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ABSTRACT

Reported is a study of the development of conservation and measurement concepts, with reference to certain task factors which may affect performance. A group of 129 first and second graders were given a test of conservation and measurement consisting of five problem types crossed with three transformation types. The problems all involved moving liquid from one of two identical containers into a container of a different shape. The dominance of perceptual versus numerical cues was varied by using clear and opaque containers, by measuring out the liquid using equal or unequal units, and by varying the order of the cues. The transformations were those making equal quantities appear unequal; those making unequal quantities appear equal; and those appearing to reverse the direction of inequality between two quantities. Achievement models were proposed and tested by multivariate analysis of variance. Results indicated that numerical cues were as significant as perceptual cues in most conservation problems; that measurement was meaningful to the majority of the children tested; and that order and equivalence problems were of equal difficulty. (MM)

THE RELATION BETWEEN THE DEVELOPMENT OF CERTAIN CONSERVATION AND MEASUREMENT CONCEPTS

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The purpose of this investigation was to determine the effect of certain factors on the development of conservation and measurement concepts. Specifically, three basic factors were investigated: 1. Whether conservation failures are a result of young children's dependence on perceptual comparisons. 2. Whether the relation between quantities being compared affects performance on conservation and measurement problems. 3. Whether recognition of compensating relationships between dimensions plays any significant part in conservation judgements.

Piaget, Inhelder, and Szeminska (1960) have described the earliest stages in the development of conservation and measurement concepts as characterized by a complete inability to conserve or apply measurement processes and a total dependence on one dimensional perceptual judgements. Conservation and measurement concepts develop gradually as children become increasingly less dependent on a single immediate dominant dimension.

For Bruner, Olver, and Greenfield (1966) this reliance on the perceptual aspects of an event is the single most important factor contributing to conservation errors. They conclude that conservation errors occur because the immediate perceptual properties of the conservation problems override the logical properties that imply conservation and that conservation would occur if the factors that contribute to this "perceptual seducation" were removed from the conservation problems.

There is some evidence, however, that young children may not be strictly dominated by the perceptual qualities of a situation. The results of an earlier study (Carpenter, in press) indicate that young children respond to numerical cues with about the same frequency as perceptual cues; and the results of a study by Bearison (1969), in which measurement operations were used to teach nonconservers to conserve, imply that young children may attend to certain numerical cues even more readily than perceptual cues.

By comparing young children's performance on conservation problems, in which all cues were visual, with their proformance on measurement problems in which certain cues were visual and others numerical, the current investigation attempted to determine whether conservation errors are a function of perceptual dependence or simply result from children centering on the last cue available to them.

The second factor investigated in this study was the effect of equivalence and order relations on performance on conservation and measurement problems. Traditionally conservation problems have involved comparisons of equal quantities that are subsequently transformed to appear unequal. Saltz and Sigel (1967) noted a tendency of young children to overdiscriminate and look for differences where differences do not exist. It could be hypothesized that this tendency to seek inequality is a significant factor contributing to conservation errors.

In the study cited above (Carpenter, in press) measurement problems in which unequal quantities were compared were significantly easier than corresponding problems in which equal quantities were compared. Similar results favoring inequality in conservation studies were reported by Beilin (1968), Piaget (1968), and Rothenberg (1969); however, experimental variables appeared to favor the nonequivalence situations in the Beilin and Rothenberg studies.

On the other hand, Zimiles (1966) found no significant difference between conservation items due to different relations between the number of objects in the sets being compared, and an analysis of individual items in studies by Carey and Steffe (1968) and Harper and Steffe (1968) indicates no clear cut difference between relations.

Several factors may explain this rather mixed collection of results regarding the role of equivalence and order relations in conservation and measurement problems. First, certain of the nonequivalence problems may not have required true conservation judgements. For example, if unequal quantities are made to appear equal by measuring them with different size units so that they measure the same number of units, it is still possible to accurately compare the quantities on the basis of unit size with no reference to the previous state. Second, although there does not appear to be any difference in difficulty between equivalence and nonequivalence problems with discrete objects, equivalence nonequivalence differences may exist for contin ous quantity problems, where precise judgements of equality are more difficult than judgements of inequality.

This study investigated whether there are significant differences between young children's performance on conservation and measurement problems due to three different relations: 1. Equivalence: Equal quantities were transformed to appear unequal. 2. Nonequivalence I: Unequal quantities were transformed so that the dominant dimension in each quantity (height of the liquid in conservation problems, number in measurement problems) was equal. 3. Nonequivalence II: Unequal quantities were transformed so that the direction of the inequality appeared to be reversed.

As noted above for most Nonequivalence I problems the correct relation between quantities can be determined from the distracting cues by simply focusing on the second dimension. To determine whether any differences favoring Nonequivalence I were simply the result of this sort of pseudo-conservation, the study also assessed differences between relations in measurement problems in which it was not possible to visually distinguish the larger unit.

The third factor this study investigated was the importance of recognizing that an increase in one dimension of a quantity is compensated for by a decrease in another dimension to young children's conservation judgements. Piaget (1952) asserts that this recognition of compensating relationships is a significant factor in the development of conservation. By contrasting measurement problems in which it was possible to visually distinguish this compensating relationship to problems in which it was not, this study attempted to provide some insights as to the importance of this factor for young children's conservation judgements.

Finally, the study investigated young children's understanding of the following basic measurement concepts: 1. Two quantities are equivalent if and only if they measure the same number of units, and a quantity is less than a second if and only if it measures fewer units of measure. 2. In order to compare quantities on the basis of measurement, the same unit must be used to measure both quantities. 3. When equivalent quantities are measured with different units, an inverse relation exists between unit size and the number of units.

Method

Items

In order to investigate the above questions, 13 conservation and measurement items were administered to a group of 129 first and second graders. The items consisted of five basic types of problems crossed with the three relations described above.

The first set of problems involved the classical liquid conservation problem in which one of two identical containers of liquid is poured into a taller narrower container.

The second set of problems differed from the first in that the two quantities of liquid were measured into opaque containers using different size units of measure; therefore, the distracting cues were numerical rather than visual. For example, two equal quantities of liquid in identical containers were measured with different units so that one measured five units and the other measured four. Responses based strictly on the number of units or the unit size would lead to errors similar to those in the conservation problems. However, if judgements were based primarily on perception, it would follow that this set of problems would be significantly easier than the corresponding conservation problems, or at least the majority of incorrect responses would result from centering on the size of the unit.

The third set of problems was identical to the second except that it was not possible to visually distinguish the larger unit.

In the fourth set of problems quantities were measured into different shaped containers using a single unit of measure. The final state was identical to that in the conservation problems. The difference between this set of problems and the conservation problems was that in these problems the correct cues were numerical rather than visual. If young children are perceptually dominated it would follow that these problems would be significantly more difficult than the corresponding conservation and measurement problems in which the correct cues 're visual.

The fifth set of problems was designed to test the effect of the order of the cues. It was similar to the fourth except that the order in which the cues appeared was reversed. The quantities of liquid started out in the different shaped containers and were measured into opaque containers using the same unit of measure.

Each of the first three sets of problems contained three items: an

Equivalence item, a Nonequivalence I item, and a Nonequivalence II item. The fourth and fifth sets each contained two items, an Equivalence item and a Nonequivalence II item. In the second set, for example, for the Equivalence problem equal quantities were measured with different units so that one quantity measured three units and the other measured five. For the Nonequivalence I problem two unequal quantities both measured three units, and for the Nonequivalence II problem the smaller quantity measured four units and the larger measured three units.

Subjects

This study was run over a nine day period in the spring of 1971. The subjects for the study were selected from three of the five first grade classes and two of the five second grade classes in one of the two elementary schools in Edgerton, Wisconsin. The sample, which included all students in the five classes except three who were absent on the testing days, consisted of 75 first graders and 54 second graders.

Procedures

In order to keep the number of tasks administered to each subject reasonably small, items were split into two groups and each group was administered to a different set of subjects. Subjects were randomly assigned to one of the two groups, 61 to Part A and 68 to Part B. The 61 subjects in Part A received the complete set of conservation problems and both sets of problems in which quantities were measured with different units. Each of the three sets of problems were administered with each of the three relations. The 68 subjects in Part B received all four types of measurement problems with both Equivalence and Nonequivalence II relations. Thus, there were a total of nine problems in Part A and eight in Part B. Each subject within each group received the same basic set of problems; however, the order of the problems was randomized for each subject.

All items were administered in a small room apart from the classroom by one experimenter, who was a stranger to the subjects. Each subject sat at a table opposite the experimenter. Procedures and protocols were kept as consistent as possible between items; however, certain procedures were randomly varied between subjects in order to control for responses based on experimental variables.

To control for a tendency of young children to respond to the last choice available to them, some subjects were always asked if quantities were the same or if one had more, and for others the "more-same" order was reversed. Similarly, for some subjects the smaller quantity was always measured first in the nonequivalence problems, and for others the larger was always measured first. Both of these variations were randomly assigned to subjects.

Design

Part A of this study was a 3 X 3 repeated measures design. The factors were problem type (conservation and the two measurement problems with different units) and relation (Equivalence and Nonequivalence I and II). Based on the results of a pilot study and the results of earlier studies, the model represented in Table I was hypothesized.

Table I
Hypothesized Item Means for Items in Part A

Problem type	Relation		
	Equivalence	Nonequiv. I	Nonequiv. II
Conservation continuous quantity	$\mu + \theta + \alpha$	$\mu + \theta + \alpha + \gamma + \delta$	$\mu + \theta + \alpha$
Measurement with distinguishably different units	$\mu + \theta$	$\mu + \theta + \gamma$	$\mu + \theta$
Measurement with indistinguishably different units	μ	μ	μ

Part B of this study was a 2 X 4 repeated measures design. The factors were problem type (all four measurement problems) and relation (Equivalence and Nonequivalence II). As in Part A a model was hypothesized (see Table 2).

Table 2

Hypothesized Item Means for Items in Part B

Problem type	Relation	
	Equivalence	Nonequiv. II
Measurement with distinguishably different units	$\mu + \theta$	$\mu + \theta$
Measurement with indistinguishably different units	μ	μ
Measurement into different shaped containers	$\mu + \theta + \gamma$	$\mu + \theta + \gamma$
Measurement from different shaped containers	$\mu + \theta + \gamma + \alpha$	$\mu + \theta + \gamma + \alpha$

Analysis

The hypotheses were tested using a multivariate analysis of variance program due to Finn (1967). Although the nominal data of this study do not fit all the assumptions required for parametric statistics, Cochran (1950) has found that parametric statistics can generally be applied to nominal data if one is cautious about attaching importance to marginally significant results. Since for several of the contrasts it was most interesting to show that significant differences did not exist, nonparametric statistics were undesirable in that failure to find significance could have resulted from lack of power of the statistical test.

In addition to the fundamental test for significance, each of the hypotheses was tested to determine whether it was significantly influenced by sex, grade, or order of the items.

Results

Part A

The means for individual items in Part are summarized in Table 3. Depending on the problem, between 89% and 98% of the errors in the measurement problems resulted from the subjects responding strictly on the basis

Table 3

Item Means for Part A

Problem type	Relation		
	Equivalence	Nonequiv. I	Nonequiv. II
Conservation	.41	.56	.39
Measurement with distinguishably different units	.43	.57	.41
Measurement with indistinguishably different units	.33	.34	.33

of the number of units. No subject consistently responded that there was more where the unit was larger, and only one subject completely ignored the measurement cues and correctly answered the measurement problems but failed to conserve when the transformations were visual.

Correct responses were generally justified either by noting that the quantities were the same before the transformation when they were in identical glasses or by noting the compensating rel·tionship between dimensions or between unit size and number of units. Seven of the eight subjects who could successfully measure when the larger unit was distinguishable but not when it was not gave compensation as the reason for at least one of their correct responses.

On the measurement problems with the indistinguishably different units, only five of the subjects were able to use the information from the measurement operation to correctly identify the larger unit. The rest were unable to apply the inverse relationship between unit size and number of units to this problem and simply responded incorrectly on the basis of the unit that looked larger.

The test of the proposed model for Part A indicates that the model is appropriate. This implies that there are no significant differences between Equivalence and Nonequivalence II relations for any of the problems tested or between any of the three relations for measurement problems in which the larger unit is not distinguishable ($p = .99$).

Analysis of the parameters of the model is summarized in Table 4.

Table 4

MANOVA--Parameters of Model for Part A

Source	df	MS	F	p<
Multivariate	5,23		30.5264	.0001
μ	1	6.7776	67.1332	.0001
θ	1	.4376	3.6255	.0677
γ	1	1.8074	11.6189	.0021
β	1	.0164	.0608	.8072
α	1	.0164	.1180	.7339

Degrees of freedom for error = 27

These results indicate that there are significant differences between Nonequivalence I and the other two relations for the conservation problems and for the measurement problems in which the larger unit is distinguishable, but there are no significant differences between the two types of measurement problems for Equivalence and Nonequivalence II relations or between the measurement problems in which the larger unit is distinguishable and the conservation problems for any of the three relations.

Significant differences between grades were found for overall means (p = .0001), but no significant differences between grades were found for any of the parameters of the model (p> .42). No significant differences were found due to se· or order in which the items were administered (p>.16).

Part B

The means for individual items are summarized in Table 5.

Table 5

Item Means for Part B

Problem type	Relation	
	Equivalence	Nonequiv. II
Measurement with distinguishably different units	.32	.38
Measurement with indistinguishably different units	.16	.19
Measurement into different shaped containers	.69	.71
Measurement from different shaped containers	.94	.85

Between 95% and 100% of the errors on problems in which different units were used resulted from subjects responding strictly on the basis of the number of units. One subject completely ignored the number cues, even though he successfully counted the number of units; consequently, he missed all the problems in which quantities were measured with the same unit but answered correctly the items in which quantities were measured with different units. Another subject who was in the "more-same" protocol group responded "same" to every item.

On the measurement problems in which the larger unit was not distinguishable, only two of the subjects were able to use the information from the measurement operation to correctly identify the larger unit. As in Part A correct responses tended to be justified by reference to the previous state or compensation. Only two fo the five subjects who could successfully measure when the larger unit was distinguishable but not when it was not gave compensation as a reason for any of their responses.

The test of the proposed model for Part B indicates that the model is appropriate. This implies that there is no significant difference between Equivalence and Nonequivalence II relations ($p = .19$).

Analysis for the parameters of the model is summarized in Table 6.

Table 6

MANOVA--Parameters of Model for Part B

Source	df	MS	F	p<
Multivariate	3,38		70.8403	.0001
θ	1	2.1176	20.3702	.0001
γ	1	8.4706	33.6859	.0001
α	1	2.4853	19.5404	.0001

Degrees of freedom for error = 40

These results indicate that each of the differences between the four types of measurement problems in Part B are significant.

Significant differences were found for the parameter due to sex and order of the items ($p = .02$). No significant differences for any of the other parameters were found due to grade, sex, or order of the items.

The measurement problems in Part B in which quantities were measured with the same unit into apparent inequality were significantly easier ($p < .01$) than corresponding conservation problems in Part A.

Discussion

The results of this study indicate that the order of the cues is the major factor in determining which cues children attent to. Young children are not totally dominated by the perceptual qualities of an event and conservation errors are not simply due to the perceptual seduction inherent in most conservation problems. Numerical distractors produce approximately the same number of errors as perceptual distractors, and problems in which the correct cues are numerical are significantly easier than either the conservation problems or the measurement problems in which the correct cues are visual. This conflict with the conclusions of Piaget (1952, 1960), Bruner, Olver, and Greenfield (1966) and others appears to be due to the fact that in all of the studies upon which they based their conclusions the distracting cues were visual, and their results which indicate that children depend upon the immediate perceptual qualities of an event are a function of this lack of experimental variability.

Similarly, the results of this study indicate that although they have a number of misconceptions regarding the measurement process and often misapply measurement operations, measurement is meaningful for the majority of students in the first and second grade. Thus--although at least 30% of the subjects in this study readily abandoned results of measurement in any situation in whicy they were followed by conflicting cues, as few as 25% completely understood the importance of using a single unit of measure, and only 6% understood the inverse relation between unit size and number of units to the degree that they could use the results of measurement operations to determine the larger unit--only 3 of the 129 subjects tested did not respond to any question on the basis of measurement cues. All of the others at least recognized that the greater quantity measures the greater number of units.

These results indicate that measurement concepts begin to appear in young children earlier than Piaget et al. (1960) concluded. This conflict appears to be due to the fact that Piaget et al. employed less structured measurement tasks than were used in this study. Their tasks required relatively sophisticated measurement manipulations in order to have any measurement cues to respond to. In the current investigation the measurement cues were forced upon the subjects; therefore, even subjects in the earliest stages had number cues to guide or distract their responses.

Third, the results of this study indicate that there is no significant difference in difficulty of conservation or measurement problems due to order or equivalence relations. No significant difference was found between problems involving Equivalence and Nonequivalence II relations; and although Nonequivalence I problems are significantly easier than corresponding problems involving the other relations, this difference does not hold up in problems in which it is not possible to identify the larger unit. These results imply that the relation between quantities does not affect performance, and the Nonequivalence I problems are easier simply because they do not require genuine conservation.

Finally, the results regarding the role of compensation in conservation judgements are ambiguous. In Part B the problems in which the larger unit was distinguishable were found to be significantly easier than corresponding problems in which it was not, but in Part A this difference failed to reach significance. The pooled results do indicate that compensation may be necessary for conservation judgements in about 10% of the population. This conclusion should be regarded with some caution, however, since the discrepancy between results in Parts A and B indicate that interaction with other tasks may affect the role of compensation

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