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ABSTRACT

This paper briefly reviews the literature concerning the Paiget-Burner debate over the roles of identify and reversibility rules in conservation acquisition, and describes an experiment designed to determine whether one group of rules is more closely related to conservation than the other. A group of children, aged 4-6 years, received tests of inversion, reciprocity, qualitative and quantitative identity, and conservation of liquid, weight, and length. A total of 75 of these children, who showed no evidence of conservation but exhibited considerable variability on the four rule tests, were selected for the experiment. Of these, 50 experimental subjects were trained to acquire liquid quantity conservation via an elementary feedback procedure. The 25 control subjects received the same liquid quantity problems during training trials, but feedback was omitted. In a posttest one week later, subjects were readministered the liquid, weight and length conservation tasks. Performance of the trained subjects in all areas was far superior to their controls. It was determined that prior knowledge of Piaget's inversion rule was an excellent predictor of conservation learning, and that neither Bruner's nor Piaget's analyses of conservation appears to be entirely correct. (ED)

PRIOR KNOWLEDGE OF RULES IN CONCEPT LEARNING*

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There has been a debate going on during the past few years over the precise role played by certain rules in the acquisition of Piaget's ubiquitous conservation concepts. Piaget, as is widely known, has long maintained that his two forms of reversibility, inversion and reciprocity, are chiefly responsible for conservation. The second of the two reversibilities usually is called "compensation" in the North American literature, and I shall henceforth adopt this usage. Bruner, on the other hand, has proposed that the development of conservation is more directly dependent upon a prior grasp of the identity rule than it is upon a prior grasp of the reversibilities (cf. Bruner, Olver, & Greenfield, 1966, Chapter 9).

Insofar as the historical origins of this disagreement are concerned, Bruner fired the opening salvo in 1966 when he observed that "On purely logical grounds, we believe [Piaget] has missed the heart of conservation. Both inversion and compensation to be effective must rest upon an appreciation of the original quantities involved ... compensation and inversion, it can be argued even more forcefully, depend on the maintenance of some primitive identity ... Such identity can be illustrated by the case in which one uses, say, a single quantity of liquid, first contained in a standard beaker, then poured into another that is taller and thinner. The only 'similarity' between the two is achieved through maintenance of their identity [Bruner, Olver, & Greenfield, 1966, p. 185]."

Bruner then presented two lines of evidence to support these claims. The first was an experiment conducted by Patrician Nair in which five-year-olds' grasp of liquid quantity conservation was compared with their

grasp of liquid quantity identity. It was observed that children invariably comprehend identity before conservation. Unfortunately, logic suggests that such data do not suffice to demonstrate that knowledge of identity is intimately connected with the acquisition of conservation: Children invariably grasp concepts such as "up," "down," "over," and "under" before they grasp conservation, and yet no one would suppose that these concepts are somehow responsible for conservation. In addition to this logical problem, Nair's data obviously do not establish that identity is more important than reversibility because there is no consideration of reversibility. Bruner's second line of evidence was the results from Francoise Frank's perceptual screening procedure for inducing conservation in previously nonconserving subjects. In Frank's procedure, the identity transformations which the child sees in the classic conservation paradigm are carried out behind an opaque screen. Conservation questions are posed in conjunction with the screened transformations. After several such trials, classic liquid quantity posttests are administered. Frank found this procedure to be a very effective technique for inducing conservation: Roughly one-third of a sample of 40 nonconservers evidenced conservation on the posttests. Since identity training was not compared with reversibility training in Frank's design, it follows that the pretest-posttest improvements do not tell us anything about the relative importance of identity and reversibility in conservation acquisition. Worse, they do not even tell us that identity training induces conservation. Several investigators have attempted to replicate Frank's experiment since Bruner's book appeared. No one, at least so

far as I know, has been able to do so. At present, the most reasonable explanations of Frank's data are repeated testing effects (there were no control groups in the experiment) and Type I measurement error on the posttests.

Piaget answered Bruner's proposals and data about identity in the way he usually replies to his critics--obscurely. Instead of attacking the data, which certainly do not prove Bruner's thesis, Piaget decided to proliferate constructs. He argued, in a review of Bruner's book published in 1967, that Bruner had failed to distinguish between so-called "empirical reversibility" and so-called "logical reversibility." The former is analogous to cyclic transformations in physical systems (e.g., thermal expansion and thermal contraction), while the latter is analogous to inverse operations in set theory and reciprocal operations in ordinary arithmetic. Piaget argued that Bruner's statements about reversibility were principally concerned with empirical reversibility and, since Piagetian theory deals only with logical reversibility, these statements perforce are not sound objections to the theory. The "two reversibilities" distinction, at the time when Piaget introduced it, was completely rhetorical. In 1967, no data existed which showed either that (a) there are distinct physical and logical reversibility rules in children's thinking or that (b) physical and logical reversibility are differentially relevant to conservation. Moreover, a very recent study by Gladstone and Palazzo (1974) failed to provide any evidence for the existence of two reversibilities which are differentially related to conservation.

Piaget raised one other objection to Bruner's claims about

reversibility, identity, and conservation. In the second of two addresses delivered at Clark University during 1967, he proposed that Bruners' identity concept is a strictly qualitative notion. He claimed, more particularly, that the identity concept consists simply of understanding that the transformed stimulus is somehow "the same" as it was before transformation. In view of the fact that conservation obviously is a quantitative notion, Piaget concluded that the proposed connnection between identity and conservation is doubtful. This line of reasoning, besides begin elliptical, is blatantly unfair. Bruner clearly intended that his notion of identity should be viewed as a quantitative concept. Essentially, he accepted Elkind's definition of identity (cf. Bruner, Olver, & Greenfield; 1966, pp. 185-186). Anyone who wishes to confirm the quantitative nature of Elkind's definition has only to check his classic paper (Elkind, 1967) or a recent review of the literature which his paper generated (Brainerd & Hooper, 1975). Despite the fact that Piaget misconstrued Bruner's identity concept, I think it is empirically and heuristically useful to distinguish the roles played by two types of identity rules--one qualitative and the other quantitative--in conservation acquisition.

What does the literature tell us about the respective roles of identity and reversibility rules in conservation acquisition? Not much as it turns out. We know a good deal about the developmental relationships between identity and reversibility, on the one hand, and conservation, on the other. Available data seem to show that conservation is preceded in children's thinking by the inversion rule (e.g., Brainerd, 1972), the compensation rule (e.g., Brainerd, 1975; Curcio, Kattef,

Levine, & Robbins, 1972), the qualitative identity rule (e.g., Papalia & Hooper, 1971), and the quantitative identity rule (e.g., Brainerd & Hooper, 1975). However, we know next to nothing about the functional connections between these rules and conservation acquisition. We know the most about inversion. Many successful conservation training studies have employed inversion as part of their training treatments and, consequently, most reviewers of this literature have tended to conclude that prior knowledge of inversion is probably essential for conservation (cf. Beilin, 1971; Brainerd, 1973; Brainerd & Allen, 1971; Glaser & Resnick, 1972). The data on the compensation rule are contradictory. Curcio et al. (1972) reported that prior knowledge of compensation greatly increased nonconservers' susceptibility to conservation training. However, I have not been able to replicate this finding in my laboratories (Brainerd, 1975). The data on the two identity rules also are contradictory. I mentioned earlier that investigators have not met with conspicuous success in their attempts to replicate Frank's identity training experiment. The only clearly successful identity training experiment of which I am aware is a recent doctoral thesis by B. O. M. Riksen (Hamel & Riksen, 1973). Riksen was able to produce conservation in previously nonconserving subjects by teaching them a combined qualitative identity and quantitative identity verbal rule. Unfortunately, Riksen's data do not tell us whether qualitative identity alone, quantitative identity alone, or some interaction of the two produced the observed improvements.

In brief, existing data provide insufficient grounds for concluding that prior knowledge of compensation, qualitative identity, and quantitative

identity are essential for conservation. Worse, they provide no information about the relative importance of reversibility rules and identity rules. This question, after all, is the crucial issue. The thrust of Bruner's argument is that reversibility rules are less important vis-à-vis conservation than identity rules--not that they are entirely irrelevant. Thus, what we really need to know is not whether reversibility rules and identity rules are related to conservation in an absolute sense, but, rather, whether one group of rules is more closely related than the other.

What type of study would be required to evaluate the relative importance of reversibility rules and identity rules? A training experiment of some sort seems to be the most logical approach. Developmental studies are subject to the functional limitations discussed earlier. Correlational studies, in which the amount of statistical covariation between each of the rules and conservation is estimated for large samples of subjects, suffers from the problem that a rule-conservation correlation does not necessarily imply causation, and, even if it did, we would not know anything about the direction of the cause-effect relation. The specific type of experiment that seems most appropriate may be described as consisting of five general steps. First, we would administer reversibility rule tests, identity rule tests, and conservation tests to a large sample of children. Second, on the basis of performance on these tests, we would select a subsample of children who show some variation on the rule tests but who show no evidence of conservation. Third, we would divide the subsample into experimental and control conditions, and train the subjects in the former group to acquire conservation. The training

treatment should satisfy two general criteria: It should be a manipulation that already is known to induce conservation, and it should be informationally neutral with respect to the identity and reversibility rules (i.e., it should not make use of either rule to train conservation). Fourth, after the training trials have been completed, we would readminister the conservation tests. Fifth, if the experimental subjects' conservation performance is significantly better than the controls', we should correlate the experimental subjects' pretraining rule performance with both their training trials performance and their posttraining conservation test performance. Each of these correlations provides an estimate of the extent to which conservation acquisition depends on prior knowledge of a given rule.

I should now like to report the findings of a recently completed experiment which conforms to the scheme just outlined. We began with a sample of 150 children between the ages of four and one-half and six. The children were administered tests of inversion, reciprocity, qualitative identity, and quantitative identity. They also were administered tests of liquid quantity conservation, length conservation, and weight conservation. After the rule tests and the conservation tests had been administered, 75 children were selected who showed absolutely no evidence of conservation but who showed considerable variability on the four rule tests. Fifty of these children were assigned to an experimental condition, and the remaining 25 served as controls. The fifty children in the experimental condition were trained to acquire liquid quantity conservation via an elementary feedback procedure. Classic liquid quantity tests were administered during the training trials, and appropriate

questions were posed by the experimenter. The subject was corrected whenever he or she made an erroneous judgment, and the subject was given a (candy) reward whenever he or she made a correct judgment. The control subjects received the same liquid quantity problems during the training trials, but feedback was omitted. One week after a given subject had received the training trials, he or she was readministered the liquid quantity, length, and weight conservation tests. The posttest performance of the experimental and control conditions then were compared.

On each of the conservation posttests, the performance of the trained subjects was far superior to their controls. The controls still showed no evidence of conservation on the posttests. In contrast, virtually all of the subjects in the training condition showed some evidence of conservation on the posttests. Moreover, roughly 40% of the trained subjects evidence perfect conservation on the liquid quantity, length, and weight areas. Thus, we may reasonably conclude two things about the training treatment. First, it induced a durable concept: The posttests were administered several days after training; so whatever the subject learned, it was not a momentary response set. Second, the treatment produced a general concept rather than a specific quantity response set: The subjects received no training in either the length or weight areas, yet their performance in these areas was far superior to the controls'. Since the training manipulation clearly was effective, we may now consider the main question, viz. the extent to which prior knowledge of identity and reversibility determines conservation acquisition.

Insert Table 1 about here

In all there were four measures of learning: (a) the experimental subjects' performance on the training trials (i.e., the ratio of "hits" to "misses"); (b) the experimental subjects' performance on the one-week liquid quantity posttest; (c) the experimental subjects' performance on the one-week length posttest; (d) the experimental subjects' performance on the one-week weight posttest. Of these, the first measure undoubtedly is the most sensitive since it is relatively independent of memory. The experimental subjects' pretest performance on each of the four rule measures was correlated with their performance on each of the four learning variables. The resulting coefficients appear in Table 1.

The empirical picture which emerges from Table 1 is clear and uncomplicated. In so far as the present experimental subjects were concerned, prior knowledge of Piaget's inversion rule turned out to be an excellent predictor of conservation learning. On three of the four learning measures, the correlation between rule knowledge and the measure accounted for roughly 25% of the observed variation. On the remaining measure, length, the correlation with prior knowledge of inversion was significant, but it accounted for only a modest 6% of the variation. Performance on the remaining three rule tests did not appear to be very strongly related to conservation learning. There are a total of 12 correlations between the remaining three rules and the learning measures in Table 1. Only one of them is significant--at the .05 level. This is about what one would expect by chance alone.

Assuming, for the sake of argument, that the findings in Table 1 can be replicated, some fairly obvious conclusions follow. In the first place, the data do not provide clear support for either Bruner's or

Piaget's respective positions. Although neither Bruner's nor Piaget's analyses of conservation appears to be entirely correct, the data indicate that Piaget's analysis is nearer to the truth than Bruner's: Reciprocity did not predict susceptibility to conservation training, but inversion clearly did. In contrast, knowledge of either or both identity rules did not seem to increase a subject's chances of profitting from conservation instruction.

In closing, I should like to mention one other finding from this experiment that is pertinent to the Bruner-Piaget debate. The Bruner passage that I quoted at the beginning of this paper alleges, in addition to the claim that conservation depends on identity, that Piaget's two reversibilities depend on identity. This suggests that performance on one or both of the two identity tests should predict performance on the reversibility tests. However, when the appropriate correlations were computed, it was observed that the statistical relationships between knowledge of identity rules and knowledge of reversibility rules were about zero. Thus, the identity rules not only failed to predict conservation, they also failed to predict reversibility. This finding cannot be explained as a result of low reliability. The test-retest reliabilities of all the rule measures employed in this experiment are high (.70 to .80).

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Table 1

Correlations Between Pretest Rule Performance and the Four Learning Variables

Learning Variable	Rule Variable			
	Inversion	Reciprocity	Qualitative Identity	Quantitative Identity
Training trials	.50**	.24*	.09	.21
Liquid posttest	.45**	.19	-.03	.06
Length posttest	.24*	-.08	.08	.09
Weight posttest	.46**	.11	.16	.13

$p < .05$

$p < .001$