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ABSTRACT

The author attempts to analyze and synthesize the literature on the development of conservation (Piaget) in children in order to aid its use as a routine assessment instrument of an important aspect of cognitive development. The nature of conservation, a review of the literature, task variables, and training variables are discussed. The author concludes that performance on a conservation task is a reliable tool for specifying the level or stage at which the child is functioning; and that it is suitable for further research purposes (obtaining a rank ordering among subjects in a sample based on one facet of their cognitive ability.) Document EC 031 245 discusses the research project conducted. (CD)

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The Development of Conservation in Children: A Review of Theory and Practice

Cynthia Roberts

University of Texas at Austin

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A Review of Theory and Practice

Cynthia Roberts
University of Texas at Austin

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Cynthia Roberts
University of Texas at Austin

Preface

Although many traditional conceptions of mental ability characterize it as a single, global factor, a more general notion--and one particularly attractive to investigators of non-normal children--is that there are many component abilities which make up a person's total cognitive capacity and that these are theoretically separable from each other (even though they may all develop virtually in lock step in a normal child). If such a conception of mental ability is accurate, then the task of mental assessment is to locate an individual simultaneously on a number of dimensions, each dimension indexing the development of some cognitive ability, skill, strategy, or what-have-you.

Working within such a framework, a developmental psychologist is very soon attracted to the conservation tasks described by Piaget In most general terms, the development of conservation by a child would seem to signal a cricial step in the ability of the child to coordinate sensory input with his already accumulated knowledge about the world. From a practical aspect, these tasks have been empirically replicated and explored by a very large number of investigators and thus they should be prime candidates for incorporation into a reliable, standardized battery of assessment devices However on closer inspection of the conservation literature, a number of apparent contradictions and anormalies seem to present themselves. Therefore, the purpose of this paper is to attempt an analysis and synthesis of this literature in order to aid its use as a routine assessment instrument of an important aspect of cognitive development.

W.S.
S.S.

The Nature of Conservation

Conservation can be described as the cognition that certain properties of a substance remain invariant in spite of transformations of other properties. An example of conservation of substance is the knowledge that the amount of clay in a lump will be the same regardless of the shape into which it might be molded. As we shall see, several different types of materials and procedures have been used in the study of conservation, but the general form of the task has been characterized succently by Elkind (1967):

> "Regardless of the content of these problems, they routinely involve presenting the subject with a variable (V) and a standard (S) stimulus that are initially equivalent in both the perceptual and the quantitative sense. The subject is then asked to make a judgement regarding their quantitative equivalence. Once the judgement is made, the variable stimulus is subjected to a transformation $V \rightarrow V'$, which alters the perceptual but not the quantitative equivalence between variable and standard. After completion of the transformation the subject is asked to judge the quantitative equivalence between the standard and the transformed variable. The entire problem can be symbolized in the following way: $S = V$, $V \rightarrow V'$, $S=V$

Cognitive development is thought by Piaget to be a sequential development through 4 distinct stages There are two important parts to this statement. First, the notion of "stage" is, according to Piaget, a real phenomenon Any one stage represents an internally consistent logical system: a set of operations that changes qualitatively from stage to stage. The second important point is that development is sequential The stages identified by Piaget are, beginning with the first: sensorimotor (0-2 years); preconceptual or intuitive (4-7); concrete operational (7-11); and formal operational (11 and older). Since the child locks at the world and solves problems in qualitatively different ways in the different stages, certain kinds of responding in a problem solving situation such as that presented by the conservation task, should reflect his current stage of development. Piaget has found the conservation task to be a reliable indicator of this development. A young child who is functioning in the sensorimotor or preconceptual stage will solve the conservation problem on the basis of sensory-motor structures; that is, he relies on perceptual features of the array. A child at a more advanced stage reasons with concrete operations; that is, his mental operations are based on rules about objects. He knows that an object s fatness is compensated for by its tallness (compensation). He knows that an object can be perceptually transformed and still be the same as it had been in amount or weight (identity) or that it can be reshaped to its former self (empirical reversibility). He acquires this new means of problem solving as he develops the ability to consider more than a single dimension of an object or a property or problem, at any one time. That is the preconceptual child can process only so much information--he abstracts invariance that is most salient for him. Since the larger part of his experience with the world has been sensorimotor, he attends to perceptual features, and uses sensorimotor operations in problem solution. But because he accommodates (and assimilates) each new experience he becomes aware of variance and invariance in other object properties and develops a new set of logical operations that will include these new considerations The concrete operational stage is "the first coherent system of mental operations with which the child can solve problems involving manipulations of concrete materials " (Piaget, 1968). The conservation problems are offered by Piaget as an index of whether or not the child has yet developed this "coherent system of mental operations."

In the earliest phases of conservation (4-6 years) the child relies on perceptual cues; he might judge that the lump of clay transformed from a ball to a sausage now has more clay because it is longer. His judgements are based on "imitations of the perceived world" (Piaget, 1968)--a sensorimotor way of dealing with the world. In an intermediate stage of conservation, the child oscillates between concrete and intuitive operations for solving the conservation problems. He has, through his experience with the world developed some rules for problem solving but his use of these rules is guided by the stimulus situation of the moment without recourse to what has been or might be (Piaget, 1968). He might judge that the number of objects in two rows are equal regardless of their position in space until he is asked to judge the equivalence of aggregates greater than 15; he will then again rely on perceptual cues for problem solving solution (Piaget, 1968). Finally, the child is able to make appropriate conserving responses for a given property, thus demonstrating the availability of one or more of the concrete operations: identity, reversibility, or compensation (Piaget, 1968). So, general competence in solving conservation problems can be interpreted as reflecting stages of cognitive development. There are also inter-problem differences that show a developmental trend within the concrete operational stage. Inhelder (1944) has shown that in the acquisition of the conservation of matter, the child learns to conserve properties in the following sequence: substance, weight and then volume. Inhelder (1944) and Uzgiris (1964) have also demonstrated an ordinal pattern for the acquisition of conservation concepts according to the kind of material in the task so that discontinuous quantities (beads, blocks) are conserved before continuous quantities (liquids, clay). Since it is the product of problem solving by a set of rules or operations conservation is a concept that applies not only to substance, but also to number and area. Conservation is not the content of a concept, but is, as Zimiles (1966) describes it, the availability of conceptual schemes and their systematic application. Thus the child's solutions of conservation problems can tell us what stage of cognitive development he has reached and how far, on an ordinal scale, he had progressed within a particular stage.

A Review of the Conservation Literature

When the American psychologists took conservation into the experimental laboratory, they did not always obtain results consistent with the predictions of the Piagetian model. Most of the work has tended to support the invariant developmental sequence of the development of substance, weight, and volume conservation and the presence of nonconservation in younger children (Sigel & Hooper, 1968). But, many have failed to find support for the age norms specified by Piaget. Since in many applications we are not particularly interested in age norms, this is not upsetting; however, we will want to look for reasons why some researchers failed to find results consistent with the stage model. In addition, we will want to know if specific kinds of experience can significantly alter the acquisition of conservation. We should then have a base for determining whether conservation is a reliable index of cognitive development, and we should also have some notion of the kind of modifications that would make the task maximally efficient for our use.

Elkind (1961) and Uzgiris (1964) have replicated Piaget's findings of a sequential development of performance on the conservation task. They have found significant age trends (in 4, 5, and 6-7 year-old children) and support for the ordinal acquisitions according to type of material and type of quantity (discontinuous-continuous; substance, weight, volume). Lunzar (1956) and Lovell & Ogilvie (1960) have argued against the stage model of conservation development and their findings are generally non-supportive of expected age trends. Another argument against the stage model is found in the work of Bever & Mehler (1967) with children younger than 4. Because conservation is observed to be in its earliest phases at ages 5-6 and to be consistent with the stage model, it has been generally assumed that children younger than 4 would not be capable of solving conservation problems. In their study, however, children of 2 years 6 months were able to choose the row of M&M's that had "more" in it regardless of its distribution. Since the 2½-year-olds performed better than the 4-year-olds in the study, the conclusion was drawn that the operations necessary to solution of number conservation problems are available to the child from an early age, but are obscured as he becomes more aware of cue features like length or width.

Task Variables

In an attempt to understand how these different results could have been found, let us first consider differences in materials and procedures which have been employed by various investigators. Bittner & Shinedling (1968) have provided a list of several task variables that affect performance on conservation problems. Parameters like sex of _E_, kind of instructions, types of materials (clay, liquids, metals, etc.) and sex of _S_ were found to interact significantly with age to affect results. For example, female experimenters elicit the best performance from first grade _Ss_ and female first-graders perform better than first-grade males. Instructions seem to have a more drastic effect on younger _Ss_ while third grade _Ss_ are more affected by the form of the questions asked. While this kind of information is important to construction of the task for maximal control, citing these factors is not sufficient as an explanation of how they affect performance in the way they do. The effect of _E_'s or _S_'s sex may be explainable in social terms, but the effect of instructions, for instance, needs some other kind of explanation.

One procedural difference frequently referred to is whether or not the experimenter requires an appropriate explanation from S as a criterion for scoring S's responses as conserving or non-conserving. Smedslund (1961, 63, 65) for example, requires such explanations while Bruner (1966) does not. Gruen (1965) indicates that these differences can have several effects on the data: First, the chances that S will make a mistake are doubled where explanations are required since he now has two responses to make: 1) judgement and 2) explanation. Of more interest, however, are the indirect effects. Weir (1968) has shown that younger children (3 years old) are more likely to stick to one hypothesis than are older children (9 years old) in a concept learning task. In fact, older children seem to sacrifice efficiency in favor of entertaining a new plausible hypothesis. Now, if we consider this fact along with the "demand" characteristics of the situation, we can generate some interesting hypotheses about what happens when E asks S why he chose one answer rather than the other. In the case of the younger child, forcing him to articulate an explanation for his actions may lead him to use that same rule to answer all succeeding questions. On the other hand, older subjects could construe E's asking him a second question "why?", as an indication that his first response was wrong or that he should begin to use a different criterion for making his judgements. Flavell and Wohlwill (1969) point out that when a child is in a transitional stage, and so less sure of his answers, his responses will be maximally susceptible to such influence.

Another problem with the verbal features of the conservation task is the facility of S with the meaning of words like "more" and "less." Donaldson & Balfour (1968) have shown that children are much more likely to respond appropriately to "more" than to "less". That is, when asked to put "more" or "less" paper apples on one tree than on another, children (aged 3½ to 4 years) tended to make the same response irrespective of which of the two words was used in the instruction and the dominant interpretation was "more." This failure to distinguish between the two words would affect performance in the conservation task. But, even if the children are pretested for the ability to make such a distinction, the meaning of a single word like "more" can cause trouble in the task. A child's experience with the word "more" does not limit it to a numerical interpretation--more milk, more cookies, more swing. When asked which of 2 rows has "more", he may respond to the most salient feature of the array to formulate a definition for "more"--length of the row, for instance. This is especially true when E manipulates a row of objects or a clay ball or does anything to the array the child is to judge. The child may adopt as his definition for "more" that property of the array to which E is attending, so that when E shortens one row of objects and then asks "which row has more?" or "are they still the same amount?", S thinks that he should base his answer on the length of the row. Rothenberg and Courtney (1969) suggest that the results of Bever & Mehler's (1967) investigation reflected a bias "produced by asking a single, suggestive question." They go on to state that very young children, 2 and 3 years old, have a tendency to say "yes" to all of E's questions more often than do older children. A bias in the questions asked, asking questions that always require a "yes" answer to be correct, for instance, can skew the data.

So, a verbal test of conservation appears to have a great many disadvantages. And, it is often found that comparing verbal and non-verbal tasks will show different results. Bever & Mehler (1967) observed that the very young children in their study did not always choose the row with the greater number of M&M's when asked to choose the one with "more" but they did consistently choose that row when they were instructed to eat all the M&M's in the row they wanted, a response that does not require much verbal mental manipulation. Wohlwill & Lowe (1962) found that non-verbal training and testing procedures produce greater change in conservation performance than do verbal procedures. One group of children was trained to respond to the correct numerical symbol for the number of corks in a row by non-verbal means. Before the child was a panel with several little doors, each marked with some number. A row of corks sat in front of the panel on a frame that could be manipulated to lengthen or shorten the row of corks. Behind the appropriate door was placed a token reward that the child could procure by opening that door. This procedure was very effective for leading the children to "absolute" conservation (Wohlwill & Lowe, 1962). Verbal training required the other group of children to practice counting different arrays. This procedure created little change in post-training tests of number conservation. The conclusion we might now want to draw is that nonverbal methods of testing are more reliable and a little better controlled since language is not a factor.

A final task variable we should consider is the problem Elkind (1967) refers to as identity vs equality. Judging that some perceptually transformed quantity is the "same" as the standard requires one more logical inference than judging that the transformed quantity is still the "same" as it was. Elkind (1967) represents the problem in the following way:

Identity:	$S = V$	Equality:	$S = V$
	$V \rightarrow V'$		$V \rightarrow V'$
	$V = V'$		$V = V'$
			$V' = S$

<u>S</u>tandard
<u>V</u>ariable

It was mentioned above that Wohlwill & Lowe (1962) found that children had learned to conserve "absolute" quantity following nonverbal training procedures. Absolute conservation meant that the children could respond appropriately to a single row of corks through a series of transformations. They could not, however, judge "relative" quantity; they could not judge whether a transformed row was the same as the standard although they "knew" that it was the same as it had been before. The distinction between identity judgements and equality judgements is not usually included in an interpretation of the results of a conservation study since the standard kinds of conservation task involve only "relative" judgements. But, the distinction is important if we want to get as much information about the child's level of cognitive functioning as possible from his solutions of conservation problem. We have seen that minor differences in materials and procedures can lead to quite different findings. These observations lead us to suggest that nonverbal tasks that include tests of conservation of continuous and discontinuous quantities, relative and absolute judgements, and problems of number, area, and matter should be included in a complete test of conservation.

Training Variables

Inhelder (1944) suggests that the rate of change is the differential that distinguishes MR performance from that of normals on the conservation task. This "rate" is gauged both over the change occurring in the test period as well as change between test periods (over months and years). Presumably differences in rate of change for normals and retardates is due to differences in the overal rate of cognitive development. Since conservation is hypothesized to reflect stages of cognitive development, it would be expected that performance on a test of conservation would also reflect developmental rather than trained trends. A number of investigators have set out to test this hypothesis by giving preconserving children various kinds of pretest experience that might influence their subsequent performance. (see Flavell & Wohlwill, 1969).

Most investigators have found it rather difficult to bring about conservation in all members of a training group. Yet, it is true that in most of the training studies, several, even as many as half, of the children conserve on a immediate post-training test of conservation where they did not in a pre-training test. Wohlwill & Lowe (1962) explored the effects of three specific kinds of training procedures on the conservation of number: reinforcement, decentration, and inference. In the reinforcement condition, children were trained and rewarded for counting aloud. Decentration training involved teaching the children to observe what happened to various object properties when a substance was transformed. A third group was given experience in addition and subtraction, a procedure designed to give the child access to the inferences necessary for a conserving response in a number task. They also included in their study a comparison of verbal and nonverbal training procedures. They found no significant differences among the training conditions (comparing pre- and post-training performance for 75 kindergarten children) in the non-verbal condition. The overall change was significantly different from zero, however, showing that for the total group conservation did increase for the nonverbal set. There were, on the other hand, very few changes in any group with respect to verbal conservation. Wohlwill & Lowe (1962) were thus led to suggest that such specific training procedures as they employed affect conservation acquisition in a "limited, nonconceptual way" or that, as quoted earlier, such training enhances the learning of conservation of absolute numbers but not of relative numbers.

Wallach and Sprott (1964) were more successful in training children to conserve number. They combined verbal and non-verbal techniques to train children in the use of reversible operations. The children were given an equal number of dolls and beds to which the dolls could be fitted. Then E altered the length of one row, either dolls or beds, and asked if each doll still had a bed. The training continued until each S in the training condition made 4 successive correct judgements. All but one of the 15 experimental and none of the control subjects conserved on a test of number conservation following the training period. Brisen (1967) used a similar technique to show children that perceptual changes of liquid quantity were reversible. Half of his experimental group conserved continuous quantity following the training while only 1 of 26 control subjects conserved on that post-test.

Thus far, we might conclude that training a child in the use of one of the necessary concrete operations is an effective way to induce conservation in a non-conserving child. Wohlwill & Lowe (1962) did not find training in decentration (or compensation) to be an effective procedure, but their results suggest that the children may have learned to use an identity operation. Wallach& Sprott (1964) apparently affected conservation by training children to use a reversibility operation. What it amounts to is giving children experience that underlies conservation. We would expect that conservation thus acquired would be of a "limited, nonconceptual nature," as Wallach & Lowe (1962) report. Wallach & Sprott (1964) report that there were no transfer of training effects to a conservation of liquid quantity task. Brison (1967) did not test for any generalization or transfer of training but confined his post-test to materials similar to those in the training condition (continuous quantities like clay and liquid). Tasks designed to train children in the use of particular concrete operations do not apparently affect the cognitive structure underlying conservation. Rather, their effects are limited to teaching children the solution to a particular problem.

An alternative training procedure is to give children experience with certain other operations, like measurement, that are involved in conservation but not specifically responsible for an appropriate conserving response. Wohlwill and Lowe (1962), as discussed above, have shown that practice in counting and training in addition and subtraction do not significantly affect conservation. Gruen (1965) also failed to induce conservation by teaching children to count. Bearison (1969), however, has been successful in getting kindergarten children to conserve by training them in some specific measurement operations. He focused on training the children to conserve continuous quantities in terms of numeration of discrete units of liquid quantity. The children were shown that a quantity could be divided into equal parts and then returned to its original shape. The training trials involved getting the subject to measure the amount of liquid in a large glass by the number of small glasses from which the liquid was poured into the large glass and then the reverse operation, counting the number of small glasses into which the liquid from the large glass was poured. A one-month post-test showed approximately 47% of the experimental and 10% of the control subjects to have shifted from non-conservation to conservation on a variety of tasks; 7 months later the percentages were approximately 75% and 30%. Bearison interprets the acquisition of conservation as the development of a quantitative set which supplants a perceptual set for solution of the problem. And, the evidence of his investigation suggests that measurement operations, that is, understanding that mass is composed of a set of equal and discrete units coupled with the ability to count those units is the source of the shift from perceptual to quantitative sets. This kind of training, then, is not the teaching of a particular rule. Rather, it serves to accelerate the normal transition from one cognitive stage to the next; at least for one kind of problem solving.

Smedslund (1966) has tested another technique for inducing conservation--cognitive conflict. That is, he has focused on bringing two cognitive schemes into conflict in the solution of the problem. In a representative study (1966), he changed the shape of a clay ball and also added or subtracted clay. Apparently, however, this procedure did not bring the perceptual and addition/subtraction schemes into conflict since the subjects consistently used one scheme or the other in solving the problem.

The weight of the evidence from studies of training is in support of the hypothesis that the cognitive structure underlying particular types of responding on the conservation task (that is, that the set of operations with which the child solves problems) is not significantly altered by any specific kind of experience. Conservation is not "acquired" as a concept, but is dependent on the development of cognitive structures that make available the necessary operations and their "systematic application" (Zimilies, 1966).

Conclusions and Suggestions

The preceding portion of this paper is structured around the conclusions we want to draw with regard to devising and using a conservation task to yield information about the level of cognitive development of the subjects in our study. We have concluded that conservation does, indeed, reflect a way of thinking rather than some conceptual content. And, it has been concluded that performance on a conservation task is a reliable tool for specifying the level or stage at which the child is functioning. We can, therefore, now conclude that a conservation task is suitable for our purposes--obtaining a rank ordering among the subjects in our sample based on one facet of their cognitive ability.

Specific suggestions about the nature of the task that would be most profitable for us can also be drawn as conclusions from the above discussion. 1) The task should be nonverbal since language seems to have extensive influence on performance without telling us anything more about underlying competence than we can determine by nonverbal means. 2) We should include tests of conservation of number, matter and possibly area in order to have as much information as possible about the reliability of any one test. 3) We should include tests of both an identity and an equality nature, since equality or relative quantity judgements seem to be more difficult than identity judgements. We can be fairly confident that data thus achieved will be reliably representative of this aspect of the child's cognitive development.

A Norm Scale for Assessing Conservation

Goldschmid and Bentler (1968; Goldschmid, 1967) have developed a conservation scale, and made available a test kit with 2 parallel forms of the scale. Each form consists of 6 conservation tasks: 2 items for number conservation; 1, substance; 1, continuous quantity (volume); 1, discontinuous quantity (volume); and 1, weight. Scores on the tests are derived from both behavior and explanation. The 2 forms were constructed from a larger set of items (43) administered to 143 kindergarten, first- and second-grade children. The 6 items for the scale were selected by applying a technique called "Multideminsional Homogeneity Scaling" (Bentler, 1966) aimed at identifying an ordinal scale of responding. The scale was then cross validated with a new sample of 107 children, and the scale was found to maintain "high levels of internal consistency and homogeneity." (Goldschmid & Bentler, 1968). In an earlier study of conservation and its relation to age, IQ, and vocabulary, Goldschmid (1967) reported that his results "both support Piaget's theory of age-dependent cognitive development for normal subjects and suggest significant individual differences within a given age group."

While this scale possesses most of the properties deemed desireable in the preceding section, there is one aspect of it which makes it, as it stands, not optimal for our uses with retarded children. This is the fact that it yields an age norm score for each child eventhough in the passage quoted above Goldschmid reports "significant individual differences within an age group" in underlying behavior. We feel that it would be much more useful for the scale merely to indicate in which conservation stage the child was currently operating. Since the reports of the test's construction indicates that the items stand fairly strictly in an ordinal relation to one another, it should not be too difficult merely to score the test for stage of development rather than for age norm.

A final suggestion for further development of this scale would be to enlarge it into an ordered but multiply-branched set of items. As long as a child correctly responded to each succeeding item in the "main line" of the test, he would progress along that main line. However upon missing one of these, he would then be given a set of supplementary items to reveal details about why he missed that item, and to further diagnose the exact intermediate stage of conservation at which he was presently operating.

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Post Script

An important conclusion reached by the above review is that a certain maturational level must be reached before a child will display conserving behavior of any generality. Undoubtedly, some appropriate environmental stimulation must also be present during maturation for conservation to appear, but it is difficult or impossible to teach a child to conserve before he is ready to learn. This sort of joint dependence of a behavioral phenomenon on both maturation and environmental influences closely mirrors current views of language acquisition. This, then, adds to our intuitive feelings that the emergence of conservation reflects something quite basic about cognitive development (as does the emergence of language). Thus, we feel it is important to look at the relation between the development of these two cognitively-based phenomena in order to get further insight into the more general question of the relation between verbal and non-verbal cognitive processes.

Our present theoretical notions are still too muddled to generate coherent hypotheses about conservation being necessary for certain aspects of language development to occur, or vice versa; however if any such idea appeared to be empirically supportable, either among normal or retarded children, an important step would have been made toward clarifying the nature of overall cognitive development.

WS
SS