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Number conservation as related to type of transformation

Marsha Taliaferro Will

Number Conservation
as Related to
Type of Transformation

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Marsha Taliaferro Will

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Number Conservation

as Related to

Type of Transformation

The undersigned, as member of the committee, have read and approved this thesis:

Joanne C. Preston, Ph.D., Chairman

Carol Bishop, Ph.D.

William E. Walker, Ph.D.

Dedicated

To Children Everywhere

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Abstract

In order to assess the negative effects of color, size, shape, and spacing (length) transformations on conservation judgements sixty-four 3, 4, 5, and 6 year old children were tested on four Piagetian type conservation of number tasks each containing one reversible color, size, shape or spacing transformation. Order of transformation presentation was counterbalanced and number of objects used per transformation were varied from 3 to 5 to 7 to 9. Results show that spacing (when compared to color, size and shape) is a prepotent cue for non-conserving 3, 4, and 5 year olds but not for 6 year olds. Results also show that color, size, and shape transformations did not appear to be exerting any negative influence (i.e., they did not lead to more consistent non-conserving responses than would be expected by chance) on the conservation judgements of the subjects in this study. Order of presentation and number of objects per transformation also did not appear to affect conservation judgements.

The typical Piagetian conservation of number task is composed of two parts. First the child is shown an array of like objects which has two sets or rows of equal numbers of objects in a one to one correspondence. Then one set is altered either by an increase of space between the objects, which results in that row being longer and less dense than the other, or by a collapsing, which results in that row being shorter and more dense than the other. Questions about the equality of the sets are asked with a demand for an adequate explanation of the answers. In the growth from a non-conserving to a fully conserving status Piaget delineates 3 stages: 1) A total absence of conservation in which the child makes global comparisons and may judge quantities by the length of the rows. 2) An intermediary stage in which the child is able to coordinate relationships for some transformations but not for all, and understand equivalence only on the intuitive level. 3) An operational correspondence stage with true and lasting equivalence in which the child knows that regardless of the transformation the number has not changed and that any change in distribution can be reversed by an inverse operation (Piaget, 1941, pp. 68-74).

Piaget's theory predicts that the preoperational child's cognitive development, in concert with changes in both the environment and those produced indirectly by the child's own growth will proceed through these stages invariantly, and that true and lasting conservation of number is attained by the child only at stage 3 " ... with the triumph of correspondence over perception" (Piaget, 1941, p. 37).

Many researchers have been fascinated with not only the "Why?" but also the "Why not?" of the conservation phenomenon, and have accordingly investigated every conceivable aspect of the problem. The research does, however, seem to fall into several broad categories - namely methodological problems, effects of training, and the use of various perceptual cues in making conservation judgements.

Methodological investigations have shown that sex has no bearing on the ability to conserve (Braine, 1959; Pratoomraj and Johnson, 1966; Shantz and Siegel, 1967; Rothenberg and Orost, 1969; all quoted in Rothenberg and Orost, 1969), but that experimenter expectancy, mental age, education, SES, order of presentation for number of items in an array, unequal arrays, numbers of objects used for the conservation task, and language and criteria used to verify conservation are all related to the results obtained on conservation problems (Hunt, 1975; Inhelder, Sinclair, and Bovet, 1974, p. 26; Rothenberg and Orost, 1969; Gelman, 1972b, p. 146; Gelman, 1972a; Rothenberg, 1969; Rothenberg and Courtney, 1969; Beilin, 1965, Brainerd, 1963; La Pointe and O'Donnell, 1974).

Experiments concerning a child's ability to be trained to conserve have shown that training has effect only when subjects are at an intermediate or transitional stage of conservation (Beilin, 1965), that addition and subtraction training does not help but that reversibility training does (Wallach, Wall and Anderson, 1967), that verbal mediation training helps older but not younger children (Stevenson, 1972, pp. 251-253), and that training is effective but dependent on feedback and an opportunity to interact with quantiative equalities and differences which presumably tell the child what is and what is not relevant to the definition of quantity (Gelman, 1968).

From the very earliest to the most recent experiments the child's use of perceptual cues in making number and conservation judgements has been a fertile area for investigation with much of the work centering on a child's use of length or density of rows as the basis for number and conservation judgements. Gelman (1968) showed that children confuse number and length and think that length confirms an increase in number. Mehler and Bever (1969) found a curvilinear relationship between age and conservation, with 2 year olds and 5 year olds being able to conserve but not 4 year olds. Piaget explained this phenomena by pointing out that young children use density as the basis for conservation judgements and not until age 4 does a strategy based on length begin to develop and with the Mehler and Bever design an opportunity to use density was not availabe to the child. Piaget further explained that density as well as length are perceptual strategies and are not the cognitive strategies that treat number as invariant regardless of the perceptual transformation (Piaget, 1968). Ginsburg (1975) lent support to Piaget's view that length as a conservation strategy does not begin to develop until age 4 by showing that children under 4 use density as a conservation strategy and children over 4 use length. This, of course, is in line with the U shaped distribution of conservers by age that Mehler and Bever found with their design.

Pufall and Shaw (1972) proposed 3 developmentally based models to account for the similarities between the 3 year olds and the 5 to 6 year olds. They argued that it appeared that the 3 year olds were sensitive and attentive to differences in arrays without relating them to number while 4 and some 5 year olds equated length with number and 6 year olds logically related the multiplication of length and density to number. Gelman, on the other hand, found no support for the Mehler and Bever curve nor for the suggestion that 3 and 4 year olds are unable to treat number logically due to the "masking by dominating perceptual strategies" (Gelman, 1972, p. 88), and showed instead that when set size is less than 5 and transformations are carried out surreptitiously, young children conserve by treating number as invariant and ignoring irrelevant transformations (Gelman, 1972b, 1975). (Support for young children's ability to estimate numerosity correctly when set sizes are 5 or less is impressive (Beckman, 1924; Descourdes, 1921; Gelman, 1972b, Lawson, Baron and Siegel, 1974; Smithers, Smiley and Rees, 1974; all quoted in Gelman and Tucker, 1975).

Pufall, Shaw and Syrdal-Lasky did not support Piaget's stage theory for number conservation but did show an increasing tendency with age to make conservation judgements in terms of length except when length is equivalent and then the child tends to base his judgements on other perceptual differences such as density of row, nearness of row, and color of objects. This study also supported the prediction that it would make no difference on the conservation task whether or not an early pre-operational child observed the transformation (Pufall, Shaw and Syrdal-Lasky, 1973).

A study by Lawson, Baron and Siegel (1974) supported Gelman showing number to be a salient cue for estimating numerosity when arrays are static and set size is small. However, on a traditional conservation task, number was not necessarily used as the basis for conservation judgements. Interestingly enough, though, those children who used number for making judgements on transformed arrays also used number on static arrays even when attending to length was more appropriate to the solution. This same study does not, however, support Pufall and Shaw's position that length is a prepotent cue in making number judgements. Lawson et al. explain this discrepancy by saying that it may be necessary to assume that children respond to whatever is most salient at the moment so that the rule prior to true conservation may be, "When the numbers are beyond estimation range, use length for quantity; when the numbers are within estimation range, use number for quantity.". Results from a study by Smither, Smiley and Rees (1974) also showed young children to be sensitive to number differences before they could make accurate number judgements. This same study, however, showed weak support for different cues being salient at different ages.

In reviewing these studies some questions and observations about perceptual cues and conserving strategies come to mind. It is generally accepted that in the face of a conservation problem (containing a reversible transformation that can be observed) a pre-operational child will not conserve but rather will attend to extraneous perceptual cues and the attended cues can vary depending on the age of the child and the circumstances of the task at hand. It is also apparent that length and density are preferred cues of both children and researchers. However, it does seem reasonable to ask whether length and density are the only perceptual cues which might capture the young child's attention in conservation problems.

Gelman's 1968 study, using a typical Piagetian paradigm, did, in fact, include color, size, and shape of objects (along with length, density, and number) as possible prepotent cues during the pretest phase. It would, however, be difficult to assess the effects of color, size, and shape on conserving since they were perfectly confounded with length, density, and number after the transformation. In spite of the fact that the results of this study did show that children could be trained to conserve, Gelman, herself, found this paradigm to be an unacceptable approach to conservation problems due to her belief that conservation is a two part process involving 1) a determination of quantity (as exhibited by estimation, iteration, or one to one correspondence) as a prerequisite for 2) the consequences of transforming quanity i.e. conserving quantity. This position led Gelman to hypothesize that if a child who has knowledge of number (counting) can " ... distinquish between events and manipulations which are relevant to number (addition, subtraction, multiplication), and those which are not (displacement or length, and rearrangement or density)" then he can conserve (Gelman, 1972b, p. 148).

In order to test this position, Gelman devised a conservation paradigm that would delete from the conservation task those factors such as language criteria and attention-drawing procedures, which confuse and mislead the child, or destroy his confidence about using number as the relevant cue for conservation judgements. The procedure involved two phases. The first was an expectancy phase. The child was shown two plates, each containing a row of toy green mice - two on one plate, three on the other. The rows were either the same length with density redundant to number, or the same density, with length redundant to number. Then while the child watched, and without mentioning number, the experimenter pointed to the plate with three mice and said, "This is the winner." Then began a "game" in which the object was for the child to guess which was the winning plate after covering, and shuffling the plates under large cans. The plates were then uncovered, the child was instructed to point to the winning plate and reinforced for a correct choice. A new trial then began and whenever a child made an error in his response as to whether he had uncovered a winner he was corrected. After 10 trials, the second phase began. To the child, the beginning of this phase appeared to be just another trial, but for the experimenter this trial involved covertly changing the winning plate either by adding to, subtracting from, lengthening, or shortening the winning row. As soon as the altered plate was uncovered, surprise reactions were noted and the child was asked why the plate was a winner or looser; what, if anything, had happened; how many mice were present now as opposed to before; if and how the game could be fixed or changed to what it used to be.

The results confirmed Gelman's hypothesis that determining number predicts using number to conserve (Gelman, 1972b, p. 160). The success with this paradigm led Gelman and Tucker (1975) to reinvestigate the problem of other perceptual cues and their effects or interactions in conservation tasks. In this study the "magic" paradigm was once again employed but during phase 2 the experimenter covertly exchanged one plate of toy green mice for either a plate of red mice or a plate of toy soldiers. The results once again showed extraneous perceptual cues (color and identity) to have no effect on conservation when a child has the ability to determine number.

Gelman has taken a strong position about these results and said of the original "magic" study, "This study (Experiment 4) supports the hypothesis that whether or not a young child estimates on the basis of number predicts whether or not he will reveal the use of number operators" (Gelman, 1972b, p. 160), where "number operators" means conserving on the basis of number and further states "insofar as measurement involves counting, the present results are consistent with the positions of Wohlwill and Bearison (1969) (who) pointed out (that) the child who is able to measure quantities can then determine on his own whether or not a transformed quantity is conserved" (Gelman, 1972b, p. 162).

However, there are some questions concerning both the theoretical position and the methodology involved. Piaget has been emphatic on the point that there is no connection between counting or one to one correspondence and the actual operations a child can perform, and sees the " ... necessary equivalence and relations" as the prerequisite for conservation (Piaget, 1941, p. 61). Piaget further points out that an intuitive equivalence operating in the face of a reversible transformation is at the heart of conservation while the lack of intuitive equivalence and understanding of reversibility (i.e., the centering on transformations as measurement cues) is the reason for non-conservation (Piaget, 1941). Even though Gelman used a typical Piagetian conservation paradigm in her original investigation involving extraneous perceptual cues and conservation (Gelman, 1968), the variation of color, size, and shape was neither within the transformation nor reversible. In her "magic" paradigm, color and identity variables were within the transformations but could not be termed reversible transformations of the objects since these transformations involved a complete replacement of objects or object rows. In addition the confounding of length and density with color, size, and shape makes it impossible to draw any conclusions about the effects of color, size, and shape transformations in a conservation of number task.

Therefore, the purpose of this experiment is to return to the Piagetian paradigm and investigate which reversible stimulus transformations (color, size, shape, and length of array) will negatively affect conservation of number and what are the interactions with children of different ages when object number is varied from small to large.

Method

Subjects

Sixty-four Montessòri School students, divided equally into four age groups, (2 yrs. 10 mos. to 3 yrs. 9 mos.; 3 yr. 10 mos. to 4 yrs. 9 mos.; 4 yrs. 10 mos. to 5 yrs. 9 mos.; 5 yr. 10 mos. to 6 yrs. 9 mos.) were tested individually by one naive examiner. All the children attend private Montessori schools in the suburbs of a metropolitan city. While the group could, in general, be classified as coming from middle socio-economic homes, their IQ classification is known to range from Low Average through Superior as measured by the full range scores on the WIPPSI and WISC-R. Their ethnic background is reflective of the city's population which means there are both Black and White children in the group. No effort was made to control or match for sex differences in the group.

Materials and Procedures

Each child was tested on four Piagetian type conservation of number tasks in which three intrinsic transformations (color, size, and shape of objects) and one extrinsic transformation (spacing or length of object rows) were presented with first 3, then 5, then 7 and finally 9 objects, in that order. The order was not counterbalanced because it was felt that any small child presented with a 7 or 9 object transformation first would feel overwhelmed. The objects used for color, size, shape, and spacing transformations in the conservation tasks were: 1) eighteen plastic cubes half of which were painted white on all six faces and half of which were painted white on three faces (i.e., the top and two sides adjacent to it) and red on three faces (i.e., the bottom and the two sides adjacent to it); 2) eighteen clear rubber ballons attached to an apparatus that allowed the examiner to inflate and deflate the ballons by pressing buttons that the child could not see (the exact description and diagram of the ballon apparatus can be found in the appendix); 3) eighteen malleable wire cages that could be expanded, collapsed and changed in shape by simple hand and finger manipulations; and, 4) eighteen plain white poker chips. The shape transformation, obviously, had to involve a size transformation, but the size transformation was purposefully made minimal enough that it can be considered negligible.

The order of color, size, shape and spacing presentations were counterbalanced and children from each age group were assigned randomly to each order. The four orders of presentation are delineated in Figure 1 and the four conservation task sequences conformed to that of Figures 2, 3, 4, and 5. In addition

Insert Figures 1, 2, 3, 4 and 5 about here

to these four tasks each child was asked to count out nine M & M

Figure 1

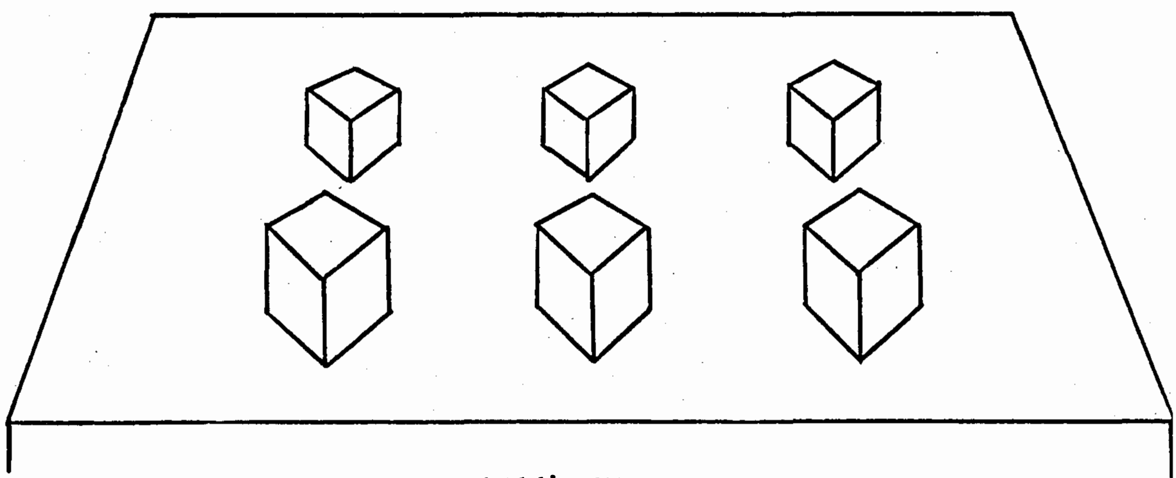
Order of presentation of extraneous cue transformations

Order 1	Order 2	Order 3	Order 4
Color	Size	Shape	Spacing
Size	Color	Spacing	Shape
Shape	Spacing	Color	Size
Spacing	Shape	Size	Color

Figure 2

Conservation Task Sequence for Color Transformation

Plastic blocks were placed in a one to one correspondence while the child watched. One row of blocks was white on all sides and the other row was white on three sides and red on three sides. The child saw only white sides.



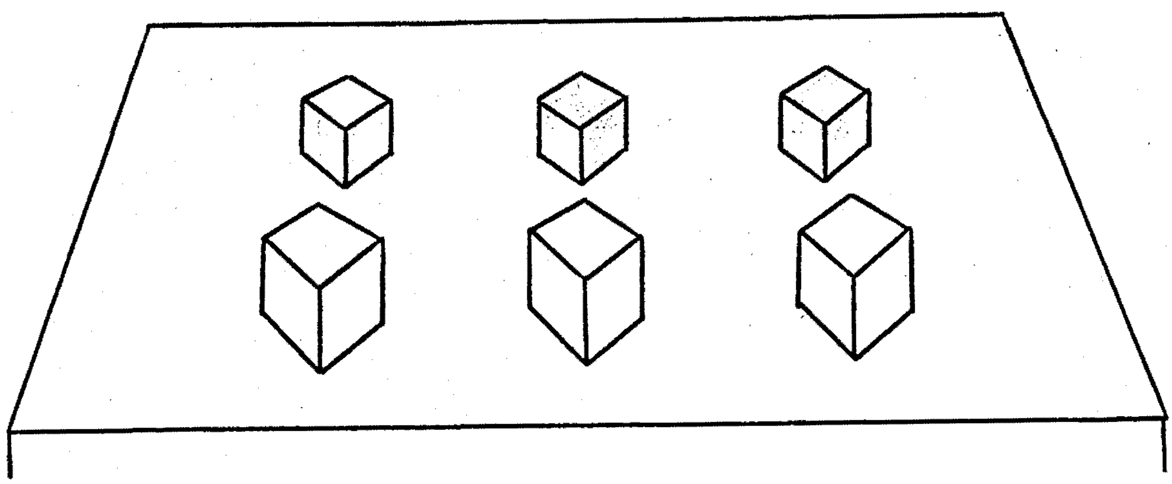
Child's View

Experimenter:

"This bunch (pointing to the child's row) of blocks is the same as this bunch (pointing to the experimenter's row) of blocks."

continued

Experimenter simultaneously reversed opposing blocks (one from each row) so that the child then saw white sides in his own row but only red sides in the experimenter's row.



Child's View

Experimenter:

Question 1: "Does this bunch (pointing to the child's row) have the same number of blocks as this bunch (pointing to experimenter's row)?"

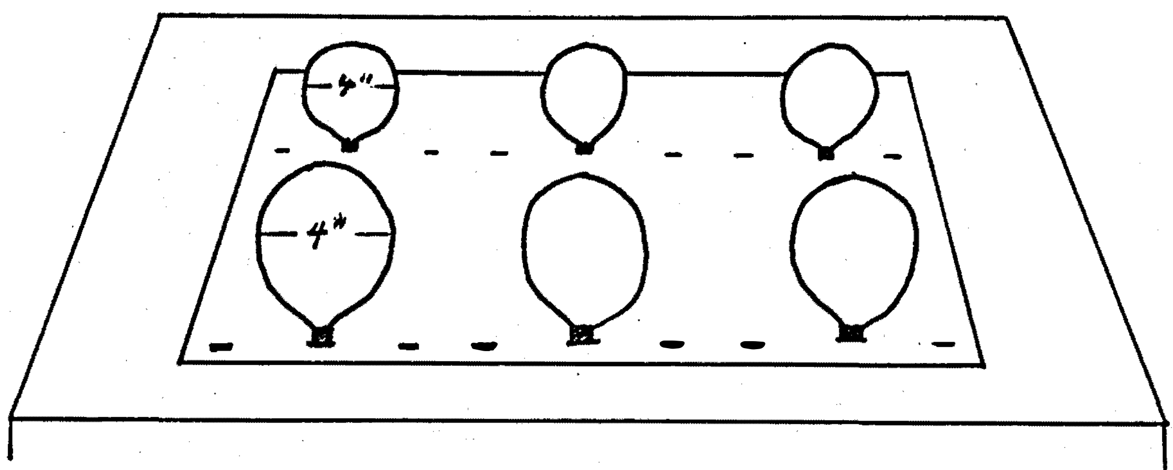
Question 2: "Does one bunch have more blocks?"

Question 3: "How do you know?"

Figure 3

<u>Conservation</u> Task <u>Sequence for Size Transformation.</u>

White ballons were inflated two at a time in a one to one correspondence while the child watched.



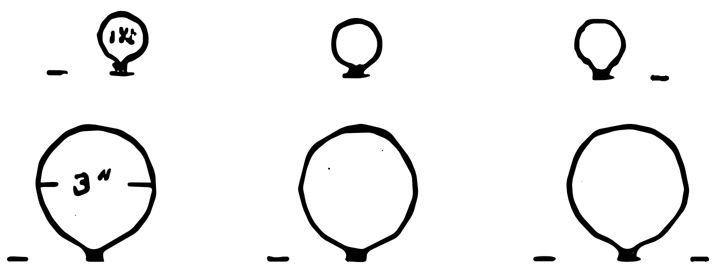
Child's View

Experimenter:

"This bunch (pointing to the child's row) of ballons is the same as this bunch (pointing to the experimenter's row) of ballons."

continued

Experimenter released air simultaneously from opposing ballons, (one from each row) until all ballons were partially deflated. However, he released more air from his own row than from the child's row so that the experimenter's ballons were approximately half the size of the child's.



Child's View

Experimenter:

Question 1: "Does this bunch (pointing to the child's row) have the same number of ballons as this bunch (pointing to the experimenter's row)?"

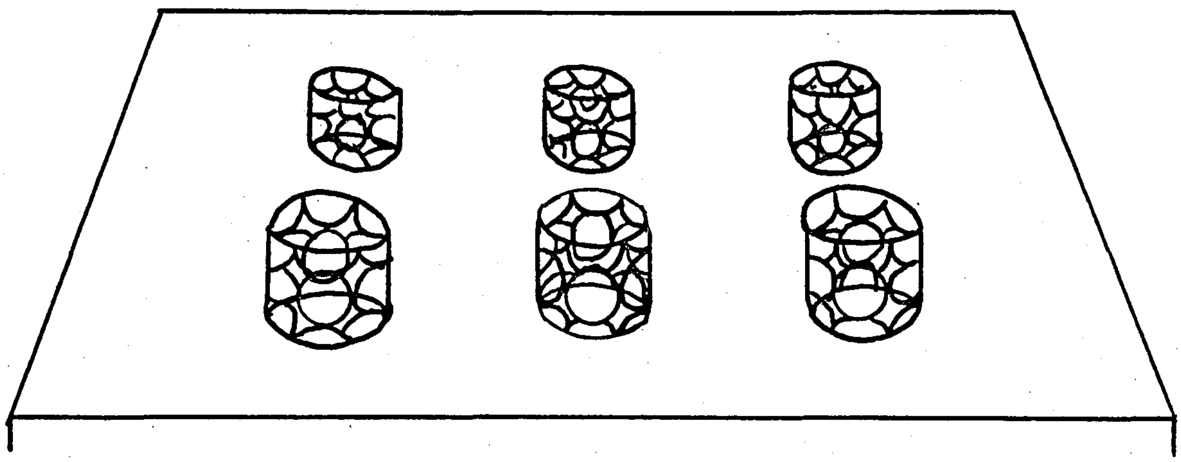
Question 2: "Does one bunch have more ballons?"

Question 3: "How do you know?"

Figure 4

<u>Conservation</u> Task <u>Sequence for Shape Transformation.</u>

Malleable wire balls shaped to look like open ended drums were placed in a one to one correspondence while the child watched.



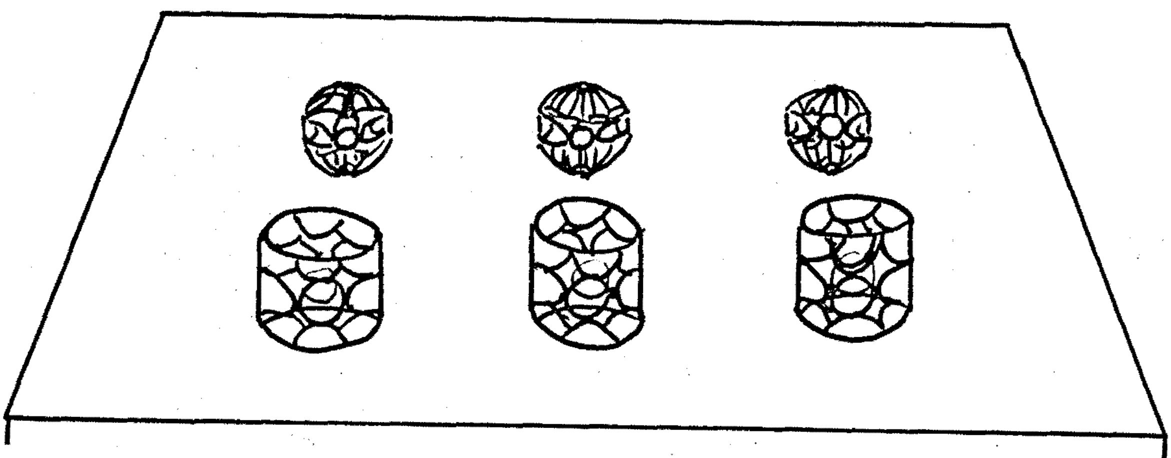
Child's View

Experimenter:

"This bunch of cages (pointing to the child's row) is the same as this bunch of cages (pointing to the experimenter's row."

continued

Experimenter simultaneously turned opposing cages over (one from each row) so that the child's cages were unchanged, and the experimenter's cages were transformed by dropping the bottom half of the wire and raising the top half to make an object shaped much like a bird cage, but, one that did not vary much in size or volume from the objects in the child's row.



Child's View

Experimenter:

Question 1: "Does this bunch (pointing to the child's row) have the same number of cages as this bunch (pointing to the experimenter's row)?"

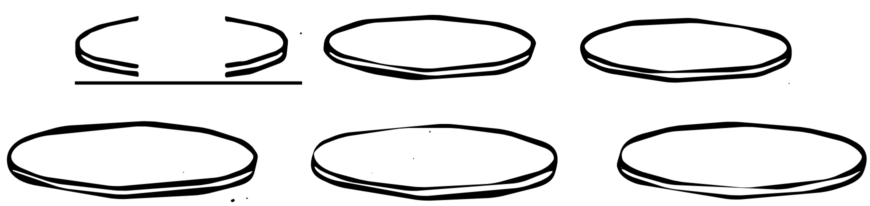
Question 2: "Does one bunch have more?"

Question 3: "How do you know?"

Figure 5

Conservation Task Sequence for Length Transformation.

Plain white poker chips were placed in a one to one correspondence while the child watched.



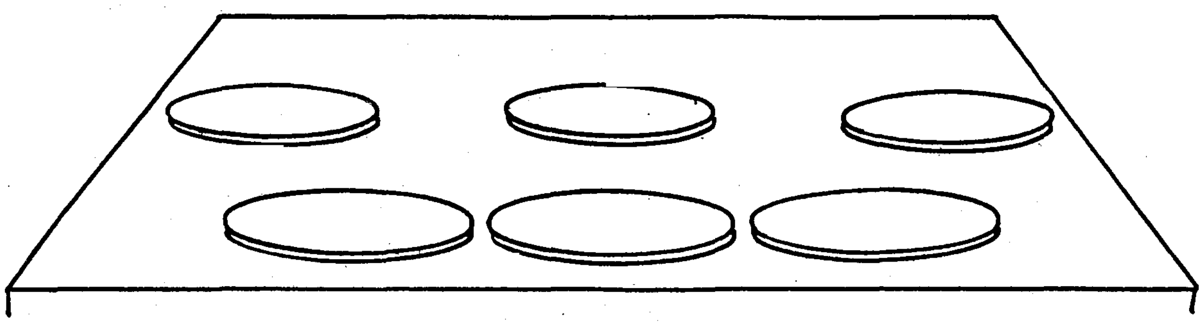
Child's View

Experimenter:

"This bunch of chips (pointing to the child's row) is the same as this bunch of chips (pointing to the experimenter's row)."

continued

Experimenter simultaneously moved opposing chips (one from each row), spacing them so that the chips at the ends of the experimenter's row exceeded the chips at the ends of the child's row by 1-1/2 to 2 times the diameter of a single chip.



Child's View

Experimenter:

Question 1: "Does this bunch (pointing to the child's row) have the same number of chips as this bunch (pointing to the experimenter's row)?"

Question 2: "Does one bunch have more chips?"

Question 3: "How do you know?"

candies from a bag, and then was allowed to keep them. Prior to each child's formal testing there was a training period during which the term "bunch" was explained and demonstrated as shown in Figure 6.

Insert Figure 6 about here

Scoring

Answers to questions one and two of each conservation task were scored as follows:

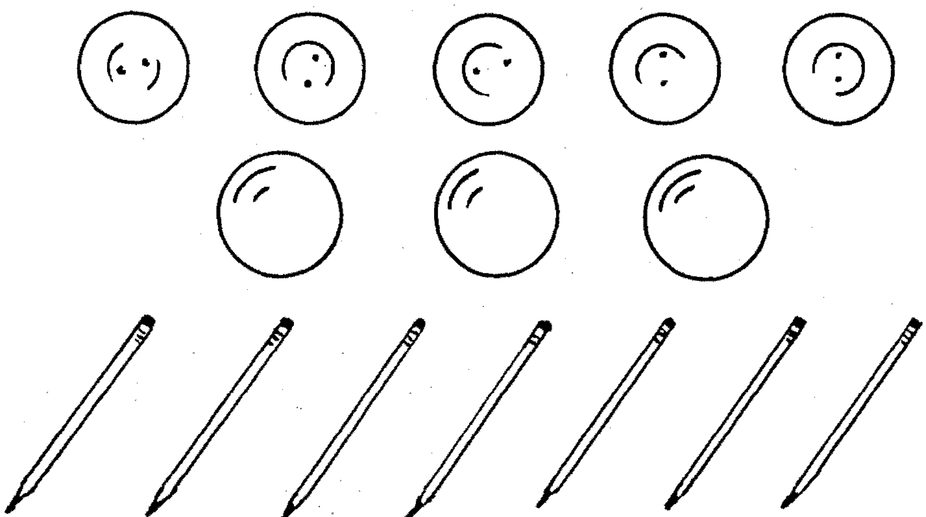
Score	2	1	1	0
Question One: "Does this bunch have the same bunch?"	No	No	Yes	Yes
Question Two: "Does one bunch have more?"	Yes	No	Yes	No

Since a correct answer to both questions one and two was required for a 0, this score indicates that a child was both correct in his conservation judgement and consistent and logical in his understanding of the words "more" and "same" and his answer is designated as consistent conserving. A score of 2 indicates that a child is wrong in his judgement about the conservation task but consistent in his understanding of the language and logical in his answers.

Figure 6

Training, Explanation, Demonstration of "Bunch".

The experimenter laid out a row of five white buttons, three red balls, and seven blue pencils.



Child's View

Experimenter:

"This (pointing to each group in turn) is a bunch of buttons (balls or pencils where appropriate). What is this (pointing to each row and coaxing, if necessary, the child to respond)?"

When the child was able to respond, by himself, to the previous question with an answer incorporating the word "bunch" for each group of objects then the criteria for understanding "bunch" had been reached.

His answers would therefore be consistent non-conserving. A score of 1 indicates that the child is wrong in conservation judgement and inconsistent and illogical in his understanding and answering of the two questions containing the words "more" and "same". His responses are inconsistent non-conserving. (In order to ease the reading and facilitate the understanding of this study, the terms consistent conserving, inconsistent non-conserving, and consistent non-conserving will hereafter be referred to as conserving, inconsistent, and non-conserving respectively.)

Answers to question three were not scored but rather recorded verbatim and analysed qualitatively not only in terms of a "correct" Piagetian response but also in terms of the degree to which a child centers on extraneous cues. A correct Piagetian response means that a child must give an adequate explanation of conservation. Adequate and inadequate responses will be judged according to the categories outlined in Figure 7 of this paper. The counting problem was also qualitatively analysed. The wording, scoring and

Insert Figure 7 about here

categorizing of questions one, two, and three are those developed and used by Rothenberg (1969). The only exception is that in her system the answers to questions one and two were scored in an ascending order as follows:

Figure 7

Adequate and inadequate explanations of conservation

Adequate Responses	Examples
Numerical	"There's five here and there's five here."
Transformational	"You just moved them but you didn't take any away."
Matching or one to one correspondence	"This one goes with this one and this one goes etc."

Inadequate Responses	Examples
Descriptive	"These are closer and these are more spread out."
Perceptual	"They look bigger (longer, etc.)."
Limited Verbal	"Because I see it."
Magical	"My Mother (teacher) told me."
Ignorant	"I don't know."
No Response	

Score	0	0	1	2
Question One: "Does this bunch have the same number of (objects) as this bunch?"	No	Yes	No	Yes
Question Two: "Does one bunch have more?"	No	Yes	Yes	No

This means that in Rothenberg's system inconsistent received a score of 0, non-conserving received a score of 1, and conserving received a score of 2.

Data Analysis

The conservation scores obtained from the two questions were analysed with a traditional 4 x 4 x 4 x 4 Latin Square ANOVA to determine the effects of types of transformation (color, size, shape, and spacing), number of objects (3, 5, 7, 9), age of children (3, 4, 5, and 6), and order of presentation of transformations (one, two, three, and four). Orthogonal analyses were planned a priori for extraneous cue transformations (color, size, shape, and spacing) at each age level. A post hoc chi square analysis was done for conservation judgement categories by age groups.

Results

The results revealed that an extraneous cue transformation by number of objects by children's ages interaction was significant ($F = 2.28$; df = 18/144; $p < .01$). (Raw data can be found in the appendix). This significant interaction implies differences in extraneous cue transformations by number of objects interactions at each age level and precludes the meaningful interpretation of number of objects by age interaction, extraneous cue transformations by age interaction, and extraneous cue transformation by number of objects interaction for age levels as one group. (See Table 1.) The design was therefore split on the age variable and

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Insert Table 1 about here

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when the extraneous cue transformation by number of objects interactions were analysed at each age group they were non-significant for 3 year olds ($F = .88$; df = 6/36; $p < .025$), 4 year olds ($F = .40$; df = 6/36; $p < .025$), and 5 year olds ($F = 90$; df = 6/36; $p < .025$), but significant for 6 year olds ($F = 3.96$; df = 6/36; $p < .01$). The design was therefore split for age 6 on the extraneous cue transformation variable and when number of objects was analysed at each transformation level they were non-significant

Table 1

Latin Square Analysis of Variance

for

Extraneous Cue Transformation (Color, Size, Shape, and Spacing)

by Number of Ocjects (3, 5, 7, 9)

by Order of Presentation (One, Two, Three, Four)

by Age (3, 4, 5, 6)

Source of Variance	df	F	P
Between Subjects	63		
Age (D)	3	16.56	.01*
Order (C or AB between)	3	1.38	.025
DC (AB between x D)	9	.99	.05
Error	48		
Within Subjects	192		
Extraneous Cue Transformations (A)	3	9.73	.01*
Number of Objects (B)	3	2.46	.05
AB within	6	1.96	.05
AD	9	1.37	.05
BD	9	2.55	.05*
AB within x D	18	2.28	.01*
Error	144		

*Indicates significance.

for color ($F = .313$; $df = 3/12$; $p < .025$), size ($F = 2.40$; $df = 3/12$; $p < .025$), shape ($F = 2.40$; $df = 3/12$; $p < .025$) and spacing ($F = .313$; $df = 3/12$; $p < .025$). Number of objects simple effects were non-significant at age 3 ($F = 2.75$; $df = 3/36$; $p < .05$), age 4 ($F = 1.80$; $df = 3/42$; $p < .05$), and age 5 ($F = .84$ $df = 3/36$, $p < .05$), but signicant at age 6 ($F = 3.93$; $df = 3/36$; p $.05$). Extraneous cue transformation simple effects were significant at ages 3 ($F = 3.44$; $df = 3/36$; $p < .05$), 4 ($F = 3.09$; $df = 3/42$; $p < .05$), and 5 ($F = 3.90$; $df = 3/36$; $p < .05$) but not at age 6 ($F = .20$; $df = 3/36$; $p < .05$). (See Tables 2, 3, 4 and 5.)

Insert Tables 2, 3, 4 and 5 about here

Preplanned orthogonal analyses of extraneous cue transformations at ages 3, 4, and 5, showed only the spacing transformation to be significantly different from color, size and shape transformations ($F = 8.38$; $df = 1/36$; $p < .01$ for 3 year olds; $F = 8.85$; $df = 1/36$; $p < .01$; for 4 year olds; $F = 10.27$; $df = 1/36$; $p < .01$ for 5 year olds). Color was not significantly different from size and shape for 3, 4, and 5 year olds ($F = 1.07$; $df = 1/36$; $p < .05$ for 3 year olds; $F = .29$; $df = 1/36$; $p < .05$ for 4 year olds; $F = 1.05$; $df = 1/36$; $p < .05$ for 5 year olds); and size and shape were not significantly different from each other at ages 3, 4, and 5 ($F =$

Table 2

Latin Square Analysis of Variance

for

Color, Size, Shape, and Spacing Transformation

by Number of Objects by Order of Presentation

at Age 3

Source of Variance	df	F	P
Between Subjects	15		
Order (C)	3	4.42	.025
Error	12		
Within Subjects	48		
Extraneous Cue Transformation (A)	3	3.44	.05*
Number of Objects (B)	3	2.75	.05
AB within	6	.88	.025
Error	36		

*Indicates significance.

Table 3

Latin Square Analysis of Variance

for

Color, Size, Shape, and Spacing Transformation

by Number of Objects by Order of Presentation

at Age 4

Source of Variance	df	F	P
Between Subjects	15		
Order (C)	3	.77	.025
Error	12		
Within Subjects	48		
Extraneous Cue Transformation (A)	3	3.09	.05*
Number of Objects	3	1.80	.05
AB within))) Pooled Error	6	.40	.025
Error)	36		

*Indicates significance.

Table 4

Latin Square Analysis of Variance

for

Color, Size, Shape, and Spacing Transformation

by Number of Objects by Order of Presentation

at Age 5

Source of Variance	df	F	P
Between Subjects	15		
Order (C)	3	1.40	.025
Error	12		
Within Subjects	48		
Extraneous Cue Transformation (A)	3	3.90	.05*
Number of Objects (B)	3	.84	.05
AB within	6	.90	.025
Error	36		

*Indicates significance.

Table 5

Latin Square Analysis of Variance

for

Color, Size, Shape, and Spacing Transformation

by Number of Objects by Order of Presentation

at Age 6

Source of Variance	df	F	P
Between Subjects	15	.94	
Order (C)	3	1.71	.025
Error	12		
Within Subjects	48		
Extraneous Cue Transformation (A)	3	.20	.05
Number of Objects (B)	3	3.93	.05*
AB within	6	3.96	.01*
Error	36		

*Indicates significance.

.82; df = 1/36; $p < .05$ for 3 year olds; F = .12; df = 1/36; $p < .05$, for 4 year olds; F = .36; df = 1/36; $p < .05$ for 5 year olds). Table 6 and Figure 8 show that for 3, 4, and 5 year olds spacing is different from a score of one in the non-conserving direction.

Insert Table 6 and Figure 8 about here

Age level, as one group, by order of presentation interaction was non-significant (F = .99; df = 9/48; $p < .05$), as was order of presentation as a main effect (F = 1.38; df = 3/48; $p < .025$). Age as a main effect was significant (F = 16.56; df = 3/48; $p < .01$). (See Table 1).

An examination of the relationship of the performance of the non-conserving judgements by extraneous cue transformations (Table 7) reveals that five (56%) of the non-conserving responses of 3 year olds, ten (45%) of the non-conserving responses of 4 year olds, and seven (64%) of the non-conserving responses of 5 year olds failed to show conservation when spacing was the extraneous cue. Further examination of Table 7 also reveals that size transformations were least likely to yield non-conserving responses in the 3, 4, and 5 year old age groups.

Insert Table 7 about here

Table 6

Raw Score Means and SDs

on Color, Size, Shape, and Spacing

for Ages 3, 4, 5, and 6

	COLOR		SIZE		SHAPE		SPACING	
AGE	M	SD	M	SD	M	SD	M	SD
3	1.06	.574	.875	.342	1.00	.365	1.31	1.854
4	1.06	.7719	.938	.6585	1.00	.7303	1.50	.7303
5	.438	.6292	.562	.6292	.688	.7042	1.13	.8851
6	.250	.5774	.188	.5439	.188	.5439	.250	.5774

Figure 8

Relationship of the Mean Number of Responses

for Color, Size, Shape, and Spacing at Ages 3, 4, 5, and 6

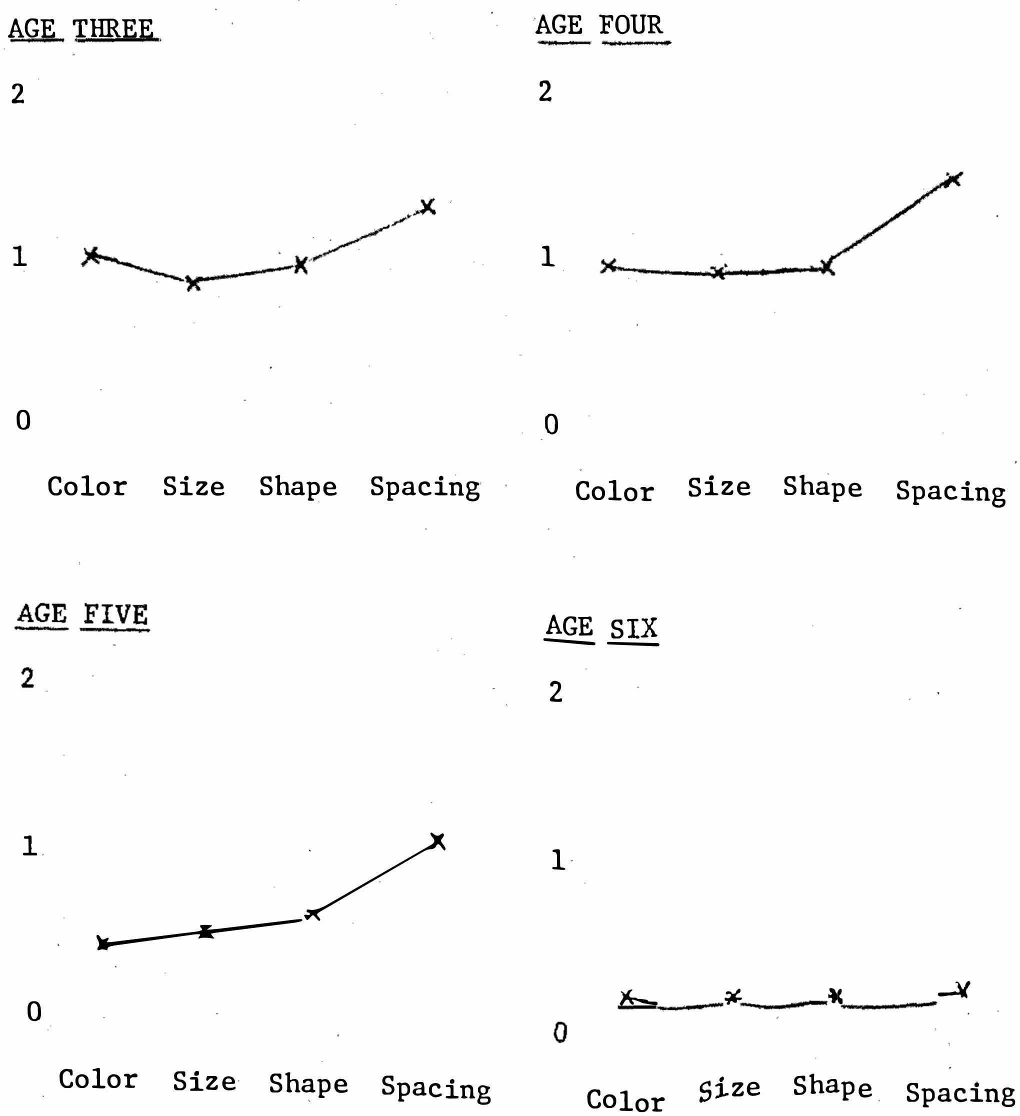

Table 7

Relationship Between Age Groups

and

Types of Extraneous Cue Transformations

for

Consistent Non-Conserving Judgements

	Extraneous Cue Transformations			
Age Group	Color	Size	Shape	Spacing
3 Year Olds	3 (33%)	0 (0%)	1 (11%)	5 (56%)
4 Year Olds	5 (23%)	3 (14%)	4 (18%)	10 (45%)
5 Year Olds	1 (9%)	1 (9%)	2 (18%)	7 (64%)
6 Year Olds	1 (25%)	1 (25%)	1 (25%)	1 (25%)

Numbers in parentheses are percentages of total consistent non-conserving responses in each age group.

A *post hoc* chi square analysis of the conserving; the inconsistent, and non-conserving responses by age groups was significant (F - 105.78; df = 1/16; $p < .001$). (See Table 8).

Insert Table 8 about here

An investigation of the percentages of conserving, inconsistent, and non-conserving responses by age groups is shown in Table 9.

Insert Table 9 about here

Examination of this table shows a steady increase of conserving responses with increasing age and a steady decrease of inconsistent responses with increasing age. Non-conserving responses, however, increase from age 3 to 4, and then decrease from age 4 to 6. Further analysis of the 3 year old inconsistent responses shows that 60% of the responses were answered with a response set of "yes-yes".

Examination of the consistency of performance of individuals across tasks shows that 39 (61%) children made judgements that place them in at least two of the three conservation categories (i.e., conserving, inconsistent, and non-conserving).

The nine types of answers given to the "How do you know?" question following the transformation in each task are grouped

Table 8

Chi Square Analysis of Types of Conservation Judgements

by Ages of Subjects

Type of Conservation Judgement	AGES 3 yr. olds	4 yr. olds	5 yr. olds	6 yr. olds	
	25.75	25.75	25.75	25.75	
Conserving	5	14	30	54	103
	26.75	26.75	26.75	26.75	
Inconsistent	50	28	23	6	107
	11.50	11.50	11.50	11.50	
	9	22	11	4	46
	64	64	64	64	256

Observed (O)	Expected (E)	O - E	$(O - E)^2$	$\frac{(O - E)^2}{E}$
5	25.75	- 20.75	430.57	16.73
50	26.75	+ 23.25	540.57	20.21
9	11.50	- 2.50	6.25	0.55
14	25.75	- 11.75	138.07	5.37
28	26.75	+ 1.25	1.52	0.06
22	11.50	+ 10.50	110.25	9.59
30	25.75	+ 4.25	18.07	0.71
23	26.75	- 3.75	14.07	0.53
11	11.50	- 0.50	0.25	0.03
54	25.75	+ 28.25	798.07	31.00
6	26.75	- 20.75	430.57	16.10
4	11.50	7.50	56.25	4.90

Chi Square = 105.78; df = 1/6; p .001

Table 9

Relationship Between Types of Conservation Judgements

and Age Groups for the Total Sample

	Types of Conservation Judgements		
Age Groups	Consistent Conserving (Score of 0)	Inconsistent Non-Conserving (Score of 1)	Consistent Non-Conserving (Score of 2)
3 Year Olds	5 (8%)	50 (78%)	9 (14%)
4 Year Olds	14 (22%)	28 (44%)	22 (34%)
5 Year Olds	30 (47%)	23 (36%)	11 (17%)
6 Year Olds	54 (84%)	6 (9%)	4 (7%)

Numbers in parentheses are percentages of total types of conservation judgements given in each group.

into adequate and inadequate explanations of conservation. Table 10 shows the actual number and the percentage of types of explanations as compared to categories of conserving. These results

Insert Table 10 about here

show that 61% adequate explanations and 39% inadequate explanations of conservation were given when a child had previously made a conservation response to questions one and two; 83% inadequate and 17% adequate conservation justifications were given when a child made a non-conserving response to the two questions; and 89% inadequate and 11% adequate reasons were given when the child was inconsistent in his answers. Of the 46 non-conserving justifications, Table 11 shows that 22 (49%) were inadequate explanations

Insert Table 11 about here

that related "more" to color, size, shape, and spacing, with 13 (59%) of the 22 falling within the spacing category. Further examination reveals that of the 13, 10 of the responses were from 4 and 5 year olds while 2 were from 3 year olds and 1 was from a 6 year old.

Examination of the counting task presented to each child at the end of all the conservation trials reveals that 8 of the 3

Table 10

Relationship Between Judgements on Conservation Questions and Categories of Explanations of Conservation for the Total Sample

Types of Conservation Judgements	Categories of Explantions of Conservation: Adequate			Inadequate		
	Actual Number	Per-cent-age (%)	Per-cent-age Total	Actual Number	Per-cent-age	Per-cent-age Total
Consistent Conserving C.C.	62	61 %	24 %	41	39 %	16 %
Consistent Non-Conserving C.NC.	8)	17 %	3 %	38	83 %	15 %
	)	13 % of Total NC.				
Inconsistent Non-Conserving I.NC.	12)	11 %	5 %	95	89 %	37 %

Table 11

Relationship Between Types of Judgements on Conservation Questions and Extraneous Cue Transformations for Inadequate Explanations of Conservation

Types of Conservation Judgements	Extraneous Cue Transformations: Color	Size	Shape	Spacing	Totals	Percentage of Total Type of Conservation Adequate and Inadequate
Consistent Conserving	1	3	1	1	6	6 %
Consistent Non-Conserving	4	3	2	13 (59%)	22	49 %
Inconsistent Non-Conserving	1	8	2	4	15	14 %

year olds and 3 of the 4 year olds could not count out nine M & M's. Of the 44 responses these 11 children made, 38 (86%) were inconsistent answers.

Discussion

The investigation of which reversible stimulus transformations (color, size, shape, and spacing]i.e., length of array] will negatively affect conservation of number among small children was the major concern of this study. The ANOVA results indicated that spacing transformations were significantly different from color, size, and shape transformations, and inspection of the means for each group (See Tables 1 through 6) shows spacing to be greater than one in the non-conserving direction for all but 6 year olds. Therefore, it would seem reasonable to say that length of array (spacing) when compared to color, size, and shape, is a prepotent cue for 3, 4, and 5 year olds but not for 6 year olds. The results also indicate that color, size, and shape transformations did not appear to be exerting any negative influence (i.e., they did not lead to more consistent - non-conserving responses than would be expected by chance) on the conserving judgements of the subjects in this study. These results are consistent with Piaget's tenet that length is the ruler of the perceptions of the pre-operational child who lacks the cognitive abilities and internal strategies to logically deny his perceptions when faced with a conservation of number task. These findings are also consistent with those of Gelman's 1968 study which showed that children think that length confirms number, and with LaPointe and O'Donnell (1974), Pufall, Shaw, and Syrdal-Lasky (1973) who all show that as age increased to 4 or 5, the tendency to use length for number increases. This tendency, of course, stops at age 6 when children begin to conserve.

Even though color has been shown to be a preferred cue for younger children on non-conservation tasks, and form (shape) a preferred cue for older children on non-conservation tasks, [with the median age of transition set at 4 years 2 months (Descourdres (1914), Colby and Robertson (1942), Corah (1964) all quoted in Suchman and Trabasso (1960)] the fact that the present study did not find means that differed greatly from one when color, size, and shape transformations were used in a conservation task probably means that children do not see these cues as related in any way to number. It would seem that cue preferences themselves do not influence conservation judgements in small children. This is particularly interesting for the size category since the word "more" in the second question could easily be taken to mean "larger" or "bigger", especially in light of the fact that length or "longer" is certainly seen as meaning and being "more" for most non-conserving children. In fact, 14 children, 3 of whom were conserving 5 and 6 year olds, made reference to the fact that one row of ballons was "bigger". However, only 3 non-conserving responders gave the size of the ballons as the reason for their incorrect conservation judgements. Bausano and Wendell (1975) showed that children do not rely on one specific dimension in order to make judgements of bigness but rather they attend to the most salient difference among stimuli. Obviously the children in this study did not see "bigness" in ballons as being a salient feature of number or "more" but did see "longer" as being very salient to "more".

Another major concern in this study was the effect of the variation from small to large (i.e., 3, 5, 7, and 9) of the number of objects used in a conservation task and what interactions might occur with different age children. The results indicate that there are no differences in the conserving performance of a 3, 4, or 5 year old child due to the number of objects used in the conservation task when the number of objects is less than 10. (The results of this study do show a significant effect for number of objects at age 6. However, since this result is primarily due to non-conserving and inconsistent responses for the 3 and 5 object categories, the resulting interpretation of this statistic leads one to question its validity. It does not seem sensible to report that 6 year olds have more difficulty with conservation judgements when the number of objects in the conservation problem are small rather than large. The result is therefore suspect and is probably a reflection of chance or subject apprehension about the testing situation.) In contrast to these results, Gelman (1972b), Lawson, Baron and Siegel (1974), and Smither, Smiley and Rees (1974) found that young children were more likely to attend to number for conservation judgements when set sizes were less than 5. The inability of the present study to replicate the findings that show conservation of number to be facilitated when set size is less than 5 may be due to the fact that this study uses a Piagetian paradigm for the conservation task and the other studies used static arrays or surreptitious transformations.

In addition to the results of the original purposes of this study several other findings became apparent.

In analysing the categories of adequate and inadequate for the answers to the "How do you know?" question following the conservation judgements, it can be seen that 39% of the conserving responders gave inadequate explanations for their judgements and 13% of the non-conserving responders (both consistent and inconsistent) gave adequate explanations of conservation. These results would seem to support those of Rothenberg (1969) and LaPointe and O'Donnell (1973) and agree with their conclusion that adequate justification of conservation judgements is too stringent a criterion for identifying the conserving subjects. This decision is also supported by Brainerd (1973), Beilin (1965), and Gelman (1972a), who all argue that an explanation of a conservation judgement is dependent on something more than the cognitive structures for invariance that Piaget says are necessary for conservation.

Also, since the scoring system allows for a distinction between a non-conserving response (one in which the responder understands the language and the task but does not conserve) and an inconsistent response (one in which the responder does not understand the language and/or the task and does not conserve), it can be seen (as previously shown in Table 9) that there is a decrease in inconsistent responses with increasing age but an increase of non-conserving responses from age 3 to 4 and a decrease thereafter. This finding is also in line with that of LaPointe and O'Donnell (1973), and Rothenberg (1969) who proposed an addition to Piaget's model of the 3 steps leading to conservation. Piaget delineates these steps as (1) no conservation, (2) an on-off type of conservation in which children conserve in some tasks but not in others (also supported by this study as well as by Rothenberg (1969), Rothenberg and Courtney (1969), and LaPointe and O'Donnell (1973)), and finally (3) a sure and intuitive conservation of number at all times. Rothenberg's proposal is to divide step one into two substages. The first substage is one of confusion because of a lack of understanding of the task or the language or both and children in this stage typically answer questions about conservation in an illogical fashion. During this phase the predisposition of small children to acquiesce when confused produces a plethora of inconsistent non-conserving responses of the "yes-yes" variety. This is followed by substage two during which the child understands the task and the language; answers the conservation questions consistently and logically but incorrectly. Further support of the substage notion can be found in the fact that 38 (86%) of the 44 responses made by non-counting 3 and 4 year olds in this study were inconsistent, while only 40 (31%) of 128 responses made by counting 3 and 4 year olds in this study were inconsistent. In spite of Piaget's (1941, p. 61) position that conservation is not dependent on counting per se, possibly understanding a conservation question or task may require some idea of numerosity.

Rothenberg's substage addition to Piaget's model is both logical and necessary. To assume that a child is not conserving because he is attending to the wrong cues or dimensions of the problem when in fact he does not even understand the task is an exercise in futility and produces questionable results for the experimenter interested in mapping the topography of conservation.

Conversely, knowing that a child understands the task and the language of the task when he does not conserve gives believable and vital clues to the child's view of the problem.

The major findings of this study would suggest 7 conclusions and recommendations. (1). Color, size, and shape do not exert any negative influence on conservation (i.e., they do not lead to more consistent non-conserving responses than would be expected by chance) for the 3, 4, and 5 year olds in the study faced with a conservation of number task but spacing (length of object row), when compared to color, size, and shape does. (2). In spite of color being a preferred cue for younger children (3 and 4 year olds) and shape being a preferred cue for older children (4, 5, and 6 year olds) in non-conservation tasks, these cues are not seen as being related to number by non-conserving children. (3). Size or "bigness" is probably not seen as meaning "more" and therefore a change in size is not confused with number in a conservation of number problem. (4). Prior to conservation children show an increasing tendency, to about age 4, to use length as a confirmation of number. After age 4, the tendency begins to decrease until the children reach age 6 and begin to conserve. (5). "How do you know?" questions following conservation judgements are probably more useful as indicators for further research than as measures of conservation. (6). Rothenberg's 2 question procedure should be used as a screening device when working with small children in conservation of number experiments so that the examiner could pinpoint which children did in fact understand the task and the language of the problem. (7). This study should be replicated in one year with the same children as a further substantiation of: a) Rothenberg's substage model of non-conservation, and b) the findings that increased size or "bigness" is not confused with "more" in a conservation of number problem.

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APPENDIX

3 yr. olds	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
3 Ballons		1	0		0										1	
5 Ballons						1	1						1	1		
7 Ballons										1	1	1				1
9 Ballons	1			1				1	1							
3 Blocks						1	1						1	1		
5 Blocks		0	0		1										1	
7 Blocks	2			1				2	2							
9 Blocks										1	1	1				1
3 Cages	1			1				1	2							
5 Cages										1	0	1				1
7 Cages						1	1						1	1		
9 Cages		1	1		1										1	
3 Chips										1	1	2				1
5 Chips	1			1				2	2							
7 Chips		2	2		1										1	
9 Chips						1	1						1	1		

4 yr. olds	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
3 Ballons	2		0							1						1
5 Ballons		0					1					0	1			
7 Ballons				0		1		1	2							
9 Ballons					1						2			1	1	
3 Blocks		1					1					0	1			
5 Blocks	2		0							1						1
7 Blocks					1						2			2	0	
9 Blocks				0		2		1	2							
3 Cages					1						1			2	1	
5 Cages				0		1		0	1							
7 Cages		0					1					0	2			
9 Cages	2		2							1						1
3 Chips				2		1		0	1							
5 Chips					2						2			1	2	
7 Chips	2		2							2						1
9 Chips		2					2					0	2			

5 yr. olds	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
3 Ballons			0	2			1									
5 Ballons	0	1						1						0		
7 Ballons										1	0	1			0	
9 Ballons						1			0				0			0
3 Blocks	0	0						1						0		
5 Blocks			0	1	0		2									
7 Blocks						1			0				0			1
9 Blocks										0	0	1			0	
3 Cages						1			1				0			2
5 Cages										1	0	1			0	
7 Cages	0	1						1						0		
9 Cages			0	1	0		2									
3 Chips										0	0	1			2	
5 Chips						0			0				1			2
7 Chips			2	2	2		2									
9 Chips	0	1						1						2		

6 yr. olds	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64
3 Ballons		2			0		0			1						
5 Ballons	0			0					0		0					
7 Ballons												0		0	0	0
9 Ballons			0			0		0					0			
3 Blocks	0			0					0		0					
5 Blocks		2			1		0			0						
7 Blocks			0			0		0					0			
9 Blocks												1		0	0	0
3 Cages			1			2		0					0			
5 Cages												0		0	0	0
7 Cages	0			0					0		0					
9 Cages		0			0		0			0						
3 Chips												1		0	0	0
5 Chips			0			0		0					0			
7 Chips		2			0		0			1						
9 Chips	0			0					0		0					

CONCEPTUAL EVOLUTION APPARATUS: SPECIFICATIONS AND MATERIALS

A Manifold to tube connectors:

Weatherhead #1581 at Auto Parts Co. (19)

B Air Manifold, 2" x 2" x 10" Plexiglas (1)

C 1/8" Inside Diameter gum rubber tubing:

Pharmaceutical Supply (24 ft.)

D Springs: #28 Gauge Music Wire formed by hand:

Hardware Stores (36)

E Polypropylene "Y" Connectors, 1/8":

Federal Scientific Co. F 19612 (18)

F #9, one hole rubber stopper: Pharmaceutical Supply (18)

G Diaphragm (Balloon): Young's Drug Products, Item #70 (18)

H Masonite Prestwood 24" x 54" x 1/4": Lumber Suppliers (3)

J Wooden Spacer 4" x 18" x 3/4": Lumber Suppliers (3)

K Plywood Keeper 4" x 54" x 1/2": Lumber Suppliers (2)

L Pressure Regulator: Welding or Air Products Suppliers (1)

M Air Supply Tank: Welding or Air Products Suppliers (1)

N Air Supply Hose: Welding or Air Products Suppliers (1)

O Vision Screen, Masonite Prestwood 4" x 54" x 1/4":

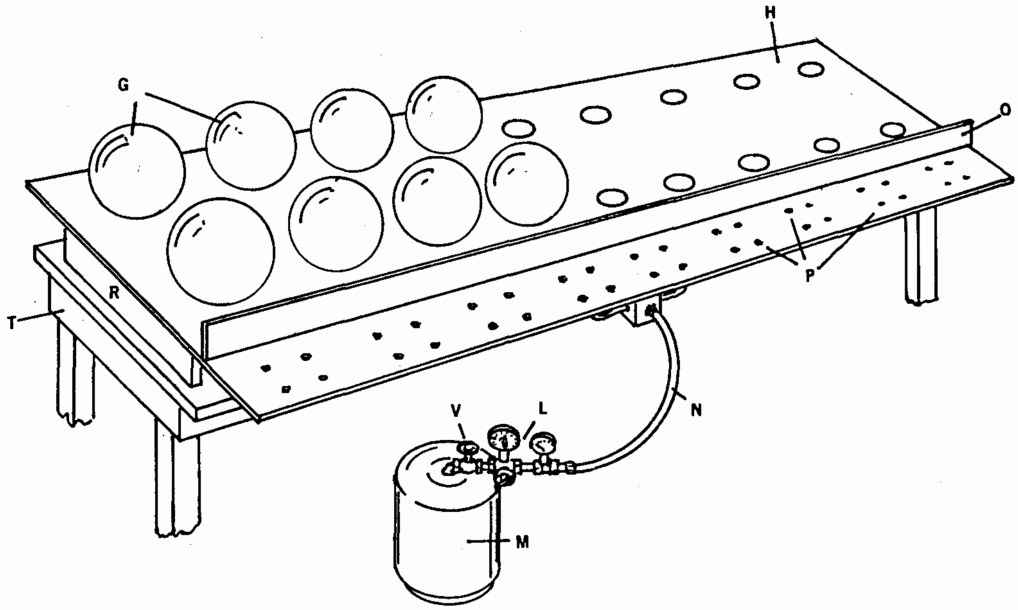
Lumber Suppliers (1)

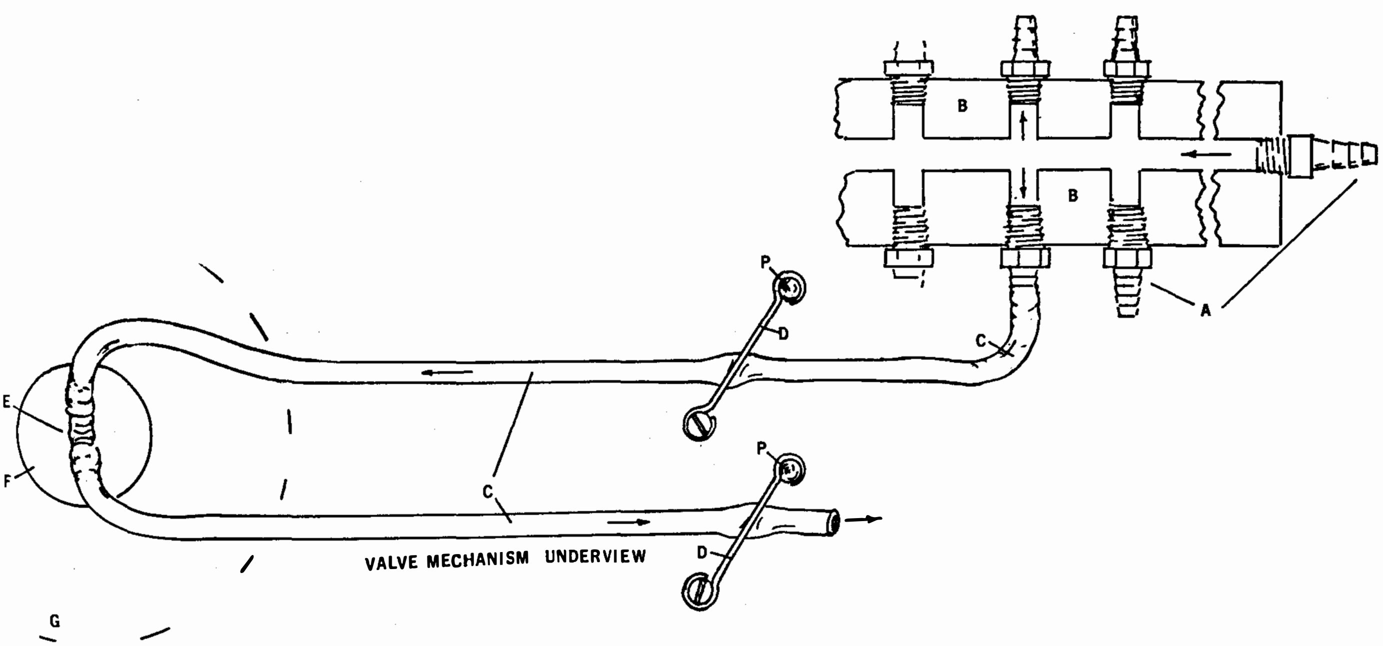
P Pushbutton: 1/4" dowel rod or surplus switch buttons:

Psychological Instruments Co. (36)

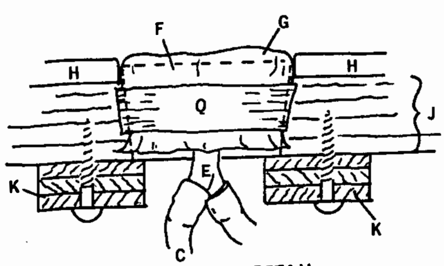
Q Rubber Band 1/16" thick x 1/2" wide x 3/4" diameter

Bicycle innertube (18)





VALVE MECHANISM UNDERVIEW



DIAPHRAGM DETAIL

VITA

Born in August, 1936 in Richmond, Virginia, Marsha Taliaferro Will was graduated from the Collegiate School in June, 1954, entered Sweet Briar College the following September, and transferred to Westhampton College in September, 1956. In May, 1957 she married Erwin Hoge Will, Jr. and they have five children, ranging in age from 7 to 19 years. Mrs. Will pursued her undergraduate degree at Westhampton College as a special student while combining homemaking, childrearing and academics from September, 1965 until June, 1975 when she received her B.A. degree in Psychology. That same summer she entered the Graduate School at the University of Richmond and will be awarded the Master of Arts Degree in Psychology at the August, 1977 commencement.

Marsha Will has worked as an Educational Consultant and Learning Disabilities teacher in the Richmond Montessori School. She will begin a year of internship as a School Psychologist in the Richmond Public Schools in September, 1977.