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ABSTRACT

Investigated was the distinction between identity conservation and equivalence conservation in 180 preschool, kindergarten and third grade students. Ss were assigned to one of six different counterbalanced orders of presentation for the conservation task battery. The factors were age, task (identity/equivalence), criterion (judgment only/judgment plus explanation), and content area (length/weight). Among results were greater difficulty indicated for equivalence than identity conservation and significant performance improvement at every grade level for the transitivity tasks. (CL)

Technical Report No. 326

MICRO-ANALYSIS OF LOGICAL REASONING RELATIONSHIPS: CONSERVATION AND TRANSITIVITY

by

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Report from the Project on
Children's Learning and Development

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ABSTRACT

An investigation into the distinction between identity conservation and equivalence conservation, theorized by Elkind (1967), was examined in two content areas, length and weight. In addition, transitivity of length and weight was examined in relationship to conservation.

The sample consisted of 180 subjects, 60 preschool, kindergarten, and third grade students. Within each grade subsample, half the children were male and half were female. Subjects were assigned to one of six different counter-balanced orders of presentation for the conservation and transitivity task battery. The design was a 3/2/2/2 mixed-model analysis of variance. The factors were age (preschool/kindergarten/third grade), task (identity/equivalence), criterion (judgment only/judgment plus explanation), and content area (length/weight).

The main effects of age, task, and criterion were large and highly significant. Equivalence conservation was observed to be of greater difficulty than identity conservation. More trials were passed under the judgment only criterion than with a judgment plus explanation criterion. Significant interactions of Age x Task, Task x Criterion, and Age x Criterion were also observed. Equivalence tasks were found to be more difficult than identity tasks for preschoolers and kindergarteners but not for third graders. Performance differences between the identity and equivalence tasks were greater with a judgment only criterion than with a judgment plus explanation criterion, and these differences between the two criteria were more pronounced with preschoolers and kindergarteners than with third graders. The preschool and kindergarten subsamples did not differ. Comparisons of the relative difficulty of the identity versus equivalence conservation cases, utilizing a dichotomous pass/fail scoring criterion, were considerably less persuasive, i.e., only the kindergarten and total sample weight cases indicated a significant lesser difficulty for identity-conservation. A significant performance improvement at every grade level for the transitivity tasks was observed, with the largest differences between the preschool and kindergarten subsamples. The transitivity tasks were significantly easier than all conservation measures at the preschool and kindergarten level, but at the third-grade level, only the transitivity of weight/conservation of weight comparison was significant.

I

INTRODUCTION

Piaget's theory of cognitive development posits a sequential ordering of stages through which human beings progress from birth to adolescence. Stage development, as employed by Piaget in the theory, emerges from the notion that "Man tends to organize his behavior and thought and to adapt to the environment. [This tendency results] in a number of psychological structures which take different forms at different ages. [Ginsburg & Opper, 1969, p. 20]." Thus, Piaget uses distinctive stages to broadly delineate the qualitative nature of psychological structures which eventually culminate in adult intelligence. Of associated importance to any discussion of stages is the notion of "invariance" in the sequential ordering of stages. Invariance implies an orderly progression, or dependency, which ensures a continuity between previous and successive stages. Intellectual development is categorized into four major periods (sensori-motor, 0-2 years; preoperational, 2-7 years; concrete operational, 7-11 years; and formal operational, 11 years and above). It is necessary for a given individual to have mastered any previous stages or levels of intellectual functioning before mastery of later, higher-order stage functions is possible. Stated schematically, the order of acquisition of stages is A-B-C-D; in order for a particular individual to have reached stage D stages A, B, and C must have been previously mastered.

Just as there exists an invariant order among stages, there also exist within-stage sequences for certain developmental periods. Perhaps the best example would be the six substages of the sensori-motor period. For the concrete operations period, Piaget and Inhelder (1962) concluded that the order of acquisition of conservation of quantity follows an invariant developmental sequence in which conservation of mass precedes conservation of weight, which in turn precedes conservation of volume. Piaget terms these progressions within a given stage, décalages horizontaux. There exists a lag in the sense that "the child may even display different levels of achievement in regard to problems involving similar mental operations [Ginsburg & Opper, 1969, p. 162]." In addition, the order in which quantity conservation develops is also invariant in that a child will proceed through the stages of non-conservation, transition, and conservation. The stage of non-conservation is exemplified by the child who never conserves, while during the stage of conservation the child always conserves. The transitional stage is exemplified by the child who is extremely variable in his or her conservation judgments.

The cognitive functioning associated with the concrete operations period is the primary focus of the research reported in this paper. Although Piaget's recent writings (e.g., Piaget, 1972) have emphasized the superordinate role played by the logical groupements dealing with class and relational concepts, the majority of the original Genevan studies and subsequent replication-validation studies have employed derivative task formats. Perhaps the best known of these concrete operations measures are the conservation of quantity tasks (e.g., mass-substance-amount, weight, volume, length, area, number). Conservation may be defined as the ability of a person to be aware of the invariant properties or dimensions of objects in the face of irrelevant spatio-temporal transformations. The major developmental importance of conservation acquisition is openly recognized. As Flavell (1963) points out:

> It was an act of creative inspiration when Piaget hit upon the idea that a wide variety of cognitive areas--number, quantity, time, etc.--are in certain crucial respects mastered according to a common procedure: to discover what values do and do not remain invariant (are and are not conserved) in the course of any given kind of change or transformation; only when this is done is the way paved for further operations (which are also common denominators across areas), e.g., qualitative and quantitative measurement, application of the transitivity law, etc. There is no question but that the formation of concrete operations is the richest chapter in Piaget's developmental story, in the sense of sheer abundance of highly interesting empirical data. It does not seem likely that all this would or could have come about without the concept of conservation-formation and related unifiers [p. 415].

The relevant aspects of the conventional conservation task as contrasted with identity conservation have been summarized previously:

> The major aspects of the conventional conservation task may be outlined as follows: Given: Two stimulus items A and B; e.g., containers with equal amounts of small seeds and three separate points or intervals in the conservation setting. Time 1: A=B (A and B are judged as containing equal amounts of seeds); Time 2: B→C (The contents of B are transferred or transformed to a container of a different shape, C); Time 3: A?C (The S is questioned as to the relationship, equality, or difference of amount, between the standard stimulus A and the comparison stimulus C).
>
> If the S, when questioned at Time 3, responds that A=C, the E infers that B and C were in fact judged equal in amount. In contrast, the response A≠C results in the E's inference that B≠C, hence a nonconservation judgment is assessed.
>
> Note that in the conventional conservation setting outlined above (designated equivalence conservation by Elkind), the S is never actually required to judge overtly the relationship of stimuli B and C. Yet, the realization that the property at issue, i.e., the substance-amount, weight or volume of the stimulus array does not alter following the transformation of B to C, is patently essential to a correct solution of the criterial task. Obviously, a S who does not judge B=C is not likely to 'conserve' the relationship of A=B; therefore, A=C as outlined above.

> Identity conservation is defined as the realization that the single stimulus transformation B into C does not alter a fundamental property of the quantity in question. Piaget's explanation and description of the processes whereby the child gradually passes from a stage of nonconservation to an intuitive and transitional stage and finally achieves the third stage of completely logically justified conservation performance is based directly on consideration of this identity case. Thus, the three major post facto rationales which are logically adequate and consistent for Piaget, e.g., addition-subtraction schemas--'nothing has been added or taken away'; reversibility--'if you poured the seeds back to the first container they would have the same amount'; and compensation-proportionality or the compensation of relations--'that glass of seeds is shorter but narrower too,' refers to the relationship of B to C as cited above. The latter explanation category, the compensation of relations, plays a primary role in Piaget's conceptualization of conservation acquisition. While identity conservation is the focus of Piaget's theoretical explanation and forms the basis for his description of the stages of conservation and quantifying coordination, his assessment format is primarily the paired-stimulus equivalence setting [Hooper, 1969a, p. 235-236].

Since identity conservation must always be inferred in the conventional conservation problem, both Elkind (1967) and Hooper (1969a) opt for the earlier appearance and understanding of identity conservation as a necessary but not sufficient condition for the successful attainment of equivalence conservation. Equivalence conservation ability also requires a deductive argument for successful completion.

While quantity conservation involves infralogical operations that are spatio-temporal and continuous in character, transitivity appears to involve only logico-mathematical operations (Flavell, 1963). In a typical transitivity task a child infers from the observations A > B, and B > C, that A must be greater than C. Thus, for example, the subject would observe that stick A is longer than stick B and that stick B is longer than stick C. He would infer that stick A is longer than stick C. As is the case with the conventional conservation task, transitivity also requires a deductive argument for successful completion. Thus, both equivalence conservation and transitivity should appear concomitant in terms of their emerging operational appearance. This position is in basic agreement with Piaget and Inhelder's (1962) claim that transitivity and conservation develop synchronously.

Previous studies have found either conservation more difficult than transitivity (i.e., Brainerd, 1973, and Lovell & Ogilvie, 1961) or transitivity more difficult that conservation (i.e., Garcez, 1969; Kooistra, McManis, 1969b; Smedslund, 1961; and Smedslund, 1963).

II

PREVIOUS RESEARCH

CONSERVATION

Although Piaget and Inhelder (1962) originally assumed identity and equivalence conservation to develop simultaneously as an all-or-none proposition, there has been conflicting evidence concerning the hypothesized décalage between identity conservation and equivalence conservation. Summaries of the identity and equivalence conservation studies reported in this section appear in Table I. A number of studies reveal data in support of the priority of the emergence of identity conservation. Elkind (1966) used 68 children, 4-7 years old, of middle to high SES, to test conservation of size, form, and length across illusory transformations, and found that children have no more difficulty attaining conservation using illusory than using real transformations. Significant age effects revealed a regular increase in mean scores with age. Significant test effects revealed that the form conservation test was easier than the tests for size and length conservation, which were of about equal difficulty, while the length test which employed the Müller Lyer illusion format proved to be the most difficult. Elkind hypothesized that conservation of form assessed only the identity problem as there was no equivalence problem present. In addition, the Müller Lyer illusion caused the most difficulty at the younger age levels. Once the Ss were of the age of concrete operations, the difference between the standard test for length conservation and the Müller Lyer length test disappeared.

Ransom (cited in Elkind, 1967) provided evidence to support the developmental priority of identity conservation for length and continuous quantities. It was hypothesized that the test for identity conservation could lead to what Inhelder (1963) termed a "pseudo conservation," which is evidenced through memory falsification on the part of the child. Because a subject has no way to compare a transformed stimulus (a clay ball rolled into a sausage) to its original appearance, it is possible to distort the memory of the original size of the ball so it will equal the apparent increase in the size of the sausage. Ransom based his conclusions on procedures whereby the previous state of a given quantity before transformation could be marked in some fashion, thus eliminating judgments based on memory falsification.

Hooper (1969a) assessed 18 males and 18 females of 6, 7, and 8 years of age and of middle SES, to test identity and equivalence conservation of a discontinuous quantity under moderate and extreme transformation. The rationale behind employing both moderate and extreme transformations in the identity and equivalence conservation types was to verify the assertion made by Piaget that children in the transitional stage between non-conservation and conservation would conserve under moderate transformation of the stimuli involved but might fail to conserve under extreme deformations. In addition, Hooper included two types of equivalence conservation tasks. Equivalence Conservation I was equated to identity conservation in terms of memory requirements and the perceptual cues that are required. The only difference between them was the additional deductive sequence required in the equivalence conservation type. Equivalence Conservation II was the conventional conservation task used by Piaget and his associates. For all ages, more children passed identity conservation than equivalence conservation. Overall, there was virtually no difference under the two equivalence conditions. Differences between identity and equivalence were most notable at the lower age level, and diminished toward first and second grade. The one surprising finding was a significant sex difference. Whereas 64.8 percent of the males were conservers under all tasks and conditions, only 37 percent of the females were conservers. The priority of identity over equivalence conservation was most significant at the kindergarten level for males and at the first and second grade levels for females. No significant differences were observed for the moderate compared to the extreme transformation conditions.

Hooper (1969b), using similar tasks and scoring criteria employed a repeated measures design to evaluate the identity/equivalence relationship. Eighty 5 and 6 year-old subjects were given the tasks. The results showed no Ss to have passed equivalence and failed identity, while 11.25 percent passed identity and failed equivalence, 13.75 percent passed both tasks, and 75 percent failed both tasks. The results were taken as adding support to the identity/equivalence distinction.

Nair (cited in Bruner, Olver, Greenfield, et al., 1966) used 40, 5 year-old Ss from a Boston suburb, to study the relationship of qualitative identity (the "same" water) and equivalence conservation of a continuous quantity. The children were divided into two groups, those who conserved on the classical pretest and those who did not. The specific task involved the filling of two identical plastic boxes with the same amount of water, one by the experimenter, the other by the child, and placing wooden ducks on their "lakes." At the suggestion of the experimenter the child moves his or her duck to three different ponds and takes the water with him. After each move, two questions were asked of the child. One question stressed the qualitative identity aspect of the task; the other question stressed the equivalence aspect of the task. The questions were given in a counterbalanced order; half the Ss were asked the identity question first and half the Ss were asked the equivalence question first. Results indicated that 50 percent of the children who conserved on the pretest argued some variation of "same" water to assert the invariance in amount of water. Of those who were classified as non-conservers on the pretest, only 10 percent used the sameness of the water to argue the invariance in amount. Also, Ss who were asked questions of identity before questions of equivalence were more successful in answering both types of questions than were Ss asked the questions in reverse order. Nair concluded that identity is a necessary if not sufficient condition for quantitative equivalence.

McManis (1969a) studied the identity/equivalence relationship in 60 retarded children, 15 Ss of each mental-age 5 to 8 years. All children were given identity and equivalence tasks which employed the use of both discontinuous (styrofoam balls) and continuous (clay and water) materials.

Within a given MA group, both task material types and the identity/equivalence tasks were presented in a counterbalanced order. Results indicated an age related progression of success in both types of conservation. Of particular importance, however, was the fact that no Ss who failed identity conservation passed equivalence conservation. Of the total subject population, 13 percent to 18 percent exhibited identity conservation abilities but not equivalence conservation. McManis concluded that identity conservation was a necessary condition for equivalence conservation.

Elkind and Schoenfeld (1972) used twenty-two 4-year-old, and twenty-two 6-year-old, lower-middle SES children, to test identity and equivalence conservation for number, length, liquids, and mass. Two sets of five pennies were used in the number task, two identical glasses, a beaker, and a pitcher of colored water were used in the liquids task; two drawing pencils were used in the length task; and two clay balls were used in the mass conservation task. Half of each group of children received the identity tasks first; half received the equivalence tasks first. Results showed (1) higher mean conservation scores for older children; (2) that identity conservation was easier to conserve than equivalence conservation in the younger group; and (3) that both age groups found conservation of number easiest to conserve, followed by length, mass, and continuous quantity.

Not all studies, however, report findings that are generally supportive of the identity/equivalence distinction. Papalia and Hooper (1971) used sixty 4-, 5-, and 6-year-olds from middle SES, to test qualitative identity, quantitative identity, and quantitative equivalence conservation of substance and number, in the order of difficulty just stated. The two conditions were with justification and without justification. The sample employed 10 males and 10 females at each age level. Each child received all the tasks and each task content area was presented in counterbalanced order. Within the specific content area, however, the tasks were administered in the hypothesized order of difficulty. Results indicated that the order of presentation did not affect the performance of a subject significantly, and that the with justification and without justification conditions did not result in any significant difference. The most important finding, however, was that although a predicted order of difficulty was found for quantity, no predicted order of difficulty was found for number conservation. Unlike the Hooper (1969a) finding of a male superiority bias on performance, this study found a slight female superiority bias for the with justification condition.

Moynahan and Glick (1972) used 57 Ss (33 boys and 24 girls), 5 years 11 months old, and 39 Ss (21 boys and 18 girls), 6 years 9 months old, of middle SES, to test for identity and equivalence conservation of number, length, continuous quantity, and weight. The results revealed that as a group, there were substantial numbers of conservers and non-conservers, thus indicating a transitional period of conservation acquisition for most subjects. Concerning the identity/equivalence distinction, only the first transformation of the length task showed results favorable to a hypothesis of an earlier emergence of identity conservation. Of the 15 Ss involved, 12 passed the identity and failed the equivalence tasks. On the content areas of number, quantity, and weight, however, results indicated a co-occurrence of identity and equivalence conservation. One possible explanation offered by Moynahan and Glick is that equivalence conservation performance does not necessarily involve the use of transitive inference, thus making it no more difficult to solve than identity conservation. An alternative explanation is, of course, that the ability to make transitive inferences is already possessed by a conserver, thus making the equivalence task no more difficult than identity conservation.

Schwartz and Scholnick (1970) examined 8 males and 32 females, of middle SES, ranging in age from 4 years 5 months to 6 years 4 months, to non-verbally assess direct comparison, identity, and equivalence estimates of discontinuous quantity using two containers that were either identical or different. Scalogram analyses revealed that when containers were identical, identity judgments were more inaccurate, whereas when containers differed, identity judgments were easier than equivalence and comparison judgments. The scaling technique also revealed that two major variables affect performance. The elements in the stimulus situation and the stimulus setting were found to affect both mastery of the conservation of a discontinuous quantity and the judgments involved.

Teets (1968) assessed 120 first, second, and third grade Ss from two SES levels to measure identity and equivalence conservation of weight. Stimuli employed in the tasks were four sets of colored differentially configured Lego blocks. Although perceptual alteration distorted the apparent from the real, all blocks were the same weight. For the total subject sample, eighty-two Ss passed both tasks, 24 Ss failed both tasks, 8 Ss failed identity and passed equivalence, and 6 Ss passed identity and failed equivalence. In the first grade, lower SES group, in which a greater number of children passed identity than equivalence, there was little evidence to indicate a priority of identity conservation over equivalence conservation.

Northman and Gruen (1970) used sixty-five second- and third-grade children ranging in age from 6 years 11 months to 9 years 8 months to assess identity and equivalence conservation of continuous quantity (water). In one sitting, three identity and three equivalence tasks were given in six different orders. The results did not support the identity/equivalence distinction. Most children conserved in an "all or none" fashion. Northman and Gruen (1970) suggested two explanations: (1) significant identity/equivalence differences may be of brief developmental duration, or (2) the logical requirements involved in conservation do not represent the psychological processes of the child.

Murray (1970) tested 113 Ss on identity and equivalence conservation tasks given in four different presentation modes. Subsamples of 33 kindergarten-first grade Ss ($\bar{x}$ age = 6.24 years) were given identity and equivalence conservation of number, while 80 second grade Ss ($\bar{x}$ age = 8.25 years) were given identity and equivalence conservation of weight. Results indicated no significant differences between identity and equivalence conservation.

Koshinsky and Hall (1973) conducted a replication of the Hooper (1969a) study employing the same tasks but with a within-subject assessment design. Seventy-two Ss, 12 male and 12 female, from kindergarten, first, and second grades were tested in the experiment. The main focus of the study centered on the comparison between identity and equivalence conservation. Results showed no significant performance effects due to sex, degree of transformation, or equivalence task. Older subjects per-

Table 1

Previous Identity and Equivalence Conservation Studies

	Subjects	Content	Response Criteria	Results
Elkind (1966)	68 Ss, 4-7 yrs. Above average intelligence. Middle-High SES.	Conservation of size, form, and length. E performed transformations in length test; S performed transformations in size test.	3 pt. scale used for scoring each task.	Main effect for age and test. Difficulty of tests from easiest to most difficult: 1. Form. 2. Size and Length (pencils) of about equal difficulty. 3. Length (Müller Lyer). Equation of differences is not necessary to judge equivalence between standard and variable stimulus. Form test (identity) implies developmental priority, but no direct test was made.
Elkind and Schoenfeld (1972)	44 Ss, 11 males and 11 females at each grade level: Preschool, and 1st.	Identity and equivalence conservation of number, length, liquid, and mass. E performed transformations. Counterbalanced order of presentation for conservation type and questions.	3 pt. scale used for scoring each task. Judgment only.	Significant age, judgment, task type, and age x judgment effect: 1. Higher $\bar{x}$ scores for older Ss. 2. Identity judgments easier than equivalence judgments. 3. Number easiest to conserve, then length, mass, and liquid. 4. Significant $\bar{x}$ score difference for identity and equivalence in younger age group, but not older group. 5. No direct intertask comparisons were reported.

Table 1 (continued)

	Subjects	Content	Response Criteria	Results
Hooper (1969a)	108 Ss, 18 males and 18 females at each grade level: Kdg., 1st, and 2nd. $\bar{x}$ ages 6,7,8 yrs. Middle SES.	Identity and equivalence conservation of discontinuous quantity. S performed transformations. Identity and equivalence conservation I equated in terms of perceptual cues and memory requirements. Identity and equivalence conservations I and II each yielded three separate trials. Warm-up preceded task conditions. Critical terms "more" and "same" were alternated in each experimental condition.	Judgment plus explanation.	Main effect for task types, age, and sex (i.e., male superiority). Identity conservation less difficult than equivalence conservation. No significant difference between equivalence conservation I and II, nor between moderate and extreme transformation.
Hooper (1969b)	80 Ss, 5-1/2 - 6-1/2 yrs. Upper-Lower and Lower-Middle SES.	Identity and equivalence conservation of discontinuous quantity. Conservation of number (conventional format).	Judgment plus explanation.	Main effect for task type, age, and sex (significant male superiority). Identity conservation precedes equivalence conservation.
Koshinsky and Hall (1973)	72 Ss, 12 male and 12 female, from Kdg., 1st, and 2nd grades. Modal ages: 5,6, 7 yrs.	Identity and equivalence conservation of discontinuous quantity (colored stones). Two types of equivalence conservation: 1. Equivalence I--equated to identity in terms of perceptual cues and memory requirements. 2. Equivalence II--conventional conservation task. Two degrees of transformation for conservation tasks (moderate and extreme).	Judgment plus empirical check.	No significant effect for degree of transformation, type of equivalence task, or sex. Significant task performance superiority for older Ss on both the identity and equivalence conservations. Developmental distinction between identity/equivalence was not supported.

Table 1 (continued)

	Subjects	Content	Response Criteria	Results
McManis (1969a).	60 retarded Ss, 15 in each of four MA ranges: 5, 6, 7, 8.	Identity and equivalence conservation of 3 types of material (styrofoam balls, clay, and water). Counterbalanced order of presentation for task material and conservation type within each MA group. E performed transformations.	Judgment only.	Main effect for age, and task type. Identity conservation necessary but not sufficient condition for equivalence conservation to occur.
Moynahan and Glick (1972)	96 Ss, 57 Kdg. (33 boys and 24 girls), and 39 1st grade (21 boys and 18 girls). x̄ age for all Ss, 6 yrs. 3 mos. Middle SES.	Identity and equivalence conservation of number, length, weight, and liquid. E performed transformations. Counterbalanced order of presentation for tasks and conservation type.	Judgment plus explanation.	Identity and equivalence conservation found to co-occur for number, weight, liquid, and second length transformation. Only first length transformation showed identity primacy. Number task easier to conserve than length, weight, and liquid. Significant age, order, sex (i.e., male superiority) effect.
Murray (1970)	113 Ss, 33 Kdg.-1st grade, 80 2nd. x̄ ages: Kdg.-1st, 6.24 yrs.; 2nd, 8.25 yrs. 3 different SES levels for 2nd grade Ss.	Identity and equivalence conservation of number given Kdg.-1st grade Ss only. Identity and equivalence conservation of weight given 2nd grade Ss only. Tasks given in four different presentation modes.	Judgment only.	No significant difference between identity and equivalence conservation. No sex differences.

Table 1 (continued)

	Subjects	Content	Response Criteria	Results
Nair (1966)	40 Ss, 5 yrs., Kdg.	Qualitative identity and quantitative equivalence conservation of continuous liquid. Ss equally divided between conservers and non-conservers on classical pretest. Counterbalanced order for questions asked. S performed transformations.	Judgment plus explanation.	Qualitative identity conservation precedes quantitative equivalence conservation. Order of question presentation effect. Superior performance by conservers when identity preceded equivalence conservation on pretest.
Northman and Gruen (1970)	65 Ss, 2nd and 3rd grade. x̄ age: 8 yrs.	Identity and equivalence conservation of continuous quantity (water). Pretest administered for relational terms. Counterbalanced order of presentation for conservation type, and random order of tasks within each conservation type. Memory check in identity task. Counterbalanced order of critical questions employed. E performed transformations.	Judgment only.	Identity and equivalence conservation were of equivalent difficulty. Most Ss conserved in an all-or-none fashion. Significant sex difference for 3rd grade (male superiority on both conservation task types).
Papalia and Hooper (1971)	60 Ss, 10 males and 10 females at each grade level: 4,5,6 yrs. Middle SES.	Qualitative identity, quantitative identity and equivalence conservation of substance and number. Conservation tasks preceded by relational terms task. Counterbalanced order of presentation for task content area. S performed transformations.	4 of 5 responses to particular task (judgment only and judgment plus explanation).	No order of presentation, or scoring criteria effect. Hypothesized order of difficulty found for quantity, but not number. Female performance superiority under judgment plus explanation condition in four- and six-year old groups.

Table 1 (continued)

	Subjects	Content	Response Criteria	Results
Ransom (cited in Elkind, 1967)		Identity and equivalence conservation for length and continuous quantity.	Not reported.	Identity precedes equivalence conservation when memory falsification is controlled.
Schwartz and Scholnick (1970)	40 Ss, 8 males and 32 females. $\bar{x}$ age: 65.8 mos. Middle SES.	Comparison, identity, and equivalence judgments of discontinuous quantity (candy) under two conditions: 1. When perceptual cues and logical judgments are congruent. 2. When perceptual cues and logical judgments are contradictory.	Judgment only.	Significant interaction between stimulus situation setting and judgment: 1. When identical containers used, comparison judgments easiest, followed by equivalence and identity judgments. 2. When different containers used, identity judgments easiest, followed by equivalence and comparison judgments.
Teets (1968)	120 Ss, 1st, 2nd, and 3rd grades. 2 SES levels.	Identity and equivalence conservation of weight.	Judgment plus explanation.	No priority of identity to equivalence conservation found. No sex differences.

formed better than younger subjects. No difference in the degree of difficulty between the identity and equivalence tasks was found. Overall, 86 percent of the Ss passed the identity/equivalence tasks in an all or none fashion, 4 percent passed identity and failed equivalence, while 10 percent passed equivalence but failed identity conservation.

TRANSITIVITY

As with the controversy surrounding the developmental priority of identity compared to equivalence conservation, much discussion surrounds the relationship of transitivity to seriation, class inclusion, and conservation. Piaget and Inhelder (1962) theorized a simultaneous development between conservation and transitivity within a given content area.

Braine (1959) questioned the validity of Piaget's studies of transitivity because they failed to eliminate variables that were not part of the transitive inference process. In particular, Piaget's studies of transitivity of length failed to separate the child's inferential response from an ability to use measuring instruments and verbal skills necessary for the conceptual understanding of the task. Braine's study investigated the development of the inferential response and of order discrimination, and the developmental relationship between these two acquisitions. He assessed 18 boys and 23 girls, ranging in age from 3 years 6 months, to 7 years, in a nonverbal, counterbalanced-order task setting. Although the results strongly supported Piaget's notion of developmental stages in the acquisition of transitivity, both inferential reasoning and order discrimination ability were found to exist two years earlier than Piaget claimed (approximately 7-8 years). Smedslund (1963), while basically in agreement with Braine's (1959) criticism of Piaget's transitivity experiments, was critical of Braine for not controlling correct judgments based on something other than the transitive inference (i.e., guessing, perceptual discrimination, non-transitive responses). Controlling for a non-transitive hypothesis, Smedslund assessed 107 Ss ranging in age from 4-10 years. As with Braine's (1959) findings, Smedslund's findings strongly supported the notion of developmental stages in the acquisition of transitivity. This study, however, also supported Piaget's notion that acquisition of transitivity usually occurs at about 8 years of age. In regard to Piaget and Inhelder's (1962) hypothesis that conservation and transitivity develop simultaneously, those Ss who displayed transitivity also displayed conservation.

Murray and Youniss (1968) took issue with the fact that most investigators assessed only one of three possible relations in the three term sets involving transitive inference. In the paradigm $A > B > C$, a child's response that $A > C$ could merely be a reflection of consistency in choosing the longer stick rather than an inferential judgment. They devised two paradigms to control for noninferential responses: $A > B = C$, and $A = B > C$, and assessed 24 boys and 24 girls at each grade level, kindergarten through second grade, on transitivity and unidimensional seriation tasks. The results indicated that the conventional transitivity paradigm, $A > B > C$, was easier than both paradigms devised by Murray and Youniss, and that the paradigm, A = B > C, revealed the "clearest" age trend. In addition, only 15 percent of the Ss who passed transitivity failed seriation, thus supporting the Piaget, Inhelder, and Szeminska (1960) claim that seriation is necessary to the understanding of transitivity.

Youniss and Murray (1970) investigated inferential behavior when controls allowed measurement but not differential size designations prior to the choice trial. Thirty-two kindergarten/first graders and thirty-two third graders were tested on three different transitivity paradigms, and a control condition. Following the transitivity trials, each child was tested for serial ordering. Results revealed that younger Ss (CA 6) failed to make transitive inferences and that older Ss (CA 8) were only moderately successful. Both the age at which transitivity occurred and the developmental priority of seriation in relation to transitivity supported the earlier assumptions of Piaget.

A number of studies have been concerned with the Piaget and Inhelder (1962) hypothesis that conservation and transitivity develop simultaneously with respect to a given content area. Smedslund (1961) tested 135 Ss ranging in age from 5 years 6 months, to 7 years. Results revealed that although 20 percent of his subjects displayed conservation of weight, only 1 percent of these subjects displayed transitivity of weight. Kooistra (1965) tested the relationship of conservation and transitivity of weight in a sample of 12 boys and 12 girls from each age level 4 to 7 years. Results showed that only two of the 96 Ss deviated from the prediction that conservation is structured in the child's thought before transitivity. McManis (1969b) found conservation of length and weight to be significantly easier than transitivity of length and weight when testing 90 normals and 90 retardates matched for mental age (MA), between 5-10 years. Garcez (1969) investigated the effect of empirical demonstration on both conservation and transitivity. Although 24 percent of the Ss trained on both conservation and transitivity gave operational responses on a posttest, none of those subjects trained on transitivity alone could give operational responses on a posttest. Garcez concluded that operational acquisition of conservation was needed for transitivity. Lovell and Ogilvie (1961) employed 262 Ss, both conservers and non-conservers, to examine the effect of transitivity abilities. Both groups of subjects were found to perform transitivity operations. Lovell and Ogilvie concluded that conservation did not affect transitivity judgments.

Brainerd (1973) conducted two studies to assess order of acquisition of transitivity, conservation, and class-inclusion of length and weight. In one study, 60 white Canadian and 60 white American second grade Ss were tested, and in another study, 60 white Canadian Ss were tested from each grade level, kindergarten, first, and second. Brainerd found transitivity to emerge before conservation, which in turn, was found to emerge before class-inclusion. These results were inconsistent with both the predictions made from Piagetian theory and the existing neo-Piagetian literature. In regard to the theory, Brainerd concluded that there were partial errors about which skills presuppose seriation and which skills seriation presupposes. Brainerd attributes the findings of neo-Piagetian literature to the relatively insensitive instruments used to test for the presence of transitive inferences.

Roodin and Gruen (1970) examined the effect of experimental manipulation of memory on making transitive inferences. Seventy-two middle SES children, 12 boys and 12 girls from each of three different grade levels, ranging in age from 4 years 8 months to 8 years 5 months, participated in the experiment. Half of the subjects at each age level, 5-7 years, were allowed the use of a memory aid to make comparisons A > B, and B > C. Results showed that those subjects who had use of a memory aid made significantly more correct transitive judgments, plus adequate explanations, at every age level than those who had no such aids. Roodin and Gruen concluded that the memory aid helped the child to use the relevant information available, and to make the judgment clear enough so he or she could verbally explain the transitive inference.

THE PRESENT INVESTIGATION

It should be abundantly clear by now that questions regarding stage sequence and stage correspondence, as they specifically relate to identity, equivalence, and transitivity abilities, remain essentially unresolved. The one conclusion that could be put forth is that experimenters have consistently failed to appreciate the complexity of the task. As was pointed out by Hooper, Goldman, Storck, and Burke (1971) "The major reasons for lack of agreement on questions concerning stage sequence and stage correspondence fall into two categories: (1) operational variables, and (2) subject variables [p. 42]." Operational variables include operational definitions, confounding variables, task format, experimental replication, and data analysis. Subject variables include specific experiences, the general developmental status, and the language ability of the subjects.

Brainerd and Hooper (1975) reviewed the literature reported in this paper concerning Elkind's (1967) two-step analysis of the conservation concept and found three major variables that could affect the supportive and non-supportive findings related to cognitive developmental sequences. Task sensitivity, as described by Flavell (1971), could mask real sequences or produce sequences where none exist. Thus, for example, if the identity task were more sensitive than the equivalence task, findings would probably support the hypothesized décalage. If, on the other hand, the identity task was relatively insensitive when compared to the equivalence task, findings would probably show no sequence at all, or perhaps a reversal. Examination of the supportive and non-supportive studies showed no clear-cut differences in terms of task sensitivity. Response criteria did differ between studies, and can be defined as either judgment only, or judgment plus explanation. Supportive data reported by Schwartz and Scholnick (1970) and Elkind and Schoenfeld (1972) employed the judgment only condition. The non-supportive data reported by Moynahan and Glick (1972) and Teets (1968) employed the judgment plus explanation condition. The nonsupportive study by Koshinsky and Hall (1973) employed a judgment plus empirical check criterion. The age of the subjects invariably affects sequence-present and sequence-absent findings. It is of interest to note the absence of preschoolers in the non-supportive studies and the inclusion of preschoolers in three of the four supportive studies.

The present cross-sectional investigation focused on incorporating within one study the necessary controls that would enable the experimenter to monitor the various operational variables that could affect the performance of the subject population. An attempt was made to equate all tasks in terms of requirements other than the specific demands of the task in question. Response criteria provided for both judgment only and judgment plus explanation conditions. The age of the subjects, particularly those in the lower age range, was intended to ensure a non-inflated performance baseline. All tasks examined two content areas, length and weight, which allowed content performance comparisons. For the present investigation, the following predictions were examined:

1. The age-grade level factor is related to all the dependent measures.
2. If the identity/equivalence distinction is in fact a valid distinction, then identity conservation is of lesser difficulty than equivalence conservation within a given content domain.
3. If the identity/equivalence distinction is valid, then the largest differences will tend to occur at the earlier age levels.
4. Transitivity is of greater difficulty than identity conservation, but approximately equivalent to equivalence conservation.
5. The with-justification condition should be significantly more difficult than the without-justification condition.
6. If the with/without justification conditions reveal age-related differences, then the largest differences will tend to occur at the earlier age levels.
7. Prediction of the conservation relationship of an object with respect to itself (identity) or another object (equivalence) will tend to be of lesser difficulty than the correct judgment of the actual deformation.

III

METHOD

SUBJECTS

The subject sample for the present investigation consisted of 180 school children, of which 120 were drawn from the Beloit, Wisconsin, Public School system, and the remaining 60 drawn from private preschools in Madison, Wisconsin. Sixty Ss were drawn from each of three grade levels, preschool, kindergarten, and third. Distribution of the subject population by age and sex is described in Table 2. The kindergarten and third grade subsamples were randomly drawn from the four elementary schools that were designated as target populations. The preschool subsample was selected randomly from the entire population of one preschool and from children returning parental consent slips at the other preschool.

Table 2

Distribution by Grade, Mean Age, and Sex of the Subject Population

Grade	Subjects	Males	Females	Mean Age	Age Range
Pre	60	31	29	4- 1	2-8 to 5-3
K	60	30	30	5-10	5-3 to 6-3
3	60	30	30	8- 9	8-3 to 9-8

DESIGN

Within each grade level ten subjects were randomly assigned to each of six counterbalanced orders of presentation (see Table 3) for the transitivity and conservation task conditions for length and weight. A warm-up to familiarize all subjects with the critical terms preceded all task orders. The questioning for all six counterbalanced orders of presentation always involved the critical terms "Same," "More," and "Less" in that order. In addition, conservation of length always preceded conservation of weight in both the identity and equivalence task formats. Within each conservation task, for both prediction and deformation, every S was required to justify his or her objective response to one of the three questions. At each grade level, one-third of the Ss were asked for justifications on questions implying the "Same," one-third on questions implying "More," and one-third on questions implying "Less." Over all the conservation tasks, each S gave eight justifications.

Table 3

Orders of Presentation for Identity, Equivalence, and Transitivity Tasks

(1) A) Identity B) Equivalence C) Transitivity	(2) A) Identity C) Transitivity B) Equivalence
(3) B) Equivalence C) Transitivity A) Identity	(4) B) Equivalence A) Identity C) Transitivity
(5) C) Transitivity A) Identity B) Equivalence	(6) C) Transitivity B) Equivalence A) Identity

MATERIALS

The materials that were used in the basic task format are outlined below (See Appendix A for complete task administration descriptions.):

1. Warm-up: a picture of two perceptibly unequal parallel lines (10-cm and 20-cm), and two perceptibly unequally weighted, cylindrical wooden blocks.
2. Transitivity of Length: two blue sticks, one 27.0-cm and one 28.0-cm, mounted on a 32" x 20" illustration board 26 inches apart, and one 28.0-cm white stick, unmounted.
3. Transitivity of Weight: one red and one grey clay ball of equal weight (5 1/2 oz.), and one grey clay ball of a lighter weight (2 oz.), but equal in diameter to the two weighted balls.
4. Conservation of Length-Identity Format: one 28.0-cm string.
5. Conservation of Length-Equivalence Format: two 28.0-cm strings.
6. Conservation of Weight-Identity Format: one green clay ball, 2 oz. in weight.
7. Conservation of Weight-Equivalence Format: two brown clay balls of equal weight (2 oz.)

PROCEDURE

The task battery was preceded by a warm-up and individually administered. In addition to familiarizing each subject with the critical terms implying "Same," "More," and "Less," the experimenter was encouraged to promote a relaxed, free, verbal interacting atmosphere between himself or herself and the subject. During this warm-up, the E placed the picture of two perceptibly unequal parallel lines in front of the S, so that the longest line was nearer the S. The following questions were then asked: (a) "Are these two lines the same length?"; (b) "Which line is longer?"; and (c) "Which line is shorter?" The E then removed the picture from the table and gave the S a cylindrical block to hold in each hand and asked: (a) "Are these two blocks the same weight?"; (b) "Which block weighs more?"; and (c) "Which block weighs less?" If the S did not seem to understand the relational terms, as indicated by the objective response, the E repeated the warm-up or that portion about which the S seemed uncertain. If a S had failed to understand the relational terms, it would have been necessary to drop that particular S from the sample and select another at random. The task battery was administered individually to each S in a room outside the child's classroom. Total administration time was approximately 20 minutes.

Actual procedures for the transitivity and conservation tasks were as follows:

1. Transitivity of Length (adapted from Brainerd, 1973):

   The E placed the board, having a 27.0-cm blue stick and a 28.0-cm blue stick glued down approximately one arm's length apart, in the middle of the table 8-10 inches from the S. Taking the 28.0-cm white stick and placing it next to the 28.0-cm blue stick, the S was asked, "Are these two sticks the same length?" Next, the E placed the 28.0-cm white stick next to the 27.0-cm blue stick, and asked the S, "Is one of the sticks longer?" If an affirmative response was given, the child was also asked, "Which one?" Finally, the E removed the white stick from the table and asked the following: (a) "Are these two sticks the same length?"; (b) "Is one of the sticks longer?"; and (c) "Is one of the sticks shorter?" If the child responded affirmatively to questions (b) and (c), the E also asked the S to indicate which stick was longer in question (b), and shorter in question (c).

2. Transitivity of Weight (adapted from Brainerd, 1973):

   The E placed the three clay balls in the middle of the table, 8-10 inches from the S. The E then asked the S to hold out his or her hands, palm up, after which one grey and one red clay ball of equal weight were handed to the S. The E then asked, "Do these two clay balls weigh the same?" The grey clay ball was then removed from the S's hand and placed on the table 8-10 inches in front of the hand in which it was held. Then the red clay ball was removed and placed in the hand opposite the one in which it originally appeared. Next, the lighter grey clay ball was placed in the remaining empty hand, while the S was asked, "Does one of the clay balls weigh more?" If the S replied affirmatively to the question, the child was also asked, "Which one?" The grey clay ball was removed and placed on the table 8-10 inches in front of the hand in which it was held. Finally, the E removed the red clay ball from the table and asked the following: (a) "Do these two clay balls weigh the same?"; (b) "Does one of the clay balls weigh more?"; and (c) "Does one of the clay balls weigh less?" If the child responded affirmatively to questions (b) and (c), the E also asked the S to indicate which clay ball weighed more in question (b), and which less in question (c).

3. Conservation of Length-Identity Format (adapted from Hooper, 1969a):

Placing the 28.0-cm piece of string in the middle of the table 8-10 inches from the S, so the length ran horizontally in a straight line from the S's left to right, the E asked the following: (a) "If I were to make this string into a circle, would the string still have the same length?"; (b) "If I were to make this string into a circle, would the string be longer?"; and (c) "If I were to make this string into a circle, would the string be shorter?" The E then formed the string into a circle (toward the S) and asked the following: (a) "Is this string the same length as before?"; (b) "Is this string longer than before?"; and (c) "Is this string shorter than before?"

4. Conservation of Length-Equivalence Format (adapted from Brainerd, 1973):

The E placed the two 28.0-cm pieces of string side-by-side in the middle of the table 8-10 inches from the S, so the length ran horizontally from the S's left to right, and so the strings were observed to be of equal length. The S was required to verbalize this latter fact. Leaving the strings exactly as they were, the E asked the following questions while pointing to the string nearest the S: (a) "If I were to make this string into a circle, would the two strings still have the same length?"; (b) "If I were to make this string into a circle, would one of the strings be longer?"; and (c) "If I were to make this string into a circle, would one of the strings be shorter?" Taking the string nearest the S and forming it into a circle, the E asked the following: (a) "Are these two strings the same length as before?"; (b) "Is one of the strings longer than before?"; and (c) "Is one of the strings shorter than before?"

5. Conservation of Weight-Identity Format (adapted from Hooper, 1969a):

Placing the green clay ball in the middle of the table 8-10 inches from the S, the E asked the following: (a) "If I were to roll this clay ball into a hot dog, would the piece of clay still have the same weight?"; (b) "If I were to roll this clay ball into a hot dog, would the piece of clay weigh more?"; and (c) "If I were to roll this piece of clay into a hot dog, would the piece of clay weigh less?" The E then rolled the piece of clay into a hot dog, and asked the following: (a) "Does this piece of clay weigh the same as before?"; (b) "Does this piece of clay weigh more than before?"; and (c) "Does this piece of clay weigh less than before?"

6. Conservation of Weight-Equivalence Format (adapted from Brainerd, 1973):

The E handed a brown clay ball to the S to hold in each hand so the S could verify the equality of weight between the two stimuli. The S was required to verbalize this latter fact. Taking the clay balls from the S and placing them on the table side-by-side, 8-10 inches from the S, the E asked the following questions while pointing to one of the stimuli: (a) "If I were to flatten this clay ball into a pancake, would the two pieces of clay still have the same weight?"; (b) "If I were to flatten this clay ball into a pancake, would one of the pieces of clay weigh more?"; and (c) "If I were to flatten this clay ball into a pancake, would one of the pieces of clay weigh less?" The E then flattened the clay ball into a pancake, and asked the following: (a) "Do these two pieces of clay weigh the same as before?"; (b) "Does one of the pieces of clay weigh more than before?"; and (c) "Does one of the pieces of clay weigh less than before?"

IV

RESULTS

INITIAL CONSIDERATIONS

Each test administrator was responsible for the reliability of the individual protocols transferred to computer score sheets for data analysis; each scored those subjects to whom he or she had administered the task battery. The test score sheets were then checked by another test administrator to ensure correct scoring. In addition, a Hoyt reliability coefficient was computed on the 24 task items under consideration when all conservation tasks were combined. Case one included all conservation tasks with supporting explanations; case two included all conservation tasks without supporting explanations (i.e., α=.95, case one; and α=.94, case two). The preschool subsample was not included in this estimate of reliability because of floor effects, and, therefore, the values computed reflect a conservative estimate. Likewise, a Hoyt reliability coefficient was computed for the 10 task items when transitivity of length and weight were combined (case one), as well as each transitivity task by itself (i.e., α=.87, case one; α=.94, case two-length; and α=.91, case three-weight). The preschool subsample was not included in this estimate of reliability.

Initial considerations concern the order of presentation effects on pass/fail dichotomous data. As indicated previously, subjects from each of the three grade levels, preschool, kindergarten, and third, were randomly assigned to one of six counterbalanced orders of presentation for the transitivity and conservation task conditions in the content areas, length and weight. With the exception of two cases, there was a notable absence of significant presentation order effects. At the preschool level, those subjects who received the transitivity tasks for length and weight first (Orders 5 and 6) and last (Orders 1 and 4) significantly outperformed those subjects who received the same tasks second (Orders 2 and 3). Results were significant for both length (χ^2=9.62, df=2, p<.01) and weight (χ^2=8.75, df=2, p<.02).

In terms of overall performance, a nonsignificant main effect of sex was found for conservation of length and weight (see Table 7). Individual pass/fail dichotomous data for each task, however, did reveal a significant male superiority on two conservation of weight cases (identity, without explanation), prediction (χ^2=5.69, df=1, p<.05) and deformation (χ^2=4.18, df=1, p<.05). A sex x grade level interaction effect was significant for the length conservation task (i.e., F=3.2205, df=2, p<.05), although post-hoc comparisons of the individual age-grade levels failed to reveal significant pair-wise differences on this dimension.

The identity and equivalence conservation tasks for length and weight content were divided into two sets of pass/fail dichotomous data, based upon both the prediction and the actual deformation of the conservation task in question, and the performance levels of the various subsamples under these conditions were compared. Thus, for each grade level, a total of eight four-fold tables (2 tasks x 2 content areas x 2 criteria) of observed frequencies were generated under the prediction/deformation conditions. A McNemar test for the significance of changes failed to indicate any differences between prediction and deformation. As a result, scores were combined across these conditions.

PRIMARY RESULTS

Conservation

The general performance patterns of the age-grade subsamples and overall composite sample are presented in Table 4 (means and standard deviations) and Tables 5 and 6 (frequency and percentages of subjects passing). A factorial variance analysis based upon a 0-6 scoring criterion for each of the conservation subtasks under the without justification condition is presented in Table 7. Observing the mean scores, the factorial variance analysis indicated a significant grade level main effect for both the length and weight measures. Mean scores on all subtasks indicate that the higher the age-grade level the better the performance level. Likewise, a significant main effect for the identity vs. equivalence factor was observed in both the length and weight measures. Mean scores were consistently better across all grade levels under the identity task condition. In addition, a significant grade level x identity vs. equivalence interaction effect was observed. When the subtasks were broken down in terms of male/female performance patterns for each grade level, mean scores fail to show clear-cut patterns between grade levels. The subsample differences between identity and equivalence subtasks at each grade level did reveal a clear pattern. Mean score differences between identity and equivalence within the same content domain were largest at the kindergarten level, followed closely by the preschool subsample, and last by the third grade, which showed the least differences.

For data analysis based upon dichotomous pass/fail data (see Tables 5 and 6), as expected χ^2 comparisons indicated significant improvements in criterial performances across the present age-grade range (i.e., all χ^2 values exceeded 50.96, df=2, $p<.001$) and, with one exception, the largest differences occurred between kindergarten and third grade. In Table 6, for conservation of weight (identity), differences in criterial performances were greater between the preschool and kindergarten subsamples (i.e., χ^2=18.89, df=1, $p<.001$) than between the kindergarten and third grade subsamples (i.e., χ^2=17.63, df=1, $p<.001$). Overall combined sample comparisons of male vs. female performances for the various conservation tasks were nonsignificant.

Pass/fail performance levels on the identity and equivalence tasks appear in Tables 8 and 9. As indicated by both tables, performance improves with age. However, more <u>Ss</u> passed both tasks under the objective response only condition, showing the clearest predicted trend. Excluding the preschool (no <u>Ss</u> at this level passed identity or equivalence), in all domains more <u>Ss</u> passed identity and failed equivalence than the reverse except the third grade subsample for length conservation. A McNemar test

Table 4

Means and Standard Deviations of the Identity and Equivalence Tasks for the Various Subsamples (Standard Deviations in Parentheses)

Grade Level	Conservation Tasks			
	Length		Weight	
	Identity	Equivalence	Identity	Equivalence
Preschool				
Males	2.48 (1.03)	1.19 (1.22)	2.35 (0.88)	1.23 (1.09)
Females	2.31 (1.47)	1.17 (1.36)	2.38 (1.08)	1.03 (1.18)
Combined Subsample	2.40 (1.25)	1.18 (1.28)	2.37 (0.97)	1.13 (1.13)
Kindergarten				
Males	3.13 (1.80)	1.93 (2.12)	3.57 (1.76)	2.13 (2.42)
Females	3.93 (1.70)	2.63 (2.31)	3.63 (1.99)	2.47 (2.30)
Combined Subsample	3.53 (1.78)	2.28 (2.23)	3.60 (1.86)	2.30 (2.35)
Third Grade				
Males	5.23 (1.45)	5.13 (1.96)	5.50 (1.36)	5.10 (2.11)
Females	4.83 (1.72)	4.03 (2.72)	4.33 (2.06)	4.00 (2.72)
Combined Subsample	5.03 (1.59)	4.58 (2.42)	4.92 (1.83)	4.55 (2.48)
Total Sample				
Males	3.60 (1.86)	2.73 (2.48)	3.79 (1.89)	2.80 (2.55)
Females	3.71 (1.93)	2.63 (2.48)	3.46 (1.93)	2.52 (2.47)
Combined Total Sample	3.65 (1.89)	2.68 (2.47)	3.63 (1.91)	2.66 (2.51)

Table 5

Frequency and Percentages of Subjects Passing the Conservation Tasks for the Various Subsamples (Objective Response and Adequate Explanation)

Grade Level	Conservation Tasks							
	Length				Weight			
	Identity		Equivalence		Identity		Equivalence	
	No.	%	No.	%	No.	%	No.	%
Preschool								
Males	0	(0)	0	(0)	0	(0)	0	(0)
Females	0	(0)	0	(0)	0	(0)	0	(0)
Combined Subsample	0	(0)	0	(0)	0	(0)	0	(0)
Kindergarten								
Males	5	(16.7)	4	(13.3)	5	(16.7)	4	(13.3)
Females	7	(23.3)	5	(16.7)	6	(20.0)	4	(13.3)
Combined Subsample	12	(20.0)	9	(15.0)	11	(18.3)	8	(13.3)
Third Grade								
Males	20	(66.7)	23	(76.6)	19	(63.3)	22	(73.3)
Females	18	(60.0)	18	(60.0)	14	(46.7)	17	(56.7)
Combined Subsample	38	(63.3)	41	(68.3)	33	(55.0)	39	(65.0)
Total Sample								
Males	25	(27.5)	27	(29.7)	24	(26.4)	26	(28.6)
Females	25	(28.1)	23	(25.8)	20	(22.5)	21	(23.6)
Combined Total Sample	50	(27.8)	50	(27.8)	44	(24.4)	47	(26.1)

Table 6

Frequency and Percentages of Subjects Passing the Conservation Tasks for the Various Subsamples (Objective Response Only)

Grade Level	Conservation Tasks							
	Length				Weight			
	Identity		Equivalence		Identity		Equivalence	
	No.	%	No.	%	No.	%	No.	%
Preschool								
Males	0	(0)	0	(0)	0	(0)	0	(0)
Females	1	(3.4)	1	(3.4)	0	(0)	0	(0)
Combined Subsample	1	(1.7)	1	(1.7)	0	(0)	0	(0)
Kindergarten								
Males	7	(23.3)	5	(16.7)	7	(23.3)	4	(13.3)
Females	10	(33.3)	7	(23.3)	11	(36.7)	4	(13.3)
Combined Subsample	17	(28.3)	12	(20.0)	18	(30.0)	8	(13.3)
Third Grade								
Males	22	(73.3)	24	(80.0)	25	(83.3)	22	(73.3)
Females	20	(66.7)	19	(63.3)	17	(56.7)	17	(56.7)
Combined Subsample	42	(70.0)	43	(71.7)	42	(70.0)	39	(65.0)
Total Sample								
Males	29	(31.9)	29	(31.9)	32	(35.2)	26	(28.6)
Females	31	(34.8)	27	(30.3)	28	(31.5)	21	(23.6)
Combined Total Sample	60	(33.3)	56	(31.1)	60	(33.3)	47	(26.1)

Table 7

Identity/Equivalence Conservation Comparisons
ANOVA Summary Table

Source	df	F Values			
		Length		Weight	
		MS		MS	
Between Subjects					
Grade Level (A)	2	279.1444	52.9768**	270.4111	52.1218**
Sex (B)	1	.0946	.0179	10.3399	1.9930
A x B	2	16.9697	3.2205*	14.8010	2.8529
Error					
(Ss within groups)	174		5.2692		5.1881
Within Subjects					
Identity vs. Equivalence (C)	1	85.0694	71.0895**	84.1000	53.4617**
A x C	2	6.1444	5.1347**	8.1333	5.1703**
B x C	1	1.0494	.8770	.0347	.0221
A x B x C	2	1.4373	1.2011	.4404	.2800
Error					
(C x Ss within groups)	174		1.1967		1.5731
	359				

*$p < .05$

**$p < .01$

Table 8

Pass/Fail Performance (Objective Response and Adequate Justification) on Identity and Equivalence Tasks at Each Grade Level (Male and Female Subsamples Combined)

Grade Level	Length Conservation			
	Pass Both	Fail Both	Pass Ident. Fail Equiv.	Pass Equiv. Fail Ident.
Preschool	0	60	0	0
Kindergarten	7	46	5	2
Third Grade	36	17	2	5
Total Sample	43	123	7	7

Grade Level	Weight Conservation			
	Pass Both	Fail Both	Pass Ident. Fail Equiv.	Pass Equiv. Fail Ident.
Preschool	0	60	0	0
Kindergarten	6	47	5	2
Third Grade	30	18	3	9
Total Sample	36	125	8	11

Table 9

Pass/Fail Performance (Objective Response Only) on the Identity and Equivalence Tasks at Each Grade Level (Male and Female Subsamples Combined)

Grade Level	Length Conservation			
	Pass Both	Fail Both	Pass Ident. Fail Equiv.	Pass Equiv. Fail Ident.
Preschool	1	59	0	0
Kindergarten	9	40	8	3
Third Grade	40	15	2	3
Total Sample	50	114	10	6

Grade Level	Weight Conservation			
	Pass Both	Fail Both	Pass Ident. Fail Equiv.	Pass Equiv. Fail Ident.
Preschool	0	60	0	0
Kindergarten	8	42	10	0*
Third Grade	36	15	6	3
Total Sample	44	117	16	3*

*$p < .01$

for significance of changes revealed significant differences between identity and equivalence for weight conservation at the kindergarten level and for the total sample ($p<.01$). Differences between identity and equivalence approached significance at the kindergarten level for length conservation ($p=.227$). In addition, McNemar tests were computed on all pairwise conservation tasks comparing identity/equivalence and with/without justification conditions. At the kindergarten level, significant differences were observed in two instances important to the present investigation. Conservation of weight under the without-justification condition showed 10 Ss passing identity without passing equivalence ($p=.002$), and conservation of weight (identity) showed seven Ss passing the without-justification condition while failing the with-justification condition ($p=.016$). At the third-grade level one significant difference was observed. For conservation of weight (identity), nine Ss passed the without-justification condition while failing the with-justification condition ($p=.004$).

An additional analysis of variance, based upon a 0-6 scoring criterion for each of the conservation subtasks, was computed for both the with- and the without-justification conditions and is presented in Table 10. The means and standard deviations for the analysis appear in Table 11. As observed in Table 10, highly significant main effects of age, task, and criterion were found. Newman-Keuls tests of the age effect indicated that the tasks were more difficult for preschoolers than they were for kindergarteners ($p<.001$) or third graders ($p<.001$) and that the tasks were more difficult for kindergarteners than they were for third graders ($p<.001$). The equivalence tasks were more difficult than the identity tasks and more trials were passed with a judgment-only criterion than with a judgment-plus-explanation criterion.

It also can be seen in Table 10 that the age x task interaction and the task x criterion interaction were both significant. Concerning the age x task interaction, Newman-Keuls tests indicated that equivalence tasks were more difficult than identity tasks for preschoolers ($p<.001$) and kindergarteners ($p<.001$) but not for third graders. Concerning the task x criterion interaction, Newman-Keuls tests indicated that the performance difference between identity and equivalence tasks was significantly greater with a judgment-only criterion than with a judgment-plus-explanation criterion ($p<.001$). Finally, the age x criterion interaction was significant. Newman-Keuls tests indicated that the discrepancy between the two criteria was more pronounced with preschoolers and with kindergarteners ($p<.01$) than with third graders ($p<.025$). The preschoolers and kindergarteners did not differ.

On the with-justification condition, Ss were given a point on each of the 8 explanation items only if they gave both a correct judgment and a correct explanation. The types of explanation were classified into the various categories which appear in Appendix B. Explanations which fell into the initial eight categories were considered correct, while explanations in the remaining two categories were considered incorrect. Table 12 represents the frequency and percentages of adequate explanations given on all conservation tasks, by grade and for the composite sample. Viewing each grade level, the higher the age-grade level, the more adequate the explanation given. With only two minor exceptions the same holds true within the various categories of explanation. Between kindergarten and third grade the frequency of explanations classified under inversion remains

Table 10

ANOVA--Trials Data (Mixed Model)
Grade Level x Task x Content x Criterion

Source	df	MS	F Values
Between Subjects			
Grade Level (A)	2	9572.1494	76.6768**
Error (Ss/Grade)	177	124.837596	
Within Subjects			
Task (B)	1	498.3347	92.3023**
A x B	2	53.4014	9.8911**
Error (Ss x B/Grade)	177	5.398941	
Content (C)	1	3.3347	.2828
A x C	2	.5597	.0475
Error (Ss x C/Grade)	177	11.792632	
Criterion (D)	1	106.5681	118.0169**
A x D	2	4.1764	4.6251**
Error (Ss x D/Grade)	177	.902990	
B x C	1	.0087	.0082
A x B x C	2	.0545	.0514
Error (Ss x B x C/Grade)	177	1.059716	
B x D	1	3.6837	45.3738**
A x B x D	2	.1920	2.3651
Error (Ss x B x D/Grade)	177	.081185	
C x D	1	.4253	5.3023*
A x C x D	2	.0316	.3939
Error (Ss x C x D/Grade)	177	.080220	
B x C x D	1	.0001	.0059
A x B x C x D	2	.0105	.7183
Error (Ss x B x C x D/Grade)	177	.014623	
	1439		

*$p < .05$

**$p < .01$

Table 11

Means and Standard Deviations of the Task x Content x Criterion Interactions for the Various Subsamples (Standard Deviations in Parentheses).

Grade Level	Conservation Tasks			
	Identity			
	Length		Weight	
	w/exp.	wo/exp.	w/exp.	wo/exp.
Preschool	1.73 (1.22)	2.40 (1.25)	1.60 (1.03)	2.37 (0.97)
Kindergarten	3.10 (1.77)	3.52 (1.78)	3.03 (1.91)	3.63 (1.85)
Third Grade	4.68 (2.06)	5.03 (1.59)	4.55 (2.01)	4.92 (1.83)

Grade Level	Conservation Tasks			
	Equivalence			
	Length		Weight	
	w/exp.	wo/exp.	w/exp.	wo/exp.
Preschool	0.90 (1.12)	1.18 (1.28)	0.82 (0.97)	1.13 (1.13)
Kindergarten	2.05 (2.10)	2.28 (2.23)	1.93 (2.20)	2.28 (2.34)
Third Grade	4.52 (2.44)	4.58 (2.42)	4.35 (2.51)	4.55 (2.47)

Table 12

Frequency and Percentages of Subjects Giving an Adequate Explanation for all Conservation Tasks

	Grade Level							
	Preschool		Kindergarten		Third Grade		Total	
	No.	%	No.	%	No.	%	No.	%
Inversion	0	(0)	14	(12.6)	14	(4.2)	28	(6.2)
Reciprocity	0	(0)	2	(1.8)	3	(0.9)	5	(1.1)
Compensatory Relations	0	(0)	1	(0.9)	0	(0)	1	(0.2)
Addition-Subtraction	0	(0)	19	(17.1)	132	(39.6)	151	(33.6)
Statement of Operations	1	(20.0)	19	(17.1)	60	(18.0)	80	(17.8)
Sameness (same stimulus)	4	(80.0)	22	(19.8)	30	(9.0)	56	(12.5)
Sameness (same quantity)	0	(0)	28	(25.2)	43	(12.9)	71	(15.8)
Previous amount or equality	0	(0)	6	(5.4)	51	(15.3)	57	(12.7)
No. and % of Explanations	5	(100)	111	(100)	333	(100)	449	(100)

unchanged, while those explanations classified under compensatory relations drops from one to zero. Differences in percent within each explanation type among the various subsamples can be attributed to an accumulation of adequate explanations within a certain category at each grade level, or to a lack thereof. Thus, for example, both the preschool and third grade subsamples reflect such a tendency while the kindergarten subsample does not. For the preschool subsample, 80 percent of the explanations fell into one category, while for the third-grade subsample, close to 60 percent of the explanations fell into two categories. For the kindergarten subsample, however, both frequency and percent of explanations are more evenly distributed, with five of the eight categories accounting for approximately 90 percent of the explanations.

Tables 13 and 14 represent the frequency and percentage of adequate explanations given on all identity and all equivalence conservation tasks, by grade and for the composite sample. For both identity and equivalence conservation, the higher the age-grade level the more explanations were given. The frequency at each grade level was approximately the same. For all equivalence explanations, the category "compensatory relations" is the exception; no explanations fell within this category. For all identity explanations, the categories "inversion," "reciprocity," and "compensatory relations" are the exception. At the third-grade level, fewer subjects gave adequate explanations in these three categories than in the kindergarten subsample. In terms of percentages, an accumulation of adequate explanations within a certain category at the preschool and third-grade level occurred for both identity and equivalence tasks. At the preschool level, all explanations fell into two categories for identity (statement of operations, 33.3 percent; and same stimulus, 66.7 percent), and one category for equivalence (same stimulus, 100 percent). For the third-grade subsample identity tasks, approximately 68 percent of the explanations fell into the categories, "addition-subtraction" and "statement of operations." For equivalence, approximately 57 percent of the explanations fell into two categories, "addition-subtraction" and "previous amount or equality." This last category is of interest in terms of identity/equivalence explanations. Whereas only 6.2 percent of the third-grade subsample used "previous amount or equality" as an explanation for identity conservation, 23.8 percent of the subsample justified their responses with this explanation type for the equivalence conservation tasks. For both identity and equivalence, the kindergarten subsample shows a much more widely spread distribution of explanations across various categories.

Transitivity

The general performance patterns of the age-grade subsamples and the overall composite sample is presented in Table 15 (frequency and percentages of subjects passing). Overall, transitivity of length appears to be of slightly greater difficulty than the counterpart task for weight. For grade-level comparisons, χ^2 tests indicate a significant performance improvement in both content domains, with the largest differences occurring

Table 13

Frequency and Percentages of Subjects Giving an Adequate Explanation for all Identity Conservation Tasks

	Grade Level							
	Preschool		Kindergarten		Third Grade		Total	
	No.	%	No.	%	No.	%	No.	%
Inversion	0	(0)	7	(11.7)	5	(3.1)	12	(5.4)
Reciprocity	0	(0)	2	(3.3)	0	(0)	2	(0.9)
Compensatory Relations	0	(0)	1	(1.7)	0	(0)	1	(0.4)
Addition-Subtraction	0	(0)	9	(15.0)	74	(46.0)	83	(37.1)
Statement of Operations	1	(33.3)	12	(20.0)	36	(22.4)	49	(21.9)
Sameness (same stimulus)	2	(66.7)	13	(21.7)	18	(11.2)	33	(14.7)
Sameness (same quantity)	0	(0)	15	(25.0)	18	(11.2)	33	(14.7)
Previous amount or equality	0	(0)	1	(1.7)	10	(6.2)	11	(4.9)
No. and % of Explanations	3	(100)	60	(100)	161	(100)	224	(100)

Table 14

Frequency and Percentages of Subjects Giving an Adequate Explanation for all Equivalence Conservation Tasks

	Grade Level							
	Preschool		Kindergarten		Third Grade		Total	
	No.	%	No.	%	No.	%	No.	%
Inversion	0	(0)	7	(13.7)	9	(5.2)	16	(7.1)
Reciprocity	0	(0)	0	(0)	3	(1.7)	3	(1.3)
Compensatory Relations	0	(0)	0	(0)	0	(0)	0	(0)
Addition-Subtraction	0	(0)	10	(19.6)	58	(33.7)	68	(30.2)
Statement of Operations	0	(0)	7	(13.7)	24	(14.0)	31	(13.8)
Sameness (same stimulus)	2	(100)	9	(17.6)	12	(7.0)	23	(10.2)
Sameness (same quantity)	0	(0)	13	(25.5)	25	(14.5)	38	(16.9)
Previous amount or equality	0	(0)	5	(9.8)	41	(23.8)	46	(20.4)
No. and % of Explanations	2	(100)	51	(100)	172	(100)	225	(100)

Table 15

Frequency and Percentages of Subjects Passing Transivitity Tasks for Length and Weight

		Length	Weight
		Number (%)	Number (%)
Preschool	(n=60)	22 (36.67)	24 (40.00)
Kindergarten	(n=60)	36 (60.00)	45 (75.00)
Third Grade	(n=60)	48 (80.00)	57 (95.00)
Total	(N=180)	106 (58.89)	126 (70.00)

Table 16

Pass/Fail Transitivity x Conservation
Task Comparisons for the
Preschool Subsample

Conservation of Length

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Length	−	38	0	36	2	38	0	37	1	38	0	35	3	38	0	37	1
	+	21	1	21	1	22	0	20	2	22	0	22	0	22	0	22	0

Conservation of Weight

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Weight	−	35	0	34	1	35	0	34	1	35	0	35	0	35	0	35	0
	+	25	0	23	2	25	0	24	1	25	0	25	0	25	0	23	2

Table 17

Pass/Fail Transitivity x Conservation
Task Comparisons for the
Kindergarten Subsample

Conservation of Length

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Length	−	21	3	19	5	21	3	19	5	20	4	16	8	21	3	18	6
	+	26	10	22	14	25	11	22	14	28	8	26	10	29	7	28	8

Conservation of Weight

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Weight	−	12	3	12	3	13	2	12	3	13	2	13	2	13	2	13	2
	+	36	9	26	19	31	14	25	20	39	6	33	12	35	10	30	15

Table 18

Pass/Fail Transitivity x Conservation
Task Comparisons for the
Third Grade Subsample

Conservation of Length

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Length	−	6	6	5	7	4	8	4	8	3	9	3	9	4	8	4	8
	+	15	33	12	36	13	35	11	37	14	34	13	35	12	36	11	37

Conservation of Weight

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Weight	−	2	1	1	2	2	1	1	2	1	2	1	2	1	2	1	2
	+	20	37	14	43	22	35	15	42	20	37	16	41	18	39	13	44

Table 19

Pass/Fail Transitivity x Conservation
Task Comparisons for the
Total Sample

Conservation of Length

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Length	−	65	9	60	14	63	11	60	14	61	13	54	20	63	11	59	15
	+	62	44	55	51	60	46	53	53	64	42	61	45	63	43	61	45

Conservation of Weight

Transitivity		Identity								Equivalence							
		Prediction				Deformation				Prediction				Deformation			
		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.		w/exp.		wo/exp.	
		−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+
Weight	−	49	4	47	6	50	3	47	6	49	4	49	4	49	4	49	4
	+	81	46	63	64	78	49	64	63	84	43	74	53	78	49	66	61

between preschool and kindergarten (i.e., for length, $\chi^2=5.64$, df=1, $p<.02$; and for weight, $\chi^2=13.64$; df=1, $p<.001$).

The remaining analysis is based upon a task x task comparison of both transitivity tasks to all length and weight conservation task conditions (prediction/deformation, identity/equivalence, with/without justification). As Tables 16, 17, 18, and 19 indicate, at both the preschool and kindergarten grade level, both length and weight transitivity tasks were significantly easier than all length and weight conservation measures. For the preschool and kindergarten subsamples (Tables 16 and 17), McNemar tests for the significance of change indicate all task x task comparisons significant beyond the .01 level. For the third-grade subsample (Table 18), McNemar tests indicate only the weight transitivity task significantly easier than the length and weight conservation measures. In addition, the third grade was the only subsample in which there was a significant difference between the length and weight transitivity measures. Transitivity of weight was significantly easier than length ($p<.05$). Eleven Ss passed transitivity of weight, and of these two Ss failed the corresponding task for length.

V

DISCUSSION

This discussion is based on the predictions mentioned previously and on the theoretical implications of the present findings. The primary concern is with results related to the conservation tasks, and the secondary concern is with the transitivity task results.

Within the conservation task domain, the factor of age-grade level was related to two of the dependent measures, task (identity/equivalence), criterion (judgment only/judgment plus explanation), but not to content (length/weight). Significant interaction effects of Age x Task and Age x Criterion indicate that as a whole, conservation tasks are more difficult the younger the age-grade level. Thus, fewer preschoolers passed conservation tasks than either kindergarteners or third graders, and fewer kindergarteners passed than third graders. More importantly, however, equivalence conservation is significantly more difficult than identity conservation for preschool and kindergarten subjects, but not for third-grade subjects. In other words, identity conservation is indeed distinct from equivalence conservation, as indicated by both its earlier emergence and the larger differences at earlier age levels. Likewise, differences between the two criteria were greater at the preschool and kindergarten level than at the third-grade level. More subjects passed the conservation tasks under the judgment-only condition than the judgment-plus-explanation condition, with the largest differences occurring at the earlier age levels. In addition, a significant Task x Criterion interaction indicates a less visable identity → equivalence sequence with a judgment-plus-explanation criterion than under a judgment-only condition. No significant performance differences were found between prediction and actual deformation of the conservation relationship in question (identity or equivalence).

For all transitivity tasks a significant performance improvement was observed at each higher grade level, with the largest differences between the preschool and kindergarten subsamples. Transitivity of length was found to be of slightly greater difficulty than transitivity of weight. Task x task comparisons of both transitivity tasks to all length and weight conservation task conditions reveal that at the preschool and kindergarten grade levels transitivity is significantly easier than all length and weight conservation measures and that for the third-grade subsample only transitivity of weight was significantly easier than all length and weight conservation measures. These findings are essentially in agreement with those results reported by Brainerd (1973). In addition, in only the third-grade subsample was a significant difference observed between length and weight transitivity. Transitivity of weight was significantly easier than the corresponding task for length.

In view of the present findings, it may be stated that Piaget's conservation problems tap two distinct concepts, as conjectured by Elkind (1967), and that the emergence of the conservation concept is not a synchronous and unitary process within the stage of concrete operations. In addition, the differences between the supportive and non-supportive findings of previous empirical investigations are largely attributable to faulty measurement and sampling techniques used in the non-supportive studies which resulted in the commission of known sources of Type II error thus masking the real identity → equivalence sequence (Brainerd & Hooper, 1975). Three of five of the non-supportive studies employed a judgment-plus explanation criterion, and all these studies failed to include pre-schoolers in their sample populations.

An examination of adequate explanations on the identity and equivalence tasks within the judgment-plus-explanation condition indicates subjects use addition-subtraction explanations most frequently to justify a given response. The type of explanation given differs between the identity and equivalence tasks within the next frequent category; subjects use a statement of operations explanation under identity conservation, and use reference to a previous amount or equality explanation for equivalence conservation. A comparison of these findings with the only other studies that examined adequate explanation categories in some detail (i.e., Hooper, 1969a; and Papalia & Hooper, 1971, for quantity only) shows both discrepancies and similarities. For all identity tasks, the present findings concur with Hooper (1969a), in that addition-subtraction is the most frequent explanation given; whereas, statement of operations is the most frequent category in the Papalia and Hooper (1971) study. For all equivalence tasks, the most frequent category employed reference to a previous amount or equality in both the Hooper (1969a), and Papalia and Hooper (1971) studies. Addition-subtraction explanations are the most frequent category, however, for the present investigation. It is of particular interest that neither the present findings, nor those reported by Hooper (1969a), and Papalia and Hooper (1971), found that reversibility, an important formal property of concrete operations, was a frequent explanation category. The two explanation categories which would reflect reversibility, inversion and reciprocity, were seldom employed.

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APPENDIX A

TRANSITIVITY AND CONSERVATION TASKS:

INSTRUCTIONS

Conservation and Transitivity

Warm-Up

Materials:

Picture of two unequal parallel lines
Two blocks of unequal weight

Instructions:

(1) Length: The E places a picture of two perceptibly unequal parallel lines (10-cm and 20-cm) to the center of the table, approximately 8-10 inches from the S. The picture is arranged such that the longest (20-cm) line is nearest the S. The E then asks the following questions:

(a) ARE THESE TWO LINES THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) WHICH LINE IS LONGER?

10-cm ____ 20-cm ____ I Don't Know ____ No Response ____

(c) WHICH LINE IS SHORTER?

10-cm ____ 20-cm ____ I Don't Know ____ No Response ____

Warm-Up continued

(2) Weight: The E gives the S a block to hold in each hand, and asks the following questions:

(a) ARE THESE TWO BLOCKS THE SAME WEIGHT?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) WHICH BLOCK WEIGHS MORE?

Small ____ Large ____ I Don't Know ____ No Response ____

(c) WHICH BLOCK WEIGHS LESS?

Small ____ Large ____ I Don't Know ____ No Response ____

Note: If a S does not seem to understand the relational terms, the E may repeat the warm-up or that portion which the S seems uncertain.

Transitivity of Length

Materials:

27-cm blue stick
28-cm blue stick
28-cm white stick

Instructions:

The E places the board, having a 27-cm blue stick and a 28-cm blue stick glued down approximately one arm's length apart, 8-10 inches from the S in the middle of the table. The sticks are positioned such that the midpoint of each stick is in direct relation to the other stick. Taking the 28-cm white stick and placing it in the middle of the board between the two blue sticks, the E says:

HERE ARE SOME STICKS WE WILL BE WORKING WITH.

The E then places the 28-cm white stick next to the 28-cm blue stick, making the ends nearest the S even with one another, and so the S can observe the sticks to be of equal length. The S is required to verbalize this latter fact.

ARE THESE TWO STICKS THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

Next, the E places the 28-cm white stick next to the 27-cm blue stick, again making the ends nearest the S even with one another, and so the S can observe that the white stick is the longer of the two. The S is required to verbalize this latter fact.

IS ONE OF THE STICKS LONGER?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

White ____ Blue ____ I Don't Know ____ No Response ____

Transitivity of Length continued

Finally, the E removes the white stick from the table, and asks the following questions:

(a) ARE THESE TWO STICKS THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IS ONE OF THE STICKS LONGER?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

28-cm ____ 27-cm ____ I Don't Know ____ No Response ____

(c) IS ONE OF THE STICKS SHORTER?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

27-cm ____ 28-cm ____ I Don't Know ____ No Response ____

Transitivity of Weight

Materials:

One red and one grey clay ball of equal weight
One grey clay ball of a lighter weight

Instructions:

The E places the three clay balls in the middle of the table 8-10 inches from the S, and says:

HERE ARE SOME CLAY BALLS WE WILL BE WORKING WITH.

The E then hands the S one red and one grey clay ball of equal weight. The S is required to verbalize this latter fact.

DO THESE TWO CLAY BALLS WEIGH THE SAME?

Yes ____ No ____ I Don't Know ____ No Response ____

Next, the E removes the grey clay ball from the S's hand and places the grey ball on the table 8-10 inches in front of the hand in which it was held. Then the red clay ball is removed and placed in the hand opposite the one in which it originally appeared. Next the lighter grey clay ball is placed in the remaining empty hand, so the S will know that the red ball is the heavier of the two. The S also is required to verbalize this latter fact.

DOES ONE OF THE CLAY BALLS WEIGH MORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

Red ____ Grey ____ I Don't Know ____ No Response ____

Transitivity of Weight continued

The grey clay ball is removed and placed on the table 8-10 inches in front of the hand in which it was held. Finally, the E removes the red clay ball from the table, and asks the following questions:

(a) DO THESE TWO CLAY BALLS WEIGH THE SAME?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) DOES ONE OF THE CLAY BALLS WEIGH MORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

Heavy ____ Light ____

(c) DOES ONE OF THE CLAY BALLS WEIGH LESS?

Yes ____ No ____ I Don't Know ____ No Response ____

(If "Yes," then) WHICH ONE?

Light ____ Heavy ____

Conservation of Length

Identity Format

Materials:

One 28-cm string

Instructions:

(1) Prediction: Placing the 28-cm string in the middle of the table 8-10 inches from the S, so the length runs horizontally in a straight line from the S's left to right, the E asks the following questions:

(a) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD THE STRING STILL HAVE THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD THE STRING BE LONGER?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD THE STRING BE SHORTER?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Length continued

(2) Deformation: The E then forms the string into a circle (toward the S), and asks the following questions:

(a) IS THIS STRING THE SAME LENGTH AS BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IS THIS STRING LONGER THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) IS THIS STRING SHORTER THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Length

Equivalence Format

Materials:

Two 28-cm strings

Instructions:

The E places the two strings side-by-side in the middle of the table 8-10 inches from the S, so the length runs horizontally from the S's left to right, and so the strings are observed to be of equal length. The S is required to verbalize this latter fact.

ARE THESE TWO STRINGS THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

(1) Prediction: Leaving the strings exactly as they are while pointing to the string nearest the S, the E asks the following questions:

(a) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD THE TWO STRINGS STILL HAVE THE SAME LENGTH?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD ONE OF THE STRINGS BE LONGER?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) IF I WERE TO MAKE THIS STRING INTO A CIRCLE, WOULD ONE OF THE STRINGS BE SHORTER?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Length continued

(2) Deformation: The E then forms the string nearest the S into a circle (toward the S), and asks the following questions:

(a) ARE THESE TWO STRINGS THE SAME LENGTH AS BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IS ONE OF THE STRINGS LONGER THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) IS ONE OF THE STRINGS SHORTER THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Weight

Identity Format

Materials:

One green clay ball

Instructions:

(1) Prediction: Placing the green clay ball in the middle of the table 8-10 inches from the S, the E asks the following questions:

(a) IF I WERE TO ROLL THIS CLAY BALL INTO A HOT DOG, WOULD THE PIECE OF CLAY STILL HAVE THE SAME WEIGHT?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IF I WERE TO ROLL THIS CLAY BALL INTO A HOT DOG, WOULD THE PIECE OF CLAY WEIGH MORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IF I WERE TO ROLL THIS CLAY BALL INTO A HOT DOG, WOULD THE PIECE OF CLAY WEIGH LESS?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Weight continued

(2) Deformation: The E then rolls the clay ball into a hot dog, and asks the following questions:

(a) DOES THIS PIECE OF CLAY WEIGH THE SAME AS BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) DOES THIS PIECE OF CLAY WEIGH MORE THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) DOES THIS PIECE OF CLAY WEIGH LESS THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Weight

Equivalence Format

Materials:

Two brown clay balls of equal weight

Instructions:

The E gives the S a clay ball to hold in each hand so the balls are observed to be of equal weight. The S is required to verbalize this latter fact.

ARE THESE TWO BALLS THE SAME WEIGHT?

Yes ____ No ____ I Don't Know ____ No Response ____

(1) Prediction: Taking the balls from the S and placing them on the table side-by-side 8-10 inches from the S, the E asks the following questions while pointing to one of the stimuli:

(a) IF I WERE TO FLATTEN THIS CLAY BALL INTO A PANCAKE, WOULD THE TWO PIECES OF CLAY STILL HAVE THE SAME WEIGHT?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) IF I WERE TO FLATTEN THIS CLAY BALL INTO A PANCAKE, WOULD ONE OF THE PIECES OF CLAY WEIGH MORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) IF I WERE TO FLATTEN THIS CLAY BALL INTO A PANCAKE, WOULD ONE OF THE PIECES OF CLAY WEIGH LESS?

Yes ____ No ____ I Don't Know ____ No Response ____

Conservation of Weight continued

(2) Deformation: The E then flattens the clay ball into a pancake, and asks the following questions:

(a) DO THESE TWO PIECES OF CLAY WEIGH THE SAME AS BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(b) DOES ONE OF THE PIECES OF CLAY WEIGH MORE THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

(c) DOES ONE OF THE PIECES OF CLAY WEIGH LESS THAN BEFORE?

Yes ____ No ____ I Don't Know ____ No Response ____

APPENDIX B

EXPLANATION CATEGORIES FOR CONSERVATION

TASKS: SCORING CRITERIA

Scoring Criteria

1) Inversion: when piece of clay or piece of string is returned to its original state, prior to transformation.

2) Reciprocity: when standard stimulus can be made to resemble the transformed stimulus.

3) Compensatory Relations: when one dimension of the transformed stimulus is exactly compensated by the other dimension. i.e., hot dog is longer, but also narrower.

4) Addition/Subtraction: nothing has been added to, or subtracted from the transformed stimulus.

5) Statement of operations performed: assertion that transformation does not affect quantity in question.
i.e., you just made string into circle, clay ball into hot dog or pancake, so still the same quantity.

6) Sameness: assertion that stimulus as a "whole" entity is the same piece of string or clay.

7) Sameness: assertion that stimulus is the same length or weight.

8) Reference to previous amount or equality: standard stimulus and transformed stimulus have same weight or length because standard stimulus and comparison stimulus (prior to transformation) had the same weight or length.

9) Immediate perceptual features: it (string, clay) looks shorter-longer, lighter-heavier, less-more, or the same.

10) Irrelevant considerations: i.e., because; I don't know; it's longer; it's flat; it's a circle; hot dogs are heavy; pancakes are light; etc.

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