THE RELATIONSHIP BETWEEN LIQUID CONSERVATION AND COMPENSATION

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GELMAN, ROCHEL, and WEINBERG, DENISE HOOTSTEIN. The Relationship between Liquid Conservation and Compensation. CHILD DEVELOPMENT, 1972, **43**, 371–383. *Children in grades 1, 2, 3, and 6 were tested for their operational understanding of liquid conservation and compensation. 2 separate compensation tests were used to compare the child's ability to pour in a compensatory fashion and explain compensation. The results show that:* (a) *modifying the criterion for compensation affects the nature of the observed relationship between compensation and conservation;* (b) *individual compensation tasks are harder than the conservation one; and* (c) *the ability to explain compensation develops after the ability to explain conservation.*

Recent work on the conservation problem has focused attention on the possible role of compensation in the development of conservation (e.g., Bruner, Olver, Greenfield, et al. 1966; Larsen & Flavell 1970). The interest in this problem derives from Piaget's account of conservation (e.g., Piaget 1952, 1967, 1970; Piaget & Inhelder 1963). This paper presents a cross-sectional study of the development of liquid conservation, liquid compensation, and their relationship.

Piaget has postulated that a true understanding of liquid conservation

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derives, in part, from an appreciation of the logical multiplication of relations or the compensation principle, that is, the principle that the relevant dimensions of a given amount of liquid in a column vary inversely. Thus, for example, Piaget states, "Before there can be acceptance of the notion of conservation of the liquid . . . , there must be understanding that every increase in height is compensated by a diminution in width" (Piaget 1952, p. 13). Although Piaget views compensation as a necessary condition for liquid conservation, he does not view it as sufficient. For example, in his (1967) review of Bruner et al., identity and compensation principles are treated as pre- or corequisites of conservation. Elsewhere we also find emphasis placed on the roles of reversibility (Piaget 1970) and a proportion schema in the development of conservation: "In order to be certain that there is equality . . . it must be possible to establish a true proportion, and not merely a qualitative correlation, between the gain in height and the loss in width" (Piaget 1952, p. 16).

There are two lines of evidence that would be consistent with the hypothesis that compensation is a *necessary* but *not sufficient* condition for conservation. One is to show that children compensate before they conserve, or, in other words, that a compensation task is easier than a conservation one (cf. Larsen & Flavell 1970). The second is to show that children who conserve always compensate. A finding that some children conserve but do not compensate would be inconsistent with the hypothesis.

There have been several investigations of the role of compensation in the acquisition of liquid and other conservations. Piaget and Inhelder (1963) report 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. And, although details of the data are not presented, Piaget (1952) notes 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. Moreover, in the same study some children were able to compensate but not conserve. These findings support the hypothesis that compensation is a necessary condition for conservation. However, there are studies that do not. Acker (1968) found children who conserved but failed the anticipation task used by Piaget and Inhelder (1963). Lee (1971) used the standard liquid conservation test and a compensation test that required children to pour the same amount of liquid into different sized beakers. She found that when children were required to pass both tests in order to be judged true conservers, the proportion of conservers was reduced from 11/15 to 6/15. This suggests that the compensation task was more difficult than the conservation task for Lee's subjects.

In a study of number and liquid conservation, Green and Laxon (1970) suggest that compensation is not a prerequisite for conservation inasmuch as very few conservation explanations included compensation statements.

And, in still a different assessment of the relationship between the multiplication of relations and conservation, Smedslund (1964) presents data that fail to support Piaget's hypothesis. In Smedslund's study the child's ability to work with a matrix involving relationships was compared with his performance on discontinuous quantity and length conservation tasks. An inspection of the data reveals that 32 length conservers and 46 discontinuous quantity conservers failed to pass the multiplication of relations task.

The foregoing indicates that some studies provide support for Piaget's hypothesis on the role of compensation in conservation, whereas others do not. Note, however, that different assessments of compensation were made in the various studies. The assessments included compensation explanations on the conservation task, a matrix task, one of two pouring tasks, an anticipation task, etc. Since Larsen and Flavell (1970) find that variations in task administration and task features alter the number of children who compensate on a liquid task, it is important to determine the effect of varying the compensation tasks. Further, where similar tasks were used (e.g., anticipation and pouring tasks) the criteria employed may have differed. It is not clear from the reports what level of accuracy was required. That is, were children required to pour (or point) to exactly where the water should come or simply pour (or point) to a height which diverged from the standard in the appropriate direction? In this regard, it is of interest that Larsen and Flavell (1970) modified their conclusions about the nature of the relationship between length conservation and compensation depending on the criterion of accuracy they set.

Given the difficulty of comparing the various reports, a conclusion as to whether Piaget's hypothesis is supported would seem premature. The present study used different compensation tests and criteria in order to clarify the interpretation of previous work.

SUBJECTS

The Ss were 80 pupils in an elementary school in a middle-class suburb of Philadelphia. Twenty Ss, half girls and half boys, were randomly selected from each of grades 1, 2, 3, and 6. All Ss were white. The median ages for each successive grade were 6-6, 7-9, 8-10, and 11-9 years.

PROCEDURE

Each S was tested individually. The session lasted approximately 15 min.

Both the conservation and compensation tests were administered to all Ss. The conservation and compensation phases were counterbalanced and the two tests within each phase randomized. The Ss were randomly assigned to one of the two conservation-compensation phase orders with the restriction that equal numbers of girls and boys in each grade be included in both orders.

Conservation test.—There were two test trials involving two standard beakers (68 mm high, 81 mm wide) and two transformation trial beakers, one of which was taller and narrower (97 × 48 mm) and the other shorter and wider (54 × 127 mm) than the standard.

To start the conservation test, a child was shown the two standard beakers—one empty and the other with 150 ml of water. He was told that the beaker with water was his, the empty one the *E*'s. Then the *E* poured an equal amount of water in her beaker while saying, "Now, I'm going to give myself some water, like this. Do both of us have the same amount of (as much) water in our glasses to drink?" If the child said, "Yes," the experiment continued; if not, he was asked why and the *E* added or subtracted water until the child agreed both had the same amount. Then the *E* placed an empty transformation trial beaker on the table and said, "Now, I'm going to give myself a new glass. So I will pour my water into this new glass." After pouring the water and removing the empty beaker, she continued, "Do both of us have the same amount to drink?" If the child said, "Yes," he was asked how he knew both had the same amount. If he had difficulty explaining, he was encouraged to try. Then he was asked if he could think of any other reasons for the glasses having the same amount. If a child said the amounts were not the same, he was asked who had more or less and how he knew this. Then the *E* returned the empty standard, poured the water in the different-sized container back, and asked the child if both had the same to drink. The procedure was then repeated with the other transformation beaker. Here, and in the compensation tasks, the assignment of possession of each of the glasses was random, and the instructions were modified appropriately (e.g., the child was told the empty beaker was his).

Compensation test.—There were two tests of compensation: (*a*) the compensation-pouring test; and (*b*) the compensation-explanation test. The pouring task was one used by Piaget (1952); the explanation task was one we introduced with a view toward encouraging compensation explanations. The materials for these tests included a standard beaker (85 × 122 mm) and two test beakers, one of which was taller and narower (120 × 63 mm) than the standard and the other shorter and wider (64 × 143 mm) than the standard. Which test beaker was paired with the standard on the pouring and explanation tasks was determined randomly for each S. Thus, if, for example, a given S's pouring test involved the standard and the tall, thin beaker, then his explanation test involved the short, wide beaker and the standard.

To start the compensation-pouring test, the *E* showed the child the standard beaker with 200 ml of water in it and the test beaker which was *empty* while saying: "(Again) we're going to pretend that this is your glass of water and this is mine [points]. You have water in yours but mine is empty. So what I want you to do is take this pitcher of water and pour water into my glass so that both of us have as much to drink in our glasses."

Then *E* handed S the pitcher of water to pour. When the S was done pouring, *E* asked S how he knew that he had poured the same amount. If the water was poured to the same level as that of the standard, this was noted. Otherwise, *E* measured the amount of water poured.

To start the compensation-explanation test, *E* displayed the standard and appropriate test beakers. Each contained 300 ml of water. The S was again told that one glass was his to drink and the other was *E*'s. Then he was told "we both have the same amount (as much) water to drink. Do you think you know why?" If S said they did not have the same amount, he was asked why not and then urged to think of a reason why they might have the same amount.

It was thought that the compensation aspect of this task might be salient enough to elicit compensation explanations.

RESULTS

Chi-square analyses of the distribution of conservation and compensation scores revealed no effect of order or sex.

Conservation scores.—In order to assess the effect of using different criteria in judging a child as a conserver or nonconserver on the relationship between conservation and compensation, the obtained conservation data were classified four ways: In the first a child was judged a conserver (Con) if he indicated that the quantities were the same on both trials regardless of his explanation, a transitional conserver (TCon) if he passed one trial by this criterion, and a nonconserver (NCon) if he failed to indicate the quantities were the same on both trials. According to the second criterion a child was classified Con if he judged both trials correctly and supported his judgment with any logical explanation, TCon if he met the criterion of same judgment plus logical explanation on one trial, and NCon if he failed to give a logical explanation on either trial whether or not he judged the quantities the same. Explanations referring to reversibility, addition-subtraction, identity, compensation, or how the transformation was irrelevant were coded as logical. The agreement between two independent ratings according to the criteria in Gelman (1969) was 96%.

The third and fourth classification schemes were included in order to assess the likelihood of a child employing a compensation explanation on a conservation task. The criterion used in the third scheme allowed a child to be scored Con if he gave even a minimal compensation explanation in support of a correct judgment. The fourth scheme required a full compensation explanation. Thus, in the third scheme a child was scored as Con, TCon, or NCon depending on whether he at least made reference to the covarying relevant dimensions (e.g., "It's taller and narrower"). In the fourth scheme, the child had to explicitly refer to the inverse relationship between these dimensions (e.g., "It's taller because it's narrower"; "whenever that amount of water goes up tall, it has to be thinner"). Henceforth the third scheme will be coded as 2-dimensional (2-D) compensation, and the fourth as full compensation. The fourth scheme was included because explanations of this type seemed to reveal an understanding of compensation in terms of proportions and might therefore represent a more advanced level of ability.

Table 1 shows the results of using these four conservation classification schemes to judge children in grades 1, 2, 3, and 6 as Con, TCon, or NCon. It can be seen that there is only a slight effect of changing the criterion from correct judgment alone to correct judgment plus adequate explanation. Only two more children are classified as NCons according to the second criterion. The high correlation between these two criteria agrees with the findings of Goldschmid and Bentler (1968). In contrast, the shift from the second to the third criterion produces a notable reduction in the number of children classified Con and an increase in the number classified as NCon. Thus, 57 children are scored NCon as opposed to 19 and 21 by the first two criterial schemes. Of particular interest is the observation that only six and nine third- and sixth-grade children, respectively, meet this conservation criterion on *at least one* of the two conservation trials. Where a full compensation explanation is required, hardly any children, no matter how old, are scored Con. Even in the sixth grade there are only six children who are able to verbalize a complete compensation explanation. Finally, note that there are proportionally fewer TCons when the first two criteria are used as opposed to when the last two are used.

Compensation scores: pouring task.—This task required a child to pour the same amount of water into an empty beaker that differed in height and width with respect to a standard beaker and to explain his action. Three assessments of compensation were made. The first simply considered the nature of the child's pouring response. If he poured the water to match the water level in the standard beaker, he was scored as a noncompensator (NCp). If he correctly poured water above (or below) the standard water line, he was scored as a compensator (Cp). The second assessment made use of both the level poured and the explanation offered. To be scored as a Cp the child had to show compensation in his pouring and explain his response by *at least* referring to the covarying dimensions (i.e., a 2-D explanation). The third required a child to show compensation in his pouring and give a full compensation explanation (see conservation scoring above).

Figure 1 shows the number of children in each grade who were judged Cps according to the three criteria for the pouring task. First, it can be seen that whether or not a child is judged Cp depends on the criterion used and that a change in criterion for compensation from pouring alone to pouring + 2-D explanation to pouring + full compensation explanation increasingly reduces the number of children classified Cp. Second, the introduction

TABLE 1

SUBJECTS CLASSIFIED AS CONSERVERS, TRANSITIONAL CONSERVERS, AND NONCONSERVERS IN EACH GRADE ACCORDING TO FOUR CRITERIA OF CONSERVATION

CONSERVATION CLASSIFICATION	CRITERION OF CONSERVATION															
	Correct Judgment				Correct Judgment + Adequate Explanation				Correct Judgment + Two-Dimensional Explanation				Correct Judgment + Full Compensation Explanation			
	Grade				Grade				Grade				Grade			
	1	2	3	6	1	2	3	6	1	2	3	6	1	2	3	6
Conserver	9	13	17	19	7	12	16	19	1	1	4	6	0	0	2	3
Transitional conserver	1	0	1	1	2	0	2	1	1	5	2	3	0	2	2	3
Nonconserver	10	7	2	0	11	8	2	0	18	14	14	11	20	18	16	14

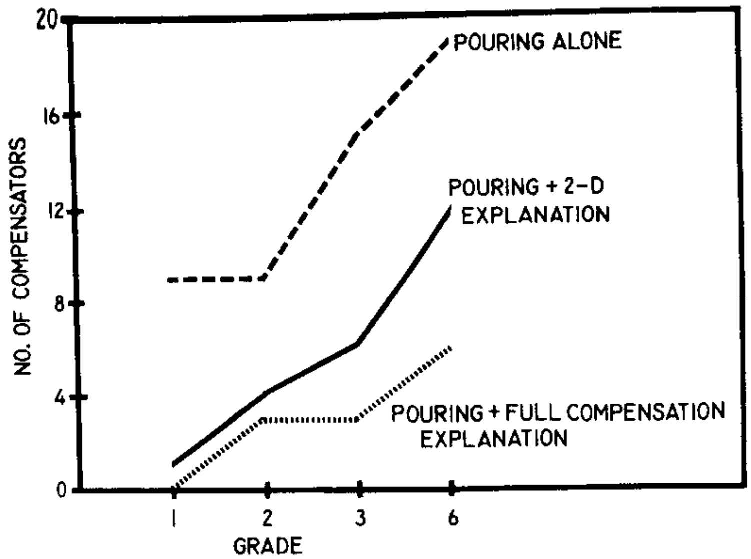

FIG. 1.—Number of children who compensate on the pouring test as determined by each of three separate criteria of compensation.

of any explanatory criterion noticeably decreases the number of children scored Cp. Finally, it is not until the sixth grade that we observe children able to verbalize compensation at all, and even these children are unlikely (6/20) to give full compensation explanations. This latter result confirms the results of the conservation test.

It is important to note that the above criteria did not require children to pour accurate amounts. It was assumed that accurate pouring probably involves experience and skill in estimation in addition to the understanding of the compensation principle. Thus, the inclusion of such a criterion could lead to an erroneously low estimate of the probability of a child using a compensation schema. In fact only 18 of 52 children poured accurately, that is, within a 10% error. That this procedure did not bias the results in favor of finding compensation (cf. Larsen & Flavell 1970) is shown by the fact that many children who met the pouring criterion given above, but did not pour accurately, provided compensation explanations. Only 11 of 23 children who met the 2-D and seven of 12 children who met the full compensation criterion also met the accurate pouring criterion.

Compensation scores: explanation task.—Here children were shown two glasses of different dimensions with equal amounts of water and told both glasses contained the same amount. They were required to explain why this might be. Children's verbalizations were scored Cp according to the two compensation criteria used in the two tasks described above (2-D explanations and full compensation explanations). Figure 2 shows these results.

As observed in the pouring task results, hardly any children are able

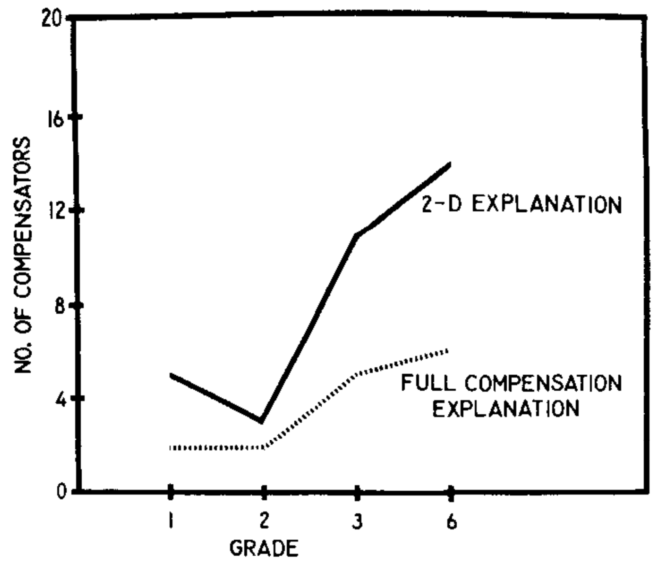

FIG. 2.—Number of children who compensate on the explanation test as determined by the two separate criteria of compensation.

to provide full compensation explanations, even in the third and sixth grades. Also more children are judged Cp according to the 2-D criterion than the full compensation criterion. And again, the ability to provide a compensation explanation develops relatively late. Although a comparison of table 1 and figures 1 and 2 shows the explanation task somewhat more likely to elicit compensation explanations, no task is very likely to do so.

Conservation and compensation performance compared.—Given the hypothesis that compensation is a necessary condition for conservation, it is of interest to assess the relative difficulty of the tasks. As indicated, for the hypothesis to be confirmed, children should either find compensation tasks easier or both kinds of problems of equal difficulty.

In the following analyses of the relative difficulty of the three separate tasks, performance on the conservation task was scored as it generally is, that is, in terms of a correct judgment plus an adequate explanation. Since these analyses were conducted with a view to deriving evidence for the order in which conservation and compensation develop, it seemed appropriate to include the earliest evidence of either conservation or compensation. Accordingly, in this instance the five TCons were classified as Cons. Similarly, if a child poured in a compensatory fashion he was judged to have passed the pouring task even if he did not meet the explanation criterion, and it was sufficient for a child to give a 2-D explanation on the explanation task.

According to the above criteria, the observed order of task difficulty was conservation, pouring, and explanation. Seventy-three of the 80 pass-fail patterns were congruent with a scaling assumption. A χ^2 comparison of the observed frequency of scaling-congruent patterns[1] against the frequency expected under an assumption of task independence supported the scaling assumption, χ^2 (1) = 13.67, $p > .001$. Green's (1956) method for a Guttman scalogram analysis yielded a consistency coefficient of .80, a finding that also supports a scaling assumption.[2]

The effect of altering compensation criteria.—As would be expected, the effect of increasing the stringency of the criteria for compensation is to increase the number of children who conserve but do not compensate. Thus, for example, if we employ an accurate pouring criterion as Larsen and Flavell did, then only 18 of 59 conservers passed the pouring compensation task.

It might be argued that as long as a child shows some evidence of compensating on any of the tasks, he should be credited with the ability to compensate. Children had four opportunities to reveal such a capacity: they could have given a 2-D or full compensation account of a conservation judgment on either or both conservation trials, or passed the pouring task by any or all of the three Cp criteria, or passed the explanation task by either of the two Cp criteria. The question of interest then is whether conservers compensated on at least one of these tasks according to any criterion. That they do is revealed by the fact that 55 of 59 conservers (as judged by the at least one adequate explanation criterion) also compensated. Further, of the 59 children who revealed evidence of compensating at least once, 55 conserved.

Thus, on the basis of this analysis, it appears that whenever a child is able to explain a conservation judgment, he will also show evidence of being able to compensate if tested in a variety of ways. However, it should be pointed out that more children pass the standard test of conservation than pass any single test of compensation.

Thus, where conservation is scored on the basis of the adequate explanation criterion, of the 59 children who conserved, only 49 passed the pouring task where pouring alone served as the criterion, and only 23 passed the pouring task where a 2-D explanation served as the criterion. In contrast, there were only three children who poured as compensators and no children who gave 2-D explanations on the same task but failed to conserve. In comparing performance on the conservation task with that on the explanation task, we observed that only 32 of 59 conservers met the 2-D explanation criterion, whereas all but one child who passed the explanation

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[1] Congruent pass-fail patterns for the conservation, pouring and explanation tasks are (+++), (++−), (+−−), (−−−).

[2] An examination of Green's formulae reveals that the use of his method with a small number of tasks ($k = 3$) may yield an underestimate of the consistency coefficient. This possibility motivated our use of the χ^2 as well as the scalogram analysis.

task by this criterion conserved. Thus, wherever the relationship between conservation and compensation is assessed by comparing performance on individual tasks, it is the case that children who compensate almost always conserve. In contrast, it is not the case that those who conserve necessarily compensate.

DISCUSSION

Our findings show that whether compensation and conservation are related as hypothesized by Piaget depends on the manner in which compensation is evaluated. If a child's conservation performance is compared with his performance on any *single* task of compensation, then no matter which compensation criterion is used, we see that conservation is easier. Even the easiest test of compensation, the pouring task, is somewhat more difficult than conservation. Insofar as these comparisons reveal children are able to conserve and not compensate, they are inconsistent with Piaget's hypothesis.

However, if one chooses to analyze our data in a way that maximizes the probability of judging a child to be a compensator, then our data could be viewed as consistent with the Piagetian hypothesis. That is, if we judge a child as a compensator when he meets at least one of a variety of compensation criteria, then we see that children who conserve almost always show *some* capacity to compensate and vice versa.

The finding that the ability to give compensation explanations is late to develop as compared with the ability to conserve is of particular interest. It suggests to us the hypothesis that, in some sense, conservation mediates compensation. It may be that the ability to verbalize a compensation rule depends on the likelihood of a child encountering examples of conservation that illustrate compensation. In many cases where a given quantity is spatially transformed, there is no obvious demonstration of compensation. Consider when a row of *N* elements is transformed into a circle, or a given amount of Play-Doh is changed from a ball to a square, etc. Some conservation situations provide clear illustrations of compensation, but it seems most do not. This may account for the observation that compensation explanations are not given in some conservation tasks (Green & Laxon 1970).

The foregoing suggests that the features of a task will affect the likelihood of a child verbalizing a compensation explanation. Larsen and Flavell's results provide evidence here. Their second graders gave a considerable number of compensation explanations of the predictions they made about water levels. Our second graders gave very few compensation explanations on either of the compensation tasks. That Larsen and Flavell used a prediction task may account for this difference. The very nature of such a task requires the experimenter to use words that could be incorporated into a compensation explanation. For example, a child is asked to answer the question, "*How high* [our italics] would it come up to?" Thus, the features of a task may facilitate the production of an acceptable explanation.

Given that the tendency of children to verbalize a compensation principle may be task specific, it seems unwarranted to rely on explanation data alone in assessing the onset of the ability to compensate. But if we accept nonverbal criteria such as pouring behavior, one might object that this is inconsistent with requiring explanations on conservation tasks. On the one hand we require concrete operations to be revealed in the verbal domain, and on the other hand, we do not. A consideration of the pouring and conservation tasks suggests that this apparent inconsistency may lie in the relative ambiguity of responses elicited in each task. When a child, on his own, pours liquids in a compensatory way, it is difficult to argue that he is not in some sense applying a compensation rule, whether or not he can explain it. But a child's judgment of "same" after a transformation in the conservation test, may derive from a *de novo* estimate of the quantities or from the belief in the conservation of identity (Elkind 1967) rather than the application of the invariance rule which Piaget wishes to test. Verbal explanations can resolve this ambiguity. To the extent that a nonverbal criterion is unambiguous, it would seem appropriate to use it. These considerations may account for the fact that Piaget accepts nonverbal criteria of compensation (Piaget 1952, 1967) but not conservation.

To summarize, compensation as assessed by any one test or criterion we used is more difficult than conservation. And, the understanding of the compensation principle, as manifested in verbal statements, continues to develop well after the age at which liquid conservation may be taken for granted.

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