but have to be constructed by compensation between two different dimensions" (Piaget, 1967a, p. 533). In his first presentation of this position Piaget (1952a) predicted that all children who conserved liquid would reveal an understanding of compensation. This meant that a child could pass a compensation task and fail a conservation task but not the reverse. In a subsequent presentation of the argument, Piaget considered the kinds of predictions children at different stages in the development of conservation should make before the transformation phase of both the conservation and compensation tasks (e.g., Inhelder, Bovet, Sinclair, & Smock, 1966; Piaget & Inhelder, 1974). At an initial stage, the nonconserver should predict that there will be conservation after the transformation and that the water level in the new beaker will *not* change. At the second stage, the nonconserver should predict that there will not be conservation and the water level *will* change. Finally, the true conserver should predict that the water level will change *and* that conservation will obtain in the face of this perceptual change. In either version of the conservation account, one should not observe a child who passes the conservation task and, nevertheless, fails the compensation task. Piaget and Inhelder (1963) reported that all but 5% of children who conserved were able to anticipate the level of water that would be reached if the contents of a standard beaker were poured into a beaker of different dimensions. Although details of the data are not presented, Piaget (1952a) noted that almost all children who conserved passed a compensation test that required children to pour as much water into an empty beaker as there was in a standard beaker of different dimensions. Piaget and Inhelder (1971) also reported a study of the ability to pass conservation and compensation tasks in support of their account of conservation. However, there are now many studies that do not support their account.

Acker (1968) found children who conserved but failed the anticipation task used by Piaget and Inhelder (1963). Lee (1971) found that when children were required to pass both tests of conservation and compensation in order to be judged true conservers, the proportion of conservers fell from 11 of 15 to 6 of 15. Gelman and Weinberg (1972) reported that 17% of their subjects who conserved failed to compensate, that is, failed to match the water level of the standard when pouring the "same amount" into a beaker of different dimensions.

More recently, Acredelo and Acredelo (1979) tested the extended version of Piaget's account of the relationship between the abilities to conserve, compensate, and anticipate conservation or compensation. They reported that 37.5% of their sample revealed success and failure patterns *not* predicted by Piagetian theory. These disconfirming patterns were expected with their alternative identity theory of conservation however. This alternative theory allows children to conserve even if they fail to compensate. Such children are viewed as being in an early stage of conservation; they focus on the absence of an addition/subtraction operation or the irrelevance of displacement transformations and pay little attention to the perceptual conflict that obtains after the transformation. Children then go on to learn that compensation is a consequence of conservation. This fits with Gelman and Weinberg's (1972) observation that the understanding of the compensation principle, as manifested in verbal statements, continues to develop well after the age at which the child's ability to conserve liquid may be taken for granted. Further, it removes the puzzle of how a child could understand compensation without presupposing an equivalence relation—as Piaget would have them do.

In sum, even when we assess the Piagetian account within a single domain (e.g., classification, seriation, conservation), the results do not lend support to the theory. The idea that concrete-operational thought is not dependent on one or even several structures d'ensemble is probably related to the turn away from Piaget's stage theory (e.g., Brainerd, 1978a, 1978b; Feldman, 1980; Fischer, 1980; Flavell, 1982; Siegler, 1981; but see also Davison, King, Kitchener, & Parker, 1980). Evidence that preoperational thought may not be preoperational makes it even harder to maintain the stage account.

Is Preoperational Thought Really Preoperational?

To say of a child that he is preoperational is to say more than that he has no concrete operations. Preoperational thought is not defined (or explained) solely in terms of what it lacks; it is also said to possess several dominant characteristics. According to Piagetian theory, the preoperational child is egocentric or (to use the more recent label) centered. His reasoning processes are perception bound: he is easily distracted by the perceptual or spatial properties of objects and, for this reason, often fails to detect more abstract, invariant relations among objects. In addition, the preoperational child is usually unable to coordinate information about states and transformations.

Are preschoolers truly preoperational? A host of recent investigations have raised questions about the validity of this characterization. In general, these studies show that under certain conditions, even young preschoolers behave in a nonegocentric manner, ignore misleading perceptual cues, integrate information about states and transformations, and so on.

Consider the claim that preschoolers are egocentric. In the perspective-taking task designed by Piaget and Inhelder (1956), children are shown a model of three mountains. A doll is placed at various positions around the model and children are asked to indicate how the mountains look to the doll from each of the positions. Children less than 6 years of age tend to choose a picture or small replica that depicts their own view rather than the doll's view. According to Piaget and Inhelder (1956), the young child is "rooted to his own viewpoint in the narrowest and most restricted fashion, so that he cannot imagine any perspective but his own" (p. 242). Similarly, when asked to describe the workings of a water tap or to repeat to another child a story he has been told, the young child does terribly. This is because "he feels no desire to influence his listener nor to tell him anything; not unlike a certain type of drawing room conversation where everyone talks about himself and no one listens" (Piaget, 1959, p. 32).

Do young children really believe that an observer standing in a different location than theirs sees the same thing they see? Recent work by Masangkay, McCluskey, McIntyre, Sims-Knight, Vaughn, and Flavell (1974) and by Lempers, Flavell, and Flavell (1977) indicates that the answer to this question is negative. In the study by Masangkay et al., a card with different pictures on each side was held vertically in front of children who were asked: "What do *you* see?" and "What do *I* see?" All of the 3-year-olds and half of the 2-year-olds tested responded correctly. In the study by Lempers et al., children 1 to 3 years of age were given hollow cubes with a photograph of a familiar object glued to the bottom of the inside. Children's task was to show the photograph inside the cube to an observer sitting across from them. Lempers et al. found that virtually all children 2 years and older turned the cube opening *away from themselves* to face the observer. These results indicate that the young child is not so egocentric as to believe others see whatever *he* sees. What then could be the source of the young child's difficulty on Piaget and Inhelder's (1956) mountain task?

Flavell (1974) distinguished between the child's identification of *what* object another sees and the more complex concept of *how* the object is seen. The findings of Masangkay et al. (1974), Lempers et al. (1977), and others (e.g., Coie, Constanzo, & Farnill, 1973) indicate that the rudimentary ability to determine what another person sees is present by age 2. The ability to recognize how an object or a scene appears to another person develops much more slowly. Borke (1975) showed that the age at which children demonstrate nonegocentric perspective-taking ability is heavily influenced by such task variables as the nature of the test displays and the type of response required. Borke's (1975) procedure was the same as that of Piaget and Inhelder (1956), with two important exceptions. First, two of the three displays Borke used were scenes containing familiar toy objects. Display 1 consisted of a small lake with a toy sailboat, a model of a house, and a miniature horse and cow. Display 2 contained different groupings of miniature people and animals in natural settings (e.g., a dog and doghouse). Display 3 was a replica of Piaget and Inhelder's (1956) three mountains. Second, Borke asked her subjects to indicate the doll's perspective by rotating duplicates of the displays. On Displays 1 and 2, Borke found that 3- and 4-year-old children correctly assessed the doll's perspective for all three positions tested between 79% and 93% of the time. In contrast, on Piaget and Inhelder's display, 3-year-olds gave 42% and 4-year-olds 67% correct responses for the three positions. Borke concluded that her results "raise considerable doubt about the validity of Piaget's conclusion that young children are primarily egocentric and incapable of taking the viewpoint of another person. When presented with tasks that are age appropriate, even very young subjects demonstrate perceptual perspective-taking ability" (p. 243). Additional support for Borke's conclusion comes from a recent study by Flavell, Flavell, Green, and Wilcox (1981). Flavell and his colleagues found that preschoolers understand that objects with different sides (e.g., a house) look different from different perspectives, whereas objects with identical sides (e.g., a ball) look the same from all perspectives.

Taken together, the results of Borke (1975) and Flavell et al. (1981) clearly indicate that children as young as 3 years of age (1) are aware that an individual looking at a display (e.g., a house) from a position other than their own will have a different view of the display; and (2) are able to compute how the display looks to this individual under certain optimal conditions. With time, children become more and more proficient at identifying how a display appears to another individual. It should be noted that this ability continues to develop well into the school years. Huttenlocher and Presson (1973, 1978), for example, found that school-aged children do better on perspective-taking tasks if they are allowed to walk around the covered display before giving their response.

Similar nonegocentric results have been obtained in other types of perspective tasks. Markman (1973a) found that preschoolers correctly predicted that 2-year-olds would fail on a memory task but would achieve some degree of success on a motoric task. Shatz and Gelman (1973) reported that 4-year-olds used shorter and simpler utterances when talking to a 2-year-old than when talking to peers or adults. Speech to the 2-year-olds typically involved remarks aimed at obtaining and maintaining the child's attention as well as show-and-tell talk. In marked contrast, adult-directed speech usually involved comments about the child's own thoughts and requests for information, classification, or support. Speech to the adults also included hedges, which are commonly assumed to mark the speaker's recognition that the listener is better informed, older, and so on (Gelman & Shatz, 1978). Maratsos (1973) reported that 3- and 4-year-olds pointed to indicate the positions of toys to a sighted adult. When the same adult covered her eyes, however, children tried—as best as they could—to describe the toys' respective positions. Likewise, Marvin, Greenberg, and Mossler (1976) reported that children as young as 4 recognized that a person who did not see an event did not know this event: Knowledge of the event could be shared only by those who had witnessed it. These are hardly the sorts of things one would expect fundamentally egocentric thinkers to be able to do (for further evidence see Donaldson, 1978; Shatz, 1978; *Shatz, vol. III, chap. 13*).

In all fairness to Piaget, we should point out that our criticism of the characterization of the young child as egocentric is addressed more to interpreters and followers of Piaget than to Piaget himself. In our survey of the Genevan literature since 1965, we never encountered the term egocentric. As Vyuk (1981) noted, Piaget switched to the term *centered* in his later writings to avoid the surplus meaning of the term egocentric.

What evidence is there that the preoperational child is *centered*, in the sense Piaget intended? One version of the centration hypothesis holds that the preoperational child's failure to conserve number or quantity is due, in part, to a proclivity to center on one dimension (e.g., length in the case of number conservation, height in the case of liquid conservation) and ignore the other dimension (e.g., density in the case of number conservation, width in the case of liquid conservation). However, Anderson and Cuneo (1978) provide compelling evidence against this version of the centration hypothesis. In one study, children 5 years of age and older were shown rectangular cookies that varied systematically in width and in height. Their task was to rate how happy a child would be to be given the different cookies to eat. During pretesting, children were taught how to use the rating scale. This scale consisted of a long rod with a happy face at one end and a sad face at the other. The children's task during the test was to point to the place on the rod that reflected their judgment of how happy or sad a child would be if he ate a cookie of a given size. Analyses of the ratings yielded significant effects of both width and height—even for preschool subjects. In a subsequent study, Cuneo (1980) obtained similar results with 3- and 4-year-old children. Analyses of the children's ratings indicated that they were using a height + width rule to evaluate the area of the test cookies. As before, there was no evidence of centering on one dimension.

What of the characterization of the preoperational child as perception bound? An early conservation training study by Bruner et al. (1966) appeared to lend support to this characterization. Children were shown two identical beakers filled with water and were asked whether or not they contained the same amount. Next, children were shown a third, empty beaker of different dimensions. This new beaker was placed behind a screen, and the contents of one of the original beakers was poured into it. Children were then asked whether the screened and the unscreened beakers contained the same amount of water. It was found that children were less likely to give up their initial judgment of equivalence with the screen present.

A conservation study by Markman (1979) makes it difficult to accept the Bruner et al. position that children's failure to conserve reflects the perception bound quality of their thought processes. Markman asked 4- and 5-year-olds to participate in one of two versions of the number conservation task. The only difference between the two versions was the terms used to label the displays. In one version—the standard Piagetian version—*class* terms (e.g., trees, soldiers, birds) were used. In the other version, *collection* terms (e.g., forest, army, flock) were used. Children in the class condition did poorly. In contrast, children in the collection condition averaged 3.2 correct judgments out of 4 *and* were able to provide explanations for their judgments. Because both versions of the task involved the exact same displays, one cannot explain the class subjects' failure to conserve on the ground that preschoolers are perception bound. Subjects in both experimental conditions obviously had equal opportunity to become distracted by the perceptual appearance of the posttransformation displays. The fact that the collection children did not raises doubt about the validity of the characterization of the preoperational child as fundamentally perception bound.

Additional evidence that preschoolers are not always perception bound comes from studies that examined their ability to distinguish between appearance and reality. Fein (1979), for instance, found that by age 3 children have no difficulty distinguishing the pretend activities involved in play from other activities. Flavell, Flavell, and Green (in press) reported that even 3-year-olds have some ability to distinguish between real and apparent object properties. In one experiment, children were shown a white paper that looked pink when placed behind a piece of pink plastic. More than half of the 3-year-olds tested correctly differentiated between the appearance (pink) and the reality (white) of the paper. In a similar vein, Gelman, Spelke & Meck (in press) found that 3-year-olds recognize that a doll and a person are more alike perceptually than are a doll and a rock. But they also understand—as evidenced by spontaneous comments to this effect—that a doll can only "pertend" walk, sit, eat, and so on.

Work by Gelman, Bullock, and Meck (1980) raises questions about yet another characterization of preschool thought, which is that preschoolers have serious difficulty relating states (in Piaget's terms, figurative knowledge) and transformations (operative knowledge). The experiment was based on Premack's (1976) finding that chimpanzees are able to select the appropriate instrument (e.g., a scissors) to relate two different states of an object (e.g., a whole apple and a cut apple). In the Gelman et al. study, 3- and 4-year-olds were asked to select one of three choice-cards to fill in the missing element in three-item picture sequences. Test sequences had either the first, second, or third position empty. Each completed sequence consisted of an object (e.g., a cup), an instrument (e.g., a hammer), and the same object transformed by the application of the instrument (e.g., a broken cup). Half the sequences depicted familiar events (e.g., cutting a piece of fruit), half depicted unusual events (e.g., sewing the two halves of a banana together or drawing on a piece of fruit). Performance in both age groups was nearly perfect, indicating that the children could reason about the relationship between object states before and after the application of various instruments.

In a second experiment, Gelman et al. (1980) showed 3- and 4-year-olds picture sequences in which the deleted item was always the instrument. The children's task was to relate the two object states first from one direction (e.g., whole apple, cut apple) and then from the opposite direction (e.g., cut apple, whole apple). As in the first experiment, performance in both age groups was very good, indicating that children could represent reciprocal transformations. Gelman and her colleagues concluded that although preschoolers may not *always* be able to represent the same object states with reference to reciprocal transformations (e.g., pretransformation and posttransformation displays in a clay-conservation task), there are clearly cases where they can do so.

In this section, we have reviewed a number of studies that indicate preschool children are not fundamentally egocentric, centered, or perception bound. The general implication of these studies is that the mentality of the preschool child is qualitatively more similar to that of the older child than Piagetian theory leads one to suspect. This is not to deny, obviously, the cognitive limitations of

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served as the true dependent variable. All age groups implicitly integrated time and velocity values with a multiplicative rule. This is revealed by significant interaction effects in an analysis of variance between time and velocity. How did such young children do this? Wilkening's eye-movement data show that the children (as well as the older subjects) followed the imaginary movement of an animal along the bridge. When the dog stopped barking, they pointed to the position their eyes had reached. Because they adjusted the rate of their eye movements as a function of animal, the fact that the time × velocity interactions were significant is explained.

Wilkening points out that the ability to integrate distance and velocity to judge time requires the use of a division rule, likewise the ability to judge velocity as a function of distance and time. Furthermore, the definition of the unit is more complex, as are the information processing demands of tasks that require these integrations. The youngest group did not succeed on distance, that is, the velocity task, where success is defined in terms of the use of a division rule. Whether these velocity tasks require an explicit understanding of the relevant units of measurement remains a question for further research. What is clear now is that even young children can, under some conditions, make correct judgments of relative amounts of continuous quantities. Still, there is much room for development.

Classification

In an earlier section (*Assessment of the Characterization of Concrete Operations*), we discussed the role classification structures play in Piaget's (1952a) theory of the development of numerical reasoning. In this section, we focus on Inhelder and Piaget's (1964) theory of the development of classification skills, and on the implications this theory has for concept acquisition.[4]

Concepts have traditionally been characterized in terms of classes and class-inclusion hierarchies. Like classes, concepts are said to have both an intensional and an extensional component. The *intension*, or definition, of a concept specifies the criterion elements must satisfy to be regarded as members of the concept. The *extension* of a concept consists of all the elements that are appropriately described as members of that concept. (The reader is referred to Schwartz, 1977, for a review of a philosophical work that proposes an alternative approach to concepts, and to Smith & Medin, 1981, for a review of psychological research conducted within this approach.)

To Vygotsky (1962), Inhelder and Piaget (1964), and Olver and Hornsby (1966)—all of whom shared the traditional view of concepts as classes—the study of children's classifications was of special interest for two reasons. First, it was thought that analyses of the structure of children's classifications would shed light on the structure of their concepts and, more generally, would show how this structure successively approximates the logical class structure of adults' concepts. Second, it was hoped that an examination of the basis of children's classifications would reveal something of the content—whether concrete or abstract—of their concepts. Because the young child was viewed as locked in a concrete, immediate reality (e.g., Piaget, 1970; Bruner et al., 1966), it was predicted (e.g., Olver and Hornsby, 1966) that young children would establish equivalences on the basis of perceptual similarities, whereas older children would make use of more abstract criteria.

Background

Structural Properties of Children's Groupings. According to Inhelder and Piaget (1964), classification begins when the child groups together two objects that look alike in some way. The child's ability to discover similarities between objects is *not* regarded as sufficient, however to warrant the conclusion that the child can classify. True classification is said to involve the active construction of classificatory systems.

Inhelder and Piaget (1964) began their investigation of classification skills with a detailed examination of children's productions in free-sorting tasks. They found three main phases in the development of free classification. In the first phase (2 to 5½ years), graphic collections, three types of grouping were obtained: alignments, collective objects, and complexes. All three types are based on configurational variables rather than similarity. The child becomes distracted by the spatial arrangement of the objects, or by the descriptive properties of the whole, and builds without regard for similarity. The geometric design objects form or the representative, situational content they evoke (e.g., a train, a cake, a castle) sway the child's attention away from the perceived likeness and differences of the objects themselves. In the second phase (5½ to 7 years), nongraphic collections, the child is no longer misled by considerations of patterns: objects are assigned to groups on the basis of similarity alone. Inhelder and Piaget list four types of nongraphic collections. At the least advanced level, a number of small groups are formed, each based on a different criterion. Further, only some of the objects that constitute the array are assigned to groups. The second type of nongraphic collections again involves various small groups based on a multiplicity of criteria. At this level, however, there is no unclassified remainder: all of the objects in the array are classified. At the next level, fluctuations of criterion are eliminated. Objects are now assigned to groups on the basis of a single, stable criterion without any remainder and without overlap. At the fourth and most advanced level, groups formed on the basis of one criterion are subdivided according to a second, stable criterion.

Children are, thus, able, by the end of the nongraphic collections phase, to form stable, nonoverlapping collections and to divide these into subcollections. Can children, at this point, be said to be able to classify? Inhelder and Piaget argue that, although these children's classifications may be so differentiated and hierarchized as to closely resemble class-inclusion hierarchies, they are *still* preoperational. According to Inhelder and Piaget, "the true criteria by which we can distinguish such preoperations from true classification are the ability of the subject to appreciate the relations 'all' and 'some,' and his power to reason correctly that $A < B$ [i.e., that the subclass is smaller than the class in which it is included]" (Inhelder & Piaget, 1964, p. 54). That is, the preoperational child is still unable to grasp fully the logical relation of inclusion. When shown 12 roses and 6 tulips, for example, and asked, "Are there more flowers or more roses?," the preoperational child typically answers, "more roses." He is capable of adding subclasses to form a larger class (flowers = roses + tulips), but he is unable to simultaneously perform the inverse transformation (roses = flowers − tulips). As a result, he is unable to make a quantitative comparison of the class and its larger subclass. For such a comparison requires that the child separate the class into its subclasses to isolate the larger subclass, while at the same time maintaining the integrity or identity of the class, the other term in the comparison. In other words, the child must be able to attend at once to the part and to the whole, and that is precisely what the preoperational child cannot do. As soon as the subclasses are isolated, the child loses sight of the whole. As a result, he compares the two subclasses rather than the class and the larger subclass. It is only when both operations (addition and division of classes) are present and fully coordinated that the child becomes capable of contemplating at once the class and the subclass and of comparing the two. At this point (the third and last phase of development of classificatory abilities), the child's groups are no longer simply juxtaposed but constitute well-articulated, logical, class-inclusion hierarchies.

Using somewhat different procedures, Vygotsky (1962) and Bruner et al. (1966) have also studied the development of classification abilities. Although there are many differences in the types of classificatory responses reported across the three programs of research, there are also striking similarities. In particular, all three studies suggest that young children go through an initial stage in which they are caught by relationships among the elements themselves—whether spatial arrangements, thematic relations, or idiosyncratic resemblances. Further, all three studies indicate that children go through an intermediary stage in which groups are formed on the basis of similarity alone, but the criterion for grouping fluctuates. During the last stages, children progressively learn to group objects into stable, exhaustive classes and to organize the classes thus formed into logical hierarchies.

Basis of Children's Groupings. Olver and Hornsby (1966) maintained that children's classifications exhibit semantic as well as syntactic properties and that both sets of properties undergo developmental change. The syntax of classification is defined as the formal structure of the class or grouping formed. The semantics of classification are the features of objects or events children use to establish equivalences.

Working with the theory of cognitive development of Bruner et al. (1966), Olver and Hornsby proposed that in the early stage, when the child's mode of representation of the world is essentially ikonic, children would group objects solely on the basis of perceptual properties. Older children, whose mode of representation is symbolic, were expected to use more abstract criteria. In particular, it was assumed that what uses objects have and what functions they serve constitute a more abstract notion and require more "going beyond the information given" than what objects look like. Accordingly, it was predicted that younger children would form concepts based on perceptual attributes whereas older children would form concepts based on functional attributes.

Olver and Hornsby (1966) report the results of two experiments, one by each author. In Olver's study (see also Bruner & Olver, 1963) children aged 6 to 19 were presented with a series of concrete nouns and were asked how each new item was similar to, and different from, the items previously introduced. For example, the words banana and peach would be presented, and, then, the word potato would be added to the list. At this point, the child would be asked, "How is potato different from banana and peach?" and "How are banana and peach and potato all alike?" This procedure was continued until a list of nine items had been presented (e.g., banana, peach, potato, meat, milk, water, air, germs, and stones). Hornsby's procedure was closer to that of Inhelder and Piaget (1964). Children of 6 to 11 years were shown an array of 42 drawings representing familiar objects (e.g., doll, garage, bee, pumpkin, sailboat, etc.). The children's task was simply to select a group of pictures. Their grouping completed, children were asked how the pictures they had chosen were alike. The pictures were then returned to their original position in the array, and children were asked to form another group. The entire procedure was repeated 10 times.

In both Olver's and Hornsby's tasks it was found that 6-year-olds based more of their groupings on perceptual attributes (color, size, shape, position in space) than did older children. In Olver's verbal task, the use of functional attributes increased steadily from 49% at age 6 to 73% at age 19. Conversely, the use of perceptual attributes decreased steadily from roughly 25% to 10%. In Hornsby's picture task, there was again a steady decline in perceptually based equivalence from 47% at age 6 to 20% at age 11. In contrast, the use of functional and nominal attributes increased from 30% and 6% respectively to 48% and 32% respectively. Comparing these two sets of findings, Olver and Hornsby noted that the same pattern of development obtained whether words or pictures were presented and whether items were presented in random or predetermined order. They described this pattern in the following terms:

> Equivalence for the six-year-old reflects a basis in imagery, both in what he uses as a basis for grouping and in how he forms his groups. . . . With the development of symbolic representation, the child is freed from dependence upon moment-to-moment variation in perceptual vividness and is able to keep the basis of equivalence invariant. (1966, p. 84)

We are not convinced that Olver and Hornsby's data support the notion of a stage-by-stage progression from a perceptually based to a functionally based equivalence. At no age were children's groupings based solely on perceptual properties. To the contrary, even Olver and Hornsby's younger children produced a sizable percentage of functional responses. (Indeed, the largest category of responses produced by the 6-year-olds in Olver's study was functional [49%], *not* perceptual [25%].) What these results suggest to us is that if there does exist a difference between younger and older children with respect to the basis they select for classifying objects, it is one of degree and not of kind. Younger children may use perceptual criteria somewhat more frequently than do older children; but they clearly do not use perceptual criteria to the exclusion of all others. What specific criterion is selected as basis for equivalence in any given situation appears to reflect less a particular mode of representing reality than the interplay of a large number of factors. These include the mode of presentation (verbal versus visual) of the stimuli; the readiness with which the stimuli presented can be subsumed under a single, conventional label (both factors seem to have influenced subjects' performance in Olver and Hornsby's studies); the child's style of conceptualization (e.g., Kagan, Moss, & Sigel, 1963) or organizational preference (Smiley & Brown, 1979); and so on. Support for this interpretation comes from a study by Miller (1973).

Miller (1973) gave 6-year-olds and college students eight oddity problems. Each problem involved a set of four objects (e.g., an orange, a plum, a banana, and a ball), and subjects were asked to remove "the thing that doesn't belong." The same question was repeated twice, and subjects were encouraged to take out a different object each time. The sets of four objects were constructed in such a way that removal of one object left a perceptual subset (e.g., an orange, a plum, and a ball) and removal of a different object left an abstract subset (e.g., an orange, a banana, and a plum). In general, the 6-year-olds had little difficulty forming both types of subsets. Indeed, in two of three problems where reliable differences were obtained between the 6-year-olds and college students, the significant result was due to the children's inability to generate a perceptual subset. Both children and adults tended to form abstract subsets on their first correct trial. Taken together, these results suggest that: (1) 6-year-olds *can* form categories on the basis of both concrete and abstract criteria and (2) 6-year-olds do not necessarily differ from college students with respect to the kind of criterion they *prefer* to use.

A variable that may have contributed to the 6-year-olds' superior performance, in Miller's (1973) task, is the use of modeling. Miller took children through two training problems prior to testing and showed them how two different solutions (one perceptual, one more abstract) could be provided for each. There is little doubt that such careful coaching must have left children in no uncertainty as to the nature of the task or the types of responses that were expected from them (Nash & Gelman, cited in Gelman & Gallistel, 1978; Smiley & Brown, 1979).

Classification and Basic Categories

The work of Inhelder and Piaget (1964) gave rise to much experimental interest in the development of the structure of children's free classifications. By and large, the evidence collected supported Inhelder and Piaget's claim that young children are unable to sort objects into classes (see Flavell, 1970, for a review of the free-classification research published prior to 1969). However, recent work by Rosch, Mervis, Gay, Boyes-Braem, and Johnson (1976) and Sugarman (1979) indicates that even very young children can, and do, sort objects taxonomically when presented with appropriate sets of stimuli.

Rosch and her colleagues (1976) noted that the stimuli used in classification experiments were typically stimuli (e.g., a table, a dresser, a bed) that could be grouped taxonomically only at the superordinate level (e.g., furniture). They pointed out that taxonomies of concrete objects include a level of categorization (e.g., chairs, apples, shirts) that is less abstract than the superordinate level; categories formed at this level are referred to as *basic* categories. In a number of experiments, Rosch and her colleagues found basic categories to be the most inclusive categories whose members (1) possess significant numbers of attributes in common, (2) are used by means of similar motor movements, and (3) possess similar shapes.

Rosch and her colleagues (1976) predicted that basic-level categories would be the first to develop. Rosch et al. reasoned that if young children encode the world by means of sensorimotor schemes (e.g., Piaget, 1970) or images (e.g., Bruner et al., 1966), then basic objects should be learned easily. In one experiment, kindergartners and first-, third-, and fifth-graders were assigned to one of two sorting conditions (basic or superordinate). Stimulus materials were color photographs of clothing (shoes, socks, shirts, pants), furniture (tables, chairs, beds, dressers), vehicles (cars, trains, motorcycles, airplanes), and people's faces (men, women, young girls, infants). Subjects in the superordinate condition were given one picture each of the four different objects in each of the four superordinate categories. Subjects in the basic condition received four different pictures of a basic object in each of the four superordinate categories. The results were straightforward. As in previous studies, only half the kindergarten and first-grade subjects could sort objects at the superordinate level. In contrast, there were no developmental differences in the ability to sort basic-level objects—basic-level sorts were virtually perfect at all age levels. In a second experiment, 3- and 4-year-olds as well as kindergartners and first-, third-, and fifth-graders were given oddity problems with either basic-level or superordinate relations. Again, basic sorts were virtually perfect at all age levels. For the 3-year-olds, the percentage correct was 99%; for all older age groups, it was 100%. As expected, the 3-year-olds performed poorly (55% correct) on triads that could only be sorted at the superordinate level. It is interesting to note, however, that the 4-year-olds' performance was almost perfect, with 96% correct.

Recent findings indicate that even 1½- to 3-year-old children may be capable of consistent sorting at the basic level (e.g., Nelson, 1973; Ricciuti, 1965; Ross, 1980; Stott, 1961; Sugarman, 1979). In Sugarman's (1979) study, children between 12 and 36 months of age were given six grouping tasks. Materials in each task were eight small objects evenly divided into two classes, for example, four dolls and four rings. Each task involved (1) a phase of spontaneous manipulation and (2) a phase during which children were given several grouping-elicitation probes. Two types of classificatory activity were examined: (1) the order in which objects were manipulated (sequential classification) and (2) the arrangement of objects in space (spatial classification). Spontaneous and elicited performance usually coincided. In general, the results suggested a shift in children's classifications from a sequential, stimulus-bound organization of single classes to an anticipatory representation and coordination of the two classes in the array. The 12-month-olds showed a reliable tendency to manipulate identical objects successively: they repeatedly selected items from one of the two classes, generally that with greater tactile-kinesthetic salience. Their arrangement of objects in space, however, was haphazard. Complete spatial groupings of single classes (e.g., all the dolls *or* all the rings) did not appear until 18 months of age. By 24 months, sequential selection of similar objects extended to both classes and objects within a basic category were spatially grouped. Finally, whereas all but one of the younger children who grouped two classes at any point in the experiment arranged the objects one class at a time, more than half the 30- and 36-month-olds shifted between classes as they sorted. These children clearly could attend to both classes at once. Whether they constructed one-to-one correspondences between dis-