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THE EFFECTS OF EMPIRICAL COUNTING, DEVELOPMENTAL LEVEL, AND SET SIZE ON CHILDREN'S CONSERVATION PERFORMANCE

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Abstract

THE EFFECTS OF EMPIRICAL COUNTING, DEVELOPMENTAL LEVEL, AND SET SIZE ON CHILDREN'S CONSERVATION PERFORMANCE

by

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The purpose of this research was to analyze factors that influence children's use of counting to solve conservation problems. Two studies were conducted. In Study 1, two groups of nonconservers, one who demonstrated the ability to establish one-to-one correspondences to determine numerical equivalence and one who did not, were presented with one of two sets of four trials, one that consisted of a small and the other a larger set size. In Study 2, two groups of conservers, one who provided more mature explanations for conservation judgments and one who provided less mature explanations, were presented with one of two sets of six number conservation trials, one that consisted of a small and the other a larger set size. In both studies, following standard conservation assessment trials, children were asked to count the sets and then make another conservation judgment. For nonconservers, counting produced evidence of conservation. For conservers, counting produced evidence of apparent nonconservation, achieved by a surreptitious addition or subtraction of

an item during the spatial transformation.

Results indicated that nonconservers who understood the numerical significance of one-to-one correspondence were able to make use of counting information to solve conservation problems involving larger set sizes to a greater extent than those who did not understand the numerical significance of one-to-one correspondence relations. In addition, the results revealed that nonconservers who did not demonstrate the ability to produce one-to-one correspondence used counting information to form conservation judgments to a greater extent on small than on large number conservation trials. The two groups of conservers did not differ in their ability to recognize and/or explain the evidence of apparent nonconservation. However, conservers who gave less mature justifications were more able to recognize and/or explain the apparent nonconservation on small than on larger number conservation trials.

The results are discussed with respect to factors that constrain the role of empirical operations, such as counting, in the child's formation of logical concepts, such as conservation. The implications for the present findings for models of counting/number conservation relations are also discussed.

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Chapter I

INTRODUCTION

Overview

According to Piagetian theory, the origins of logicomathematical knowledge can never be found in the experience of the physical environment alone. This type of knowledge is derived from actions performed on objects and not from the objects themselves. Through manipulating objects, the individual creates relationships that did not belong to the objects before his actions upon them (Piaget, 1970). In contrast to Piaget's position, theories having their roots in the empiricist tradition maintain that the source of all knowledge is in the environment itself (e.g., Skinner, 1953). According to this view, knowledge resides solely in the properties of objects themselves.

The relationship between experience and the development of logical concepts is a fundamental issue in cognitive development. One area where this issue is particularly relevant is that of number development. The question of whether children can acquire logical concepts of conservation through the empirical information they gain by counting is a topic of current interest. Piaget (1952) maintains that logical concepts such as number conservation are the products of underlying thought structures and are not derived solely from the results of empirical strategies such as counting. In contrast to Piaget's model, some researchers propose that counting is a necessary and critical condition for the development of number conservation (Klahr & Wallace, 1976; Schaeffer, Eggleston, & Scott, 1974). Other argue that counting plays a less direct role in the formation of number conservation concepts (Fuson, Secada, & Hall, in press; Saxe, 1979a; Saxe & Cohen, Note 1). Until recently, empirical support for these models has been quite limited. The new findings suggest that information gained through counting may play more of a role in children's developing understanding of number conservation than non-counting-based models claim (e.g., Piaget, 1952). A related question concerns the way in which children who already have acquired number conservation handle counting information that contradicts their belief in conservation. This is an interesting question since children who conserve number may differ in the extent to which they understand conservation as a logical necessity, and this difference may lead them to behave differently when faced with counting information that indicates nonconservation. The purpose of the present research was to investigate developmental differences in the way nonconservers and conservers use information they produce by counting sets to solve conservation problems and the way in which the numerical size of the sets may influence these differences.

The following review of the literature is divided into three sections. The first section contains a discussion of Piaget's stages in the development of number conservation, the models of the relation between counting and number conservation, and a review of the recent empirical research. In the second section, the conservation training and conservation extinction studies are considered as evidence that the effect experience has on children's understanding of logical concepts is dependent upon the child's cognitive level. The third section consists of the rationale for the present research and the specific hypotheses tested.

Piaget's Stages in the Development of Number

In a classical set of studies on numerical cognition, Piaget (1952) demonstrated that children's understanding of number changed qualitatively with age. In the standard conservation assessment procedure, the child is presented with a linear array of objects and is asked to construct a row equal in number to the model array. Three stages in the development of number were observed. During the first stage (about 4 years of age), children do not place one object opposite each object in the model array (one-to-one correspondence); instead, they place objects so that the end points of each array are matched but the arrays differ in number. The child believes the number is the same if the length of the rows is the same. In the second stage, the child produces a one-to-one correspondence between the model and the copy and obtains the correct number. However, when this correspondence is destroyed by either spreading apart the items in one of the rows or pushing them together, the child no longer judges that the two rows are equal in number. In the final stage (about 6½ to 7 years of age), the child both correctly reproduces the number of objects and understands that number is conserved, that is, remains the same despite the spatial transformation.

Models of Counting/Number Conservation Relations

Until recently, existing models of the functional relationship between counting and the development of number conservation concepts could be classified as either counting-based models (e.g., Klahr & Wallace, 1976; Schaeffer et al., 1974) or non-counting-based models (e.g., Piaget, 1952). According to Piaget's non-counting-based model, "concepts such as number conservation develop from a logical coordination of relations, and it is this coordination which underlies the child's understanding of the logical necessity of conservation concepts. Specifically, . . . in order to achieve a mature conception of number conservation the child must understand that a change in the spatial extension of a collection of elements is compensated for by an equivalent change in element separations" (Saxe, 1979a, p. 180). For Piaget, logical concepts such as number conservation are the products of underlying cognitive structures and are not derived from empirical strategies such as counting. Whether children counted the objects in the collections seemed to have little effect on their number conservation judgments. Piaget thus concluded that counting is an extraneous activity in the development of number conservation. For Piaget, in fact, counting can not be effective as a symbolic tool to represent number prior to the understanding of number conservation.

In contrast to Piaget's model, some researchers claim that counting is a necessary and critical condition for the development of number conservation (Klahr & Wallace, 1976; Schaeffer et al., 1974). According to the strongest form of this model, that proposed by Klahr and Wallace, the child learns that spatial transformations do not change the cardinal number of an array after repeatedly counting arrays of objects before and after spatial rearrangement. Young children, who frequently err in their counting, believe that the number of items in an array varies over spatial transformations. Older children, who usually count accurately, abstract the conservation rules from their empirical counting

(Klahr & Wallace, 1976).

A third type of model has recently been advanced in which counting plays a less direct or critical role in the development of number conservation. One example of this type of model is that presented by Fuson et al. (in press). Rather than postulating counting as required for conservation, Fuson and her co-workers view counting as one empirical strategy that many children can and do use to make judgments of equivalence in a conservation situation. Another example is the model offered by Saxe (1979a). According to Saxe, children can err in their counting and therefore counting alone can not be the sole basis for the formation of logical concepts such as number conservation (Saxe, 1979a). Saxe maintains that in order for young children to use counting-based number evaluations to form number conservation concepts, they must have reached the level in their number understanding where they begin to question whether spatial transformations of a collection affect its number and be willing to verify it.

Recent Number Research

To date, evidence relating to the models of counting/number conservation relations has been very limited. Three bodies of recent research, however, have provided information crucial to evaluating the relative adequacy of these models. One set of studies has focused on developmental changes in children's acquisition and use of counting as a means to compare and reproduce number (Gelman & Gallistel, 1978; Russac, 1978; Saxe, 1977, 1979a; Schaeffer et al., 1974). A second set of studies has reported that young children can solve conservation problems when small numbers are used (Cowan, 1979; Gelman, 1972a, 1972b; Siegler, 1981; Winer, 1974; Young &

McPherson, 1976; Zimiles, 1966). The third set has been concerned with the developmental relation between children's use of counting as a symbol system for number and their understanding of number conservation (Gelman & Gallistel, 1978; Russac, 1978; Saxe, 1979a). Each of these bodies of literature will now be reviewed.

Developmental Changes in Children's Counting

Whereas early work on the development of counting generally studied age-related changes in children's knowledge of the rote system and their counting accuracy (see Gelman [1972b] for an extensive review), most of the recent research has been concerned with the logical capacities which underlie children's counting behavior and the counting strategies children employ in solving number problems (e.g., Gelman & Gallistel, 1978; Russac, 1978; Saxe, 1977, 1979a; Schaeffer et al., 1974). In general, this literature indicates that children's acquisition and use of counting to represent number undergoes significant changes in the course of development.

Schaeffer et al. (1974) view children's acquisition of counting as following a four-stage sequence based on the gradual integration of three counting skills. These skills are: (1) the mastery of the counting procedure, that is, the consistent coordination of ordered number names and counted objects, (2) the formation of the cardinality rule that the last number named during counting denotes the number of objects in an array, and (3) the growth of the knowledge that $X+1$ is greater than X. Children between the ages of 2 years and 5 years 11 months were asked to count arrays of 5 to 7 items. Schaeffer and his colleagues found that many children were able to accurately count these arrays. However, when these arrays were then screened from view and the children were asked to indicate how many objects were present, the children often reported a number other than that which they had counted. On the basis of these data, Schaeffer concluded that children's acquisition of the cardinality rule follows the mastery of the counting procedure itself.

Like Schaeffer's model, Gelman and Gallistel's (1978) model of number development views counting as a set of discrete components or "principles" which children come to coordinate and apply to sets with increasing skill in the course of time. Unlike Schaeffer, Gelman and Gallistel view counting as an ability acquired under the guidance of some basic counting principles that are available to all children. Gelman and Gallistel (1978) identified five principles:

1. the one-one principle: each item in an array must be assigned one and only one number name;
2. the stable-order principle: the number names must be drawn from a stably ordered list;
3. the cardinal principle: the last number name recited in a count specifies the numerosity of the array as a whole;
4. the abstraction principle: any set of items can be collected together for a count; and
5. the order-irrelevance principle: the order in which items are named in a count is irrelevant.

Gelman and Gallistel argue that the young child's counting ability improves as a function of the child's being able to access these principles. Consistent with the findings of Schaeffer et al., Gelman and Gallistel found that the application of the cardinal principle follows the successful application of the one-one and stable-order principles.

In contrast to the models of Gelman and Schaeffer, Saxe (1977, 1979b) considers counting as a system of symbolization and not an ability that is reducible to discrete component skills. Saxe's model of counting focuses on how children in the course of development come to use counting as a means to compare and reproduce numerical information. According to Saxe, counting can only be used as a symbol system to represent number when children can coordinate the operations of successive iteration and progressive summation, that is, when they can at once consider each element in an array as an individual and include that individual in a progressive summation. Saxe argued that since it takes time for children to achieve a coordination of these operations, there is in the course of development a progression from a prequantitative use to a quantitative use of counting. To test this hypothesis, he presented 3-, 4-, and 7-year-old children with four counting tasks consisting of three reproduction tasks and one comparison task. The reproduction tasks required that the child copy a model set either by drawing an equivalent number of objects or by placing on a table an equivalent number from a larger set. In the comparison task, the child was asked to compare two sets of objects arranged in linear rows of the same length but differing in number. Saxe found that children first manifested prequantitative counting, that is, they would count when asked to compare or reproduce numerical information but did not base their numerical judgments on the products of their counting. For example, in a comparison task children might count both sets of objects but nevertheless base their numerical evaluations on the perceptual appearance of the arrays rather than on the results of counting. With development, children demonstrated a quantitative use of counting, that is, they were able to use the results of their counting when making numerical judgments. For example, in a comparison task children might count the two sets of objects and use the counting products in their numerical evaluation. Additional support for the claim that there are developmental changes in children's use of counting to compare and reproduce number is found in studies by Russac (1978) and Saxe (1979a).

Effect of Set Size on Conservation Performance

A second source of evidence relevant to the role counting plays in the development of number conservation is the literature showing that young children (that is, children below 6 years of age) are able to solve conservation problems when small set sizes (e.g., 2 to 4 or 5 items) are used (Cowan, 1979; Gelman, 1972a; Gelman & Gallistel, 1978; Lawson, Baron, & Siegel, 1974; Siegler, 1981; Winer, 1974; Young & McPherson, 1976; Zimiles, 1966). Recent work on young children's quantification skills (Gelman & Gallistel, 1978) indicates that young children are quite competent at determining the numerosities of small sets and thus could be succeeding on small number conservation problems by means of direct quantification, that is, by quantifying the sets both before and after the spatial transformation and basing their judgments on the results of this strategy. In the Piagetian view, however, conservation judgments based upon empirical information do not constitute "true" conservation. True conservation involves regarding conservation as a logical necessity and is based on immediate deduction without recourse to empirical evidence.

The studies of young children's small number conservation performance may be grouped into those which consider the children's success to be a function of an empirical solution procedure and those which view children's success to be a function of their inherent logical ability. A review of the studies consistent with each of the explanations, that is, the empirical hypothesis and the logical hypothesis, follows in the next section.[1]

The logical hypothesis. Gelman's (Gelman, 1972a, 1972b; Gelman & Gallistel, 1978) model of the development of number concepts holds that young children understand that lengthening and shortening of an array does not alter its numerical value. According to Gelman, the standard Piagetian conservation task contains features which prevent young children from demonstrating their understanding of number invariance. Specifically, these features are the verbal nature of the questions, the visibility of the spatial displacement, and the number of items used, namely, a number that exceeds young children's quantification ability. In order to control for these variables, Gelman (1972a) developed a "magic" task to investigate young children's understanding of number invariance. Her procedure involves two phases. In Phase 1, children are shown two arrays representing different numbers, for example, 2 and 3. Without mentioning numerosity, the children are told that one array is the "winner" and that the other is the "loser." Then a series of trials is given in which the children are required to find and identify the "winner." The arrays are covered by cans and shuffled as in a shell game. A trial consists of mixing up the cans, uncovering an array, and identifying it. When the children have completed at least 11 trials, Phase 2 begins. In Phase 2, children

[1]The present classification of studies as consistent with either the logical or empirical hypothesis is one conceived by the present author and not one the investigators would necessarily agree with.

encounter the effects of a change in the arrays, the experimenter having surreptitiously changed the length of the "winner" array. When the children uncover the altered array they are asked if it is the "winner." Children's surprise reactions to the transformed array are noted and the children are asked why the array won or lost, whether anything had happened, and if so, what. On the basis of the results with the magic task, Gelman (1972a; Gelman & Gallistel, 1978) concluded that young children treat lengthening and shortening as transformations that do not alter the number of items in an array.

Taking Gelman's claim that young children understand number invariance at least as far as small numbers are concerned, Winer (1974), using a training study format, investigated the effect of set size on children's performance on the standard conservation assessment procedure. Four-year-old children were randomly assigned to one of two groups: a small set size group (e.g., 2 and/or 3 items) and a large set size group (e.g., 5 and/or 6 items). Half of the children in each group (experimental subjects) received pretest, training, posttest, and transfer trials, while the other half (control subjects) received the same sequence of trials except that an extraneous activity was substituted for the training. Four tests of number conservation served as both the pretests and the posttests. Training consisted of four blocks of three trials and was aimed at inducing the child to focus on quantity and to ignore irrelevant perceptual cues. The results of the pretests revealed that a larger number of children conserved on small set size problems than on large set size problems. Posttest results indicated that the performance of all experimental subjects trained on small quantities improved compared with only 25% of the experimental subjects trained on larger quantities.

The empirical hypothesis. Evidence in support of the empirical hypothesis comes from both theoretical and empirical sources. A number of years ago, Piaget and his co-workers (see Apostel, Mays, Morf, & Piaget [1957] and Inhelder & Piaget [1963] cited by Flavell [1970]) argued that there was a stage in the development of number conservation in which children needed empirical evidence before they would commit themselves to a conservation judgment. Although Piaget's studies involved set sizes greater than those used in the research being reviewed here, the basic notion is the same.

In the first study to investigate the effect set size has on children's conservation performance, Zimiles (1966) presented kindergarten children with both small and large number conservation problems in counterbalanced order. The results revealed that children were more successful on both small and large number conservation problems when the small set problems preceded the large set problems rather than the reverse. Zimiles hypothesized that the ease with which small number sets can be "counted at a glance counteracts the effect of the rearrangement" (Zimiles, 1966, p. 36) and allows number to serve as the criterion for judging quantity. Although his phrase "counted at a glance" appears to be a reference to subitizing (see below), Zimiles (1963), in an earlier article, recognized counting as a method young children come to rely on more and more in order to make quantitative evaluations.

Klahr and Wallace (1973, 1976) propose that the development of conservation is dependent upon the emergence of different quantification processes. According to their formulation, children discover the conservation rules underlying invariance judgments by applying various quantification "operators," e.g., subitizing, counting, and estimation, to arrays before and after spatial transformations. These processes emerge in a fixed order. Subitizing, a process by which number is abstracted by some direct apprehension mechanism, is the first quantification operator to develop and it is limited in its range of application to numbers below 6. Counting and estimation emerge later in development, in that order.

Guided by the Klahr and Wallace model which posits that the methods of quantification available to children determine their invariance judgments, Young and McPherson (1976) administered a series of conservation problems to children between the ages of 4 and 7. Prior to the presentation of the conservation problems, the children's subitizing and counting levels were assessed. The conservation problems consisted of five trials at each of three set sizes: those within the child's subitizing range, those within the child's counting range, and those beyond the child's counting range. The results supported the Klahr and Wallace model since children showed an understanding of number invariance initially for small numbers within their subitizing range, then for numbers they could count, and finally for numbers beyond their counting range.

In a series of three experiments, Silverman, Rose, and Phillis (1979) modified Gelman's (1972a; Gelman & Gallistel, 1978) magic paradigm to make it more comparable to the classic conservation task. Their aim was to determine whether the modifications would have an effect on children's performance on the magic task. Specifically, the changes included performing the displacement openly rather than surreptitiously, presenting the arrays simultaneously rather than successively, and presenting the arrays placed one above the other rather than placed side by side. The results indicated that, even with these modifications, 3-year-old children were able to treat displacement as irrelevant to number. With regard to the question of whether young children are able to conserve small numbers, Silverman and his colleagues were reluctant to provide an answer. They pointed out that the few explanations offered were consistent with the interpretation that children were solving the task by determining the numerosity of the sets each time they were presented. That is, the explanations did not indicate that the child was thinking of the initial arrays and the transformations performed on them. Rather, the most frequent explanation for the posttransformation identifications referred to the array's number.

In a follow-up study, Silverman and Briga (1981) tested the notion that young children solve small number conservation problems by making independent estimates of numerosity on each trial. By means of a procedure of screening one or two elements in the more numerous of two arrays following a visible displacement of the array, Silverman and Briga demonstrated that 3-year-old children were highly dependent on immediately available information in determining the relative numerosities of two arrays. It was therefore concluded that 3-year-olds are not able to conserve small numbers. Rather, they succeed on small number problems by using an empirical quantification strategy.

In the second of two experiments, Cowan (1979) also examined the question of whether young children's success on small number conservation problems might be attributed to an empirical quantification strategy.

Four-year-old children received both an open and a screened condition of a conservation of identity (single array of items) problem using three set sizes: 2, 5, and 15. In the open condition the array was visible both before and after the transformation. In the screened condition the items were first arranged in a row before the child. Then, with the child watching, the blocks were placed in a box and the box was shaken. The child was asked whether there were more blocks now that they were in the box or whether there were more blocks when they were on the table. It was found that the superiority of performance with small set sizes in the open condition was reduced but not eliminated when the opportunity to requantify the array (after the transformation) was removed. In other words, empirical quantification seems to have played a role, but it did not fully account for the results.

Finally, Siegler (1981), in one of a series of experiments aimed at illustrating a new technique for studying both within- and between-concept developmental sequences, compared young children's performance on small and large number conservation problems. On two consecutive days, 3-, 4-, and 5-year-old children were presented with a total of 48 trials, 24 small number problems and 24 large number problems, arranged in alternating blocks of 12. Of the 24 trials within each set size, 16 trials involved adding or subtracting items in conjunction with expansions and contractions of the rows, 4 trials involved moving the items back and forth without changing the length of the row and the remaining trials consisted of the standard number conservation problems. The results were consistent with those of previous studies in showing that children generally performed at more advanced levels on small number problems than on large number problems. Beyond this, the findings showed that 4- and 5-year-old children used different strategies on the conservation problem depending on the set size and the type of transformation performed. According to Siegler (1981), children initially solve number conservation problems by empirical strategies, e.g., counting or pairing, and only later do they understand without counting or pairing that adding an item means that the row necessarily has more, that subtracting an item means that it necessarily has fewer, and that doing neither means that the row necessarily has the same number of items as before.

Before concluding this section it should be mentioned that Piaget's theory itself allows for small number conservation to precede large number conservation. According to Piaget (1952), small numbers provide the child with perceptual supports for coordinating the relation between the whole set and the individual elements. That is, with small sets (e.g., 3 items), unlike large sets (e.g., 30 items), the perception of the whole array provides information about the discrete number of items (Saxe, Cohen, & Rindskopf, Note 2). An implication of this analysis is that young children will succeed on small number conservation problems before large number problems because on small sets children are able to produce accurate numerical evaluations even without having achieved the cognitive ability to coordinate the elements and the whole set into a summation of elements, the operation involved in counting (Saxe, 1979b). As Piaget (1952) states: "Apart from these privileged examples, which give rise to what might be called the intuitive numbers 1 to 5, numbers that still adhere to the objects numbered and are perceptual rather than operational, children at the first stage cannot perform enumeration and addition one as a function of the other" (p. 199).

Taken together, the results of the foregoing studies provide support for the view that empirical quantification plays a role in young children's success on small number versions of conservation problems. The nature of this role, however, seems to vary from that of being totally necessary (e.g., Silverman & Briga, 1981) to being contributory (e.g., Cowan, 1979).

Developmental Relations between Counting and Conservation

According to Piaget (1952), children can not use counting as a symbolic vehicle to represent number prior to the development of number conservation. His argument rested on the assumption that in order for number names to serve a numerical function, they must refer to correspondence relations which are maintained over spatial transformations. Contrary to the Piagetian view, however, recent findings indicate that young children can use counting to inform their numerical judgments prior to attaining number conservation (Gelman, 1972a; Gelman & Gallistel, 1978; Russac, 1978; Saxe, 1979a). The new findings, however, are based on the fact that the number names can be used solely to represent correspondence relations with static sets. For example, Gelman (1972a) found that young children can obtain accurate numerical representations of sets by counting before they can conserve number. Young children's ability to determine the numerosity of an array, however, is limited to small sets because on large sets children make errors in counting. Russac (1978) also found that children could use counting to construct collections numerically equivalent to a model set prior to having acquired number conservation. In contrast to Gelman's study, Russac tested older children, namely, kindergarten, first-, and second-grade children and used larger collections of 7 to

10 items.

Further evidence that children can use their counting for quantitative ends before they understand number conservation comes from a study by Saxe (1979a). In this study, children between 4 and 6 years of age were administered two counting tasks and a number conservation task. The counting tasks included a comparison task and a reproduction task. In the comparison task, the child was asked to compare two parallel rows of dots differing in number and length in order to determine whether they were numerically equivalent or nonequivalent. In the reproduction task, the child was required to place the same number of beads on a table as indicated by an array of dots on a stimulus card placed on the floor. The results indicated that children develop quantitative counting strategies (but do not necessarily count accurately) before they develop number conservation concepts.

An interesting phenomenon that is related to children's ability to use quantitative counting in the context of transformed sets (e.g., the Piagetian conservation problem) rather than with static sets (as described in the above studies) has been reported by Greco (1962). The phenomenon has been called "quotity" (Greco, 1962; Inhelder, Sinclair, & Bovet, 1974) and refers to the case in which prior to a spatial transformation, some children count both sets and indicate that the sets are equal in number, but after the transformation, these children base their quantitative judgments on spatial features of the arrays while continuing to assert that both arrays have the same numerical label. Thus, at the conceptual level of quotity, children's use of counting to represent number (with transformed sets) is overshadowed by the physical arrangement of the items.

The new findings of developmental changes in children's use of counting, of young children's success on small number conservation problems, and of quantitative counting preceding number conservation have direct implications for models of counting/number conservation relations. If children can use their counting for quantitative ends prior to conserving number, then perhaps information gained through counting plays more of a role in the formation of number conservation concepts than non-counting-based models propose. However, according to Saxe (1979a), this role must be an indirect one. Saxe demonstrated that learning disabled children who counted inaccurately were nevertheless able to conserve number (Saxe, 1979a). On the basis of these data, Saxe argued that an empirical method such as counting is necessarily subject to error and therefore its products cannot be the sole source of concepts which have the status of logical truths. He suggested that in order for children to use counting as an effective means to determine whether number is conserved, children must have reached the level in their number development where they begin to question whether spatial transformations of a collection affect its number and be willing to verify it. The products of empirical counting, then, can serve to support the idea that spatial transformations of a collection do not alter its number. Some evidence for this position has recently been obtained by Saxe and Cohen (Note 1). Three-, 4-, and 5-year-old nonconservers were presented with a conservation task in which they counted a set of beads prior to an expansion transformation. After the transformation, the children were asked to predict the number of beads that were before them. Once the children made their prediction, they were asked to recount the set. The question of interest was how the children would reconcile the discrepancy between their belief in nonconservation and the information they gained by counting sets before and after spatial transformations. The results revealed that 3- and 4-year-old children did not alter their belief in nonconservation when counting produced results which contradicted this belief. Older children, in contrast, who are closer to the age when conservation concepts are naturally acquired, tended to change their belief in conservation to accord with their empirical counting, that is, they changed from nonconservation to conservation judgments.

Further evidence that counting may serve as a basis for children to develop number conservation concepts comes from two recent experiments by Fuson and her co-workers (in press). In the first experiment, 4½- to 5½-year-old children's conservation performance was compared under a count, match, and control (standard) condition. In the count condition, children were told to count the items in each row before they were asked the conservation question. In the match condition, the interviewer helped the child connect each item in one row to its corresponding item in the second row (and ensured that the pairs remained attached during the transformation) before the conservation question was presented. The results indicated that counting was a very effective strategy for many children in that it allowed them to make correct equivalence judgments in a conservation situation. In the second experiment, slightly older children were tested on a conservation task in order to determine the extent to which they spontaneously used empirical strategies. The results indicated that empirical strategies were the predominant methods used by 5 year olds. In addition, it was found that the use of empirical strategies and the production of Piagetian justifications coexisted in 11 of 28 children.

Thus, the picture that emerges from the Saxe and Fuson studies is that information produced through counting does lead many older nonconservers to give conservation judgments.

The following discussion of the conservation training and the conservation extinction studies provides further support for the thesis that the effect experience has on children's understanding of logical concepts is dependent upon the child's developmental level.

Relationship between Experience and Developmental Level

Before proceeding, it is necessary to state that the term "developmental level" will be used in two senses in the following discussion. First, developmental level refers to gross categories of cognitive status according to which children differ, for example, conservers and nonconservers. The second sense refers to differences within each of the gross categories that further differentiate children from one another. For example, conservers consist of children who may have just acquired the concept in question as well as children who conserve that concept and many others. The conservation training and extinction studies can be viewed as settings in which to examine the way children handle empirical evidence that is not consistent with their belief systems. As the following sections demonstrate, conservers and nonconservers treat contradictory empirical information differently, as do conservers who differ in the extent of their understanding of conservation.

Conservation Training Studies

For the purpose of the present research, only those training studies based on the use of quantifying procedures, e.g., counting and measuring, will be reviewed. In general, this literature indicates that information gained through quantifying activities leads nonconservers to develop conservation concepts.

One of the earliest investigators of the role of counting in the development of number conservation was a study by Wohlwill and Lowe (1962). After being individually pretested on both a nonverbal test of conservation and the standard verbal form, kindergarten children were randomly assigned to one of three training conditions or a control condition. In all conditions, children were asked to count the items. Posttest results revealed that none of the conditions were effective in leading children to understand conservation. The authors, however, noted a possible confounding factor which may have contributed to the negative results. In one condition, the act of counting may have interfered with rather than fostered the condition's aim of having children disregard the length cue.

Bearison (1969) reports a study based on counting of discrete units of liquid quantity. Kindergarten-aged children were provided with graduated experience in subdividing liquid quantities into small beakers. The beakers served as units of measurement. Children were asked to count the beakers before the liquid was poured into differently shaped containers. A significant number of children not only acquired conservation of continuous quantity as a result of this procedure but transferred the conservation understanding to other dimensions as well, e.g., mass, number, and length.

The potential significance of information gained through measurement operations in the development of conservation concepts was also recognized by Kingsley and Hall (1967) in a study of length and weight conservation. In training for length conservation, for example, Kingsley and Hall used paper strips both as objects to be measured and as measuring instruments themselves. Through repeated practice in measuring the lengths of many objects whose relative lengths they first estimated, children were encouraged to rely on the information they gained through empirical quantification. The results indicated highly significant training effects for both length and weight conservation.

A study by Curcio, Robbins, and Ela (1971) included a counting procedure as one of several types of training for number conservation. Two groups of preschool children received the counting instruction. One group consisted of children who demonstrated number conservation when their own fingers were involved but not when external objects were used. The other group showed neither number conservation with fingers nor number conservation with objects. The results revealed that, for both groups of children, counting was no more effective than an addition/subtraction procedure in inducing number conservation with objects.

Inhelder et al. (1974) also used quantifying activities in a training study for length conservation. Only children who had acquired number conservation served as subjects,as the purpose of the experiment was to study the developmental link between number conservation and conservation of length. Children were asked to use matches to construct "roads" of the same length as model roads laid out in various configurations and formed by matches of different sizes. Children were questioned about the number of matches and/or the lengths of the roads. The results showed that children made progress in acquiring length conservation. The counting procedure, however, was interrelated with a conflict training procedure,and as a result the effect of counting itself is not known.

Beilin (1978), in his extensive review of the training literature, cites a group of Soviet studies which based their training on measurement operations (Obuchova, 1966). The training is reported to be successful, although details concerning methodology and data are not available.

In a recent training study, Gelman (1982) argued that she produced evidence supporting a nativist interpretation of number development. Gelman asked 3- and 4-year-old children to count one of two small set size arrays placed in one-to-one correspondence and then indicate its cardinal value. The procedure was repeated for the second array. The child was then asked to make a judgment of equivalence or nonequivalence with the arrays uncovered. Next, the children watched as the interviewer transformed the length of one of the arrays and then were asked to judge whether the specific number of items in each row had changed. Finally, the children were asked to judge whether the two rows had the same number or a different number of items and to explain their judgments. Two control conditions were included. Both involved having children count single arrays instead of paired arrays and in one condition, children were asked the cardinality question and in the other they were not. Number conservation problems using small and large set sizes were presented immediately after the training. The results indicated that both 3- and 4-year-old children succeeded on standard conservation trials with both small and large set sizes following the training, even when success was defined as being able to give a correct judgment and explanation on at least one of the small set size problems and on one of the large set size problems. Gelman interpreted her findings as indicating that the training had allowed children to access an available, although implicit, ability to use one-to-one correspondence as a basis to judge numerical equivalence. According to Gelman, young children have an implicit knowledge of the one-to-one correspondence principle but need an explicit understanding of this principle to succeed on the number conservation task.

Conservation Extinction Experiments

Like the training studies, the conservation extinction studies also provide children with empirical information that contradicts their beliefs. In extinction studies, children are presented with evidence of nonconservation in contrast to the evidence of conservation they receive in the training studies. In general, the findings indicate that conservers are not affected by evidence of nonconservation for most concepts, but that they are influenced by evidence of nonconservation for weight conservation. As Miller (1976) has pointed out, however, conservation of weight appears to be an atypical concept in its susceptibility to extinction, and this may be largely a function of the particular extinction procedure used.

The first extinction study was carried out by Smedslund (1961). Both natural and trained conservers were presented with a single extinction trial for conservation of weight. On this trial the experimenter surreptitiously removed clay from one of two objects which had previously been judged to be equal in weight. The child was thus confronted with an instance of apparent nonconservation. Extinction or resistance was inferred from the child's explanation for the unexpected outcome. Thus, "You took some away" was regarded as an instance of resistance; "It's lighter because it's flatter" an example of extinction (Miller, 1976). Smedslund found that natural conservers were significantly more likely to resist extinction than were trained conservers. A second finding was that only 6 of 13 natural conservers were able to resist extinction. This low percentage of resistance among natural conservers was subsequently replicated by other studies for conservation of weight (Hall & Kingsley, 1968; Hall & Simpson, 1968; Kingsley & Hall, 1967). More recent weight extinction studies (e.g., Miller, 1973; Strauss & Liberman, 1974), with their extensive probes and posttests, however, have found a higher percentage of resistance than was reported in the earlier studies.

There have been two studies that have attempted to extinguish conservation of number (Amaiwa, 1973; Strauss & Liberman, 1974). Both studies used a procedure involving a surreptitious addition or subtraction of items to create the extinction trials. Feedback was provided by visual inspection of the material. The results of these studies were consistent in finding that resistance was virtually total by the criterion of performance on a conservation posttest. In other words, almost all children resisted the evidence of apparent nonconservation. Amaiwa (1973) also examined resistance to extinction of length, area, and weight conservation. She found high percentages of resistance for length and area conservation, but a somewhat lower percentage for weight conservation.

Despite the finding of greater resistance in the more recent extinction studies, many children do appear to abandon their belief in conservation of weight when faced with contradictory empirical evidence. Miller (1976) has suggested that the difference between weight and other conservation concepts may be a function of the fact that in extinction studies with weight, the feedback is usually provided by a machine (a balance scale), whereas in studies with other concepts the feedback must be provided by visual inspection. As a result of this difference, changes in quantity in the latter studies must necessarily be large in order that they can be readily perceived by the child, whereas changes on weight trials are not immediately apparent and the amount of the change can be left unspecified (Miller, 1976). Thus, interconcept differences in extinction may be a reflection not of differential certainty with which concepts are held but rather a function, at least in part, of the specific nonoperational outcomes that have been provided.

With regard to developmental level in the second sense, that is, within groups (e.g., conservers or nonconservers), there is one study that compared the performance of two levels of concrete operational conservers on extinction of number. Strauss and Liberman (1974) tested children who conserved only number and children who conserved number, length, and weight. The results revealed that 80% of the children with less elaborated structures (subjects who only conserved number) and all of the children with more elaborated structures (subjects who conserved all three concepts) resisted the evidence of apparent nonconservation.

Rationale and Hypotheses

As the preceding review demonstrates, the recent research on children's counting, on young children's performance on small number conservation problems, and on the developmental relationship between counting and number conservation suggests that the early models of the role of counting in the formation of concepts of number conservation may not be adequate. Contrary to Piaget's theory, which considers young children's counting to be merely an aspect of rote knowledge, new evidence indicates that young children use quantitative counting prior to the development of number conservation. In addition, the invariant order in the development of quantitative counting and number conservation suggests, as counting-based models hold, that the child may use counting as a means of gathering information to help understand number conservation. However, children may err in their counting, and therefore counting alone cannot be the sole basis for the formation of logical concepts such as number conservation. The role of counting remains unclear.

The purpose of the present research was to examine the way in which children at different stages in their understanding of number conservation resolve the conflict between information produced through counting and their belief about conservation and the way in which set size may influence the resolution. Two studies were conducted. An overview of the studies will serve to make the following hypotheses understandable. Four groups of children were tested on number problems involving small or large set sizes. In Study 1, the two groups consisted of nonconservers who could establish one-to-one correspondence (Level 2 nonconservers) and those who could not (Level 1 nonconservers). In Study 2, the two groups consisted of conservers who provided less mature explanations for their conservation judgments (Level 1 conservers) and those who provided more mature explanations (Level 2 conservers). In order to determine the effect information gained through counting has on children's understanding of conservation, children were presented with a task in which the results of their empirical counting contradicted what their belief in conservation would lead them to expect. In Study 1, nonconservers were presented with standard conservation trials (4) with the following addition. After answering the conservation question, the children were told to count the arrays and then were again asked the conservation question. In Study 2, conservers were also asked to count the arrays after they had made conservation judgments. Following the count, they too were asked to make another conservation judgment. In the case of conservers, however, in order to provide children with a contradiction, trials involved a surreptitious addition or subtraction of an item during the spatial transformation. As a consequence, when conservers counted they discovered that the previously equivalent rows were no longer equivalent in number (apparent nonconservation). Nonconservers were scored in terms of the extent to which the information they obtained through counting was used to determine their final quantitative judgments. Conservers were scored in terms of the extent to which they recognized and/or explained the contradiction between their belief in conservation and the evidence of nonconservation they produced by counting.

The following hypotheses were tested:

Study 1:

1. Level 1 nonconservers will change to conservation following counting on small set sizes to a greater degree than on large set sizes.
2. Level 2 nonconservers will change to conservation following counting on small set sizes to a greater degree than on large set sizes.
3. Level 2 nonconservers will change to conservation following counting on small set sizes to a greater degree than Level 1 nonconservers.
4. Level 2 nonconservers will change to conservation following counting on large set sizes to a greater degree than Level 1 nonconservers.

Study 2:

5. Level 1 conservers will recognize and/or explain the apparent nonconservation to a greater extent

following counting on small set sizes than on large set sizes.

6. Level 2 conservers will not differ in their ability to recognize and/or explain the apparent nonconservation following counting on small and large set sizes.
7. Level 2 conservers will recognize and/or explain the apparent nonconservation to a greater extent following counting on small set sizes than Level 1 conservers.
8. Level 2 conservers will recognize and/or explain the apparent nonconservation to a greater extent following counting on large set sizes than Level 1 conservers.

Chapter II

STUDY 1

Method

Design

The experimental design of the study was a 2 x 2 factorial with developmental level and set size as the between-subject factors.

Subjects

Sixty children ranging in age from 3 years 9 months to 6 years 5 months served as subjects. The children were drawn from several day care centers and elementary schools in a middle-class suburban area of New York City. The children were divided into two groups. One group was composed of 30 Level 1 nonconservers with an average age of 4 years 10 months (*SD* = 8.2 months), and the other group consisted of 30 Level 2 nonconservers with an average age of 5 years 4 months (*SD* = 9.1 months).

Procedure

All children were seen individually by the author. Although the procedure was continuous, three phases can be identified: conservation assessment, counting, and conflict phases.

Assessment phase. This phase served to identify two levels of nonconservers. Two sets of buttons, one gold-colored and the other silver-colored, measuring 1.9 cm in diameter, were shown to the children. The children were told that the interviewer wanted to play a few games with them using the buttons. The children were first presented with a linear array of 8 silver buttons placed 1 inch apart and an available set of gold buttons. They were then asked to put down on the desk the same number of buttons that were spread out before them. Children who were unable to establish a one-to-one correspondence on the first trial were given two additional trials to do so. After the third trial, the interviewer constructed the one-to-one corespondence and told the child that the rows were equal in number. Once the children had set up the one-to-one correspondence or had it constructed for them and acknowledged numerical equivalence between the rows, the interviewer either expanded or contracted one of the rows while saying, "Now, watch what I'm doing." Following the transformation, children were asked if they and the interviewer now had the same number of buttons or whether one of them had more than the other, and if so, who. The children were also asked to justify their answers, for example, "How do you know?"

Each child received three trials at set size 8. The trials consisted of both expansion and contraction transformations. The order of administration of the transformations alternated for each child and were counterbalanced across subjects. Two orders of conservation assessment trials were used: (1) expand subject's row, contract subject's row, expand experimenter's row, and (2) contract subject's row, expand subject's row, contract experimenter's row. The order of the response alternatives in the conservation question was also counterbalanced across subjects.

Children's responses were classified as falling into one of two categories based upon Piaget's criteria (Piaget, 1952). Children who could not establish a one-to-one correspondence on any of the trials and gave no conservation judgments were called Level 1 nonconservers. In Piaget's system, these children would be considered as being at Stage 1 in the development of the number concept. Children who could establish a one-to-one correspondence on each trial but did not produce any conservation judgments were called Level 2 nonconservers. This category of nonconserver is consistent with Piaget's second stage. Any child who did not fit into either of the above categories was not included in the study.

Counting phase. The purpose of this phase was to ensure that children had certain counting skills with which to participate meaningfully in the subsequent conflict phase. Three questions were administered. The first question was designed to determine the child's ability to count an array of items. To this end, the child was presented with a linear array of pennies (3, 6, or 9), placed 1 inch apart, and asked to count them aloud. After the child had counted the pennies, the row was immediately covered with a sheet of paper, and the child was asked a second question, "How many pennies are underneath the paper?" The purpose of this question was to determine if the child understood the cardinality rule, that is, that the last numeral recited in counting a set of objects represents the cardinal value of the set. Third, children were asked if they were certain that they had counted correctly or whether they thought they might have made a mistake. This question assessed children's confidence in their counting.

The questions were presented three times, involving sets of 3, 6, and 9 pennies. The order of administration of the three sets was counterbalanced across subjects. Children had to meet the following three criteria in order to continue in the study. First, they had to count accurately on the trials using 3 and 6 pennies and not be in error by more than 2 numerals on the trial with 9 pennies. Second, children had to be confident about their counting products on all three trials. Finally, children had to be correct on the cardinality question on two of the three trials. The criterion of two of three correct trials was used in order to include children who, due to anxiety, short attention span, memory, etc., may have responded incorrectly on one trial. Children who recited all the numbers up to and including the last numeral in response to the cardinality question were included. On the basis of these criteria, a total of five children, three at Level 1 and two at Level 2, were not included in the study.

Conflict phase. The purpose of this phase was to have nonconservers produce counting information which indicated conservation. Children were randomly assigned to either a small set size condition (4 items) or a large set size condition (8 items) within their respective level of conservation understanding. This resulted in four groups of 15 subjects each.

The child was presented with two linear arrays equal in number and aligned in one-to-one correspondence. Once the child acknowledged that the two sets were equal in number or was told that both sets were equal (which was sometimes necessary for the Level 1 nonconservers), the interviewer expanded or contracted one of the arrays and asked the conservation question. The interviewer then repeated the child's response, e.g., "So, I/you have more buttons." The children were then told to count the buttons aloud in order to be sure. If necessary, the interviewer helped them with their counting to ensure an accurate count. The interviewer then repated aloud the numbers the children produced in their counts, e.g., "So, there are ___ buttons here [pointing to one row], and there are ___ buttons here [pointing to the other row]." This statement was designed to ensure that the children were attending to the fact that the two sets they had just counted contained the same number of items. The conservation question was again administered along with a request for an explanation for the judgment.

There were four conflict trials. Children who produced conservation judgments on the fourth trial were administered a countersuggestion. If the child produced a conservation judgment after counting on the fourth trial, the countersuggestion took the form, "Before you said that I/you had more buttons. Now we both have the same number. Which do you think is right? Why?" If the child produced a conservation judgment on the fourth trial prior to the count, the countersuggestion took the following form, "Another boy/girl that I saw said that this row [pointing to the longer row] had more buttons because it goes out to here [pointing to both ends]. Do you think that boy/girl was right? Why or why not?"

The four trials consisted of both expansion and contraction transformations. The order of administration of the transformations alternated within the set and were also counterbalanced across subjects. The conservation question was phrased in two ways, also counterbalanced across subjects. One form of the question was the following, "Do we both have the same number of buttons or do I have more buttons or do you have more buttons?" The other form of the question was, "Do we both have the same number of buttons or do you have more buttons or do I have more buttons?"

Scoring

Children were assigned scores for their judgments for each of the four trials. A score of 0 was assigned to each judgment that indicated that the information gained from counting was not used to determine the final quantitative judgment. In other words, children maintained their original nonconservation judgment after counting. A score of 1 was given to each conservation judgment that indicated that the child's count on that trial was used as the basis for changing to conservation. A score of 2 was assigned to each conservation judgment that preceded the count and was evidently based on counting information obtained on the previous trial or trials (or in the case of small set sizes, numerical information gained through a direct perceptual mechanism). Since there were four trials, total conservation change scores ranged from 0 to 8.

Children's responses to the countersuggestion were recorded as either returning to a nonconservation judgment or maintaining the conservation judgment.

Results and Discussion

The presentation of the results includes the following four analyses. The first analysis compared the mean scores for the two subject groups at each level of set size to determine whether children's performance on the conservation problems was influenced by their developmental level and the number of items used. A second analysis focused on children's conservation judgments on the first trial and the last trial to determine if the two groups of nonconservers were equally influenced by the repeated trials. The third analysis compared the two groups of nonconservers in terms of their patterns of conservation judgments across trials. The fourth and last analysis compared the number of children who retained the conservation judgment following the countersuggestion and those who did not.

Table 1 contains the means and standard deviations of the conservation change scores for the two subject groups at each level of set size. A square root transformation was used in order that the data more closely approximate homogeneity of variance. Planned comparisons (Keppel, 1973) revealed that Level 2 nonconservers (NCs) changed from nonconservation to conservation judgments following counting on large set sizes to a greater extent than Level 1 NCs ($\underline{F}[1,56] = 13.84$, $\underline{p} < .001$). The analysis also revealed that Level 1 NCs changed from nonconservation to conservation judgments to a greater extent on small than on large set sizes ($\underline{F}[1,56] = 4.49$, $\underline{p} < .04$). Thus, these analyses provide direct support for Hypotheses 1 and 4.

A further way to investigate developmental differences in the way nonconservers use counting information that contradicts their belief about conservation is to look at the conservation judgments on each of the four trials. On each trial one of three types of conservation responses were possible: (1) N--nonconservation judgment after counting, (2) C-A--conservation judgment after counting, and (3) C-B--conservation judgment before counting (see superscript on Table 1). The frequency of each type of conservation judgment for each trial for the two subject groups is presented in Table 2. If counting-based theories of number conservation are correct, then nonconservers should change to conservation as a consequence of repeated trials providing counting information. If

Table 1

Means and Standard Deviations of Conservation

Change Scores across Conditions[a]

Nonconserver group	Set size			
	Small		Large	
	$\bar{X}$	SD	$\bar{X}$	SD
Level 1	2.13	2.32	0.60	1.29
Level 2	2.93	2.31	3.46	2.53

[a]There was a slight asymmetry across the set sizes in the total score likely to be attained, namely, 8 for small sets and 7 for large sets. Whereas in the small set size condition it was quite possible for subjects to earn a score of 2 on each trial, in the large set size condition it was hypothetically possible but extremely unlikely (no subject did) to predict conservation on the first trial and thereby earn a score of 2 for that trial.

Table 2

Frequency Distribution of Conservation Judgments as a Function of Trial and Nonconserver Group

NC group	Trial 1			Trial 2			Trial 3			Trial 4		
	N	C-A	C-B	N	C-A	C-B	N	C-A	C-B	N	C-A	C-B
Level 1												
Small	7	7	1	8	6	1	8	6	1	9	5	1
Large	12	3	0	13	2	0	13	2	0	13	2	0
Level 2												
Small	4	10	1	6	8	1	6	8	1	5	8	2
Large	5	10	0	6	7	2	5	5	5	5	4	6

Note. N = nonconservation judgment; C-A = conservation judgment after counting; C-B = conservation judgment before counting.

non-counting-based models are correct, there should be no change in nonconservers' performance over successive trials involving counting. To determine if the present data provided support for either of these models, the frequency of each type of conservation judgment on the first trial and on the last trial was compared for the two groups (pooling set sizes to increase the expected values). The distribution of Level 2 NCs' judgments shifted towards giving more conservation judgments before counting on the last trial than on the first trial ($\chi^2[2] = 7.50$, $\underline{p} < .03$), whereas the distribution of the Level 1 NCs' judgments showed no such change ($\chi^2[2] = .74$, n.s.).

Although the above analysis revealed that as a group the distribution of Level 2 NCs' judgments, in contrast to that of Level 1 NCs, changed from the first to the last trial, it did not indicate how individual children made use of the counting information over the four trials. Did children display consistent patterns of conservation judgments across trials, and, if so, did these patterns differ in frequency between the two groups of nonconservers? Fifty-eight of 60 children could be described by the following four patterns of conservation judgments. These are ordered from no use of the counting information (Pattern 1) to the most effective use of the counting information (Pattern 4).

Pattern 1. Nonconservation judgments were given on each trial (N, N, N, N).

Pattern 2. Conservation judgments did not follow a progressive pattern (e.g., N, C-B, C-A, C-A). A progressive pattern was one in which conservation judgments on later trials showed either more use or the same extent of use of counting information as those on earlier trials.

Pattern 3. Conservation judgments followed a progressive pattern but conservation was never anticipated (e.g., N, N, C-A, C-A).

Pattern 4. Conservation judgments followed a progressive pattern and were anticipated on later trials or on the last trial (e.g., N, C-A, C-B, C-B).

Table 3 contains the frequency of each pattern of conservation judgments for the two subject groups at each level of set size. Chi-square analyses were used to determine whether children's patterns of conservation judgments across trials were related to their developmental level. In order to increase the expected cell frequencies, the number of children who produced Patterns 1 and 2 (less mature patterns) was combined with the number of children who demonstrated Patterns 3 and 4 (more mature patterns). The results revealed that the two groups of nonconservers (pooling set sizes) differed in their patterns of conservation judgments across trials. Specifically, Level 2 nonconservers demonstrated more mature patterns than Level 1 nonconservers ($\chi^2[1] = 10.02$, $\underline{p} < .01$). Follow-up analyses indicated that Level 2 nonconservers produced the more progressive patterns than Level 1 nonconservers on large set size problems ($\chi^2[1] = 8.86$, $\underline{p} < .01$), but not on small set size problems ($\chi^2[1] = 2.28$, n.s.).

Although the present study is not a conservation training study in the traditional sense, e.g., several training conditions, multiple post-tests, transfer tests, etc., it can be viewed as a training study in the sense that repeated conservation trials involving counting information were expected to lead nonconservers to produce conservation judgments. As with any study claiming to demonstrate short-term developmental change, the question can be raised as to whether the children who changed from

Table 3

Frequency Distribution of Patterns of Conservation

Judgments for Two Groups of Nonconservers

NC group	Pattern of conservation judgment			
	1	2	3	4
Level 1				
Small set	5	4	5	0
Large set	12	1	2	0
Level 2				
Small set	4	1	8	1
Large set	3	2	4	6

nonconservation to conservation judgments really understand the concept as defined by a change in internal organization or whether they have learned to make relative quantity judgments by relying on their counting to the exclusion of perceptual cues. One means of determining whether nonconservers have actually made progress towards acquiring conservation is to look at the way in which they responded to the countersuggestion. The percentage of children who maintained conservation in the face of the countersuggestion was 37% for Level 1 nonconservers and 57% for Level 2 nonconservers. These findings, then, provide some evidence that a majority of the more advanced nonconservers who changed to conservation judgments did make developmental progress.

In sum, the results of this study indicated that the way nonconservers use information gained through counting to solve conservation problems was a function of their developmental level. There were several ways in which the effect of developmental level was demonstrated. First, Level 2 nonconservers differed from Level 1 nonconservers in their total conservation change scores. Whereas less developmentally advanced nonconservers tended to persist in their belief in nonconservation following counting, more advanced nonconservers changed to judgments of conservation to a greater extent following counting. This result, however, was limited to large set sizes. Second, Level 2 nonconservers anticipated conservation more often on the last trial in contrast to the first trial than Level 1 nonconservers. Third, Level 2 nonconservers displayed more progressive patterns of conservation judgments across trials than Level 1 nonconservers.

The present data suggest that children's developmental level with respect to their understanding of conservation determines whether counting information will be used to solve conservation problems. This finding is not fully consistent with either non-counting-based models or counting-based models of number conservation. Contrary to non-counting-based models, the present findings indicated that nonconservers were able to use counting information to inform their developing understanding of conservation. Unlike counting-based models, however, not all children benefited from the counting information. Only the more advanced nonconservers, that is, those who understood the numerical significance of one-to-one correspondence were able to use their counting to form conservation judgments.

With regard to set size, there was partial support for the view that the number of objects used in the conservation problem influences the way children treat counting information that violates their belief in nonconservation. In the present experiment, the less advanced nonconservers changed from judgments of nonconservation to judgments of conservation following counting to a greater degree on small set size problems than on large set size problems. Further discussion of the implications of these data will be taken up in the General Discussion (Chapter IV).

Chapter III

STUDY 2

The results of Study 1 provide support for the hypothesis that the way nonconservers treat counting information that violates their expectancies concerning number conservation is a function of both their developmental level and the number of items used. An additional way to investigate the role counting plays in children's understanding of logical concepts of conservation is to use children who already have acquired number conservation and study the way they reconcile counting information that contradicts their belief in conservation. This is an interesting question since conservers may differ in the way they handle contradictory counting information as a function of the extent to which they understand conservation as a logically necessary truth. Piagetian theory acknowledges that at an initial level of development, certain concepts, e.g., conservation, are only accepted following empirical verification (e.g., Apostel et al., 1957; Beth & Piaget, 1966). It is only at a later point in development that this empirically based understanding is recognized as "true and even necessary by immediate deduction" (Beth & Piaget, 1966, p. 232). It may be that young children who offer conservation judgments on number conservation tasks differ with respect to their understanding of the necessity of conservation. As a consequence they may vary with respect to how they handle counting information that violates their belief in conservation. The aim of Study 2 was to test this hypothesis. The variables of developmental level and set size were again hypothesized to be significant. Developmental level was operationally defined by the nature of the explanations given for conservation judgments. Explanations for number conservation have been quite varied, and it seemed plausible that these explanations could be used to infer children's status with regard to their understanding conservation as logically necessary. There is some support for this idea. Markman (1978), in a study of young children's numerical abilities, reported that reference to the irrelevance of the transformation is an early-appearing type of conservation justification. As an explanation given by children who have only recently acquired conservation, reference to the irrelevance of the transformation seems to be based on empirical considerations and therefore may not entail feelings of logical necessity.

In summary, Study 2 has value for several reasons. First, it is not known if there are differences among conservers in the way they handle contradictory counting information in solving conservation problems and whether the number of items used influences their behavior. Second, it was felt that knowing how conservers treat discrepant counting information would provide a more complete description of the relationship between children's production of empirical information and their understanding of logical concepts. Finally, the results would add to the sparse literature on the extinction of number conservation concepts.

Method

Design

The experimental design of the study was a 2 x 2 factorial with developmental level and set size as the between-subject factors.

Subjects

Sixty children, ranging in age from 4 years 0 months to 7 years 5 months, served as subjects. The children were drawn from several day care centers and elementary schools in a middle-class suburban area of New York City. The children were divided into two groups. One group was composed of 25 Level 1 conservers (mean age 6-0), and the other group consisted of 35 Level 2 conservers (mean age 6-4). Of the 25 Level 1 conservers, 13 children received small set size problems, and 12 received large set size problems. Of the 35 Level 2 conservers, 17 children were administered small set size problems, and 18 were administered large set size problems.

Procedure

Each child was interviewed individually by the author. As in the first study, the interview consisted of three phases: conservation assessment, counting, and conflict phases.

Assessment phase. The purpose of this phase was to identify two levels of conservers. Both sets of buttons (as described in Study 1) were shown to the children, and they were told that the interviewer wanted to play a game using the buttons. The children were then presented with a linear array of 8 silver buttons placed 1 inch apart and an available set of gold buttons. The children were asked to put down on the desk the same number of buttons that were spread out before them. Once the children had set up the one-to-one correspondence or had the interviewer construct it (some children took the correct number but did not place them in one-to-one correspondence) and acknowledged numerical equivalance between the rows, the interviewer either expanded or contracted one of the rows while saying, "Now, watch what I'm doing." Following the transformation, the children were asked if they and the interviewer now had the same number of buttons or whether one of them had more than the other and if so, who. The children were also asked to justify their responses, for example, "How do you know?"

Each child received three trials at set size 8. The trials consisted of both expansion and contraction transformations. The order of administration of the transformations alternated for each child and were counterbalanced across subjects. Two orders of conservation assessment trials were used: (1) expand subject's row, contract subject's row, expand experimenter's row, and (2) contract subject's row, expand subject's row, contract experimenter's row. The order of response alternatives in the conservation question was also counterbalanced across subjects.

Children's responses were classified as falling into one of two categories. Children who (1) established numerical equivalence between the two sets on each trial, (2) made conservation judgments on each trial, and (3) gave explanations referring to number, the act of counting, or the irrelevance on the transformation were called Level 1 conservers. Children who (1) established numerical equivalence between the sets on each trial, (2) made conservation judgments on each trial, and (3) gave explanations referring to the fact that nothing had been added or taken away (identity), that the original spatial arrangement could be reestablished (inversion), that the rows were initially equal in number, or that the larger spaces in the longer row made it equal to the shorter row (compensation) were called Level 2 conservers. Level 1 conservers were considered the less cognitively mature conservers as their explanations suggested a more empirically based understanding of conservation. Level 2 conservers were considered the more cognitively mature conservers as their explanations suggested a more logical appreciation of the concept.

Counting phase. The purpose of this phase was to ensure that children had certain counting skills with which to participate meaningfully in the subsequent conflict phase. The procedure and criteria for judging the counting performance were the same as that described in Study 1.

Conflict phase. The aim of this phase was to present conservers with conservation trials in which the results of counting contradicted what their belief in conservation would lead them to expect. In addition to the gold and silver buttons previously described, a ring with a very small magnet attached to it was used. The buttons were made of a ferrous material and thus were attracted by the magnet.

The child was presented with two linear arrays equal in number (either 4 or 8 depending on set size condition) and aligned in one-to-one correspondence. Once the child acknowledged that both arrays were equal in number, the interviewer expanded or contracted one of the arrays, while at the same time surreptitiously removing one button or adding one button to that array. On the expansion trials, the interviewer surreptitiously removed one item from the expanded row by means of the ring. On the contraction trials, one item was surreptitiously added to the contracted row. Immediately following the transformation, the child was asked the conservation question, "Now, do we both have the same number of buttons or do I/you have more buttons, or do you/I have more buttons?" Children who wanted to count the buttons before making their judgment were told to "just guess." Children who advised that the arrays were unequal in number were asked, "How do you know?" Any spontaneous comments regarding the apparent nonconservation were recorded. For children who acknowledged equality, the interviewer repeated the child's response, e.g., "So, we both have the same number of buttons." The child was then told to count the buttons aloud in order to be sure. If necessary, the interviewer helped children with their counting to ensure an accurate count. The interviewer then repeated the numbers the children produced, e.g., "So, there are ___ buttons here [pointing to one row] and there are ___ buttons here [pointing to the other row]." This statement was designed to ensure that the children were attending to the fact that the two sets they had just counted differed in number. Again, any spontaneous comments were recorded. Children who acknowledged inequality after the count, or in the case of small set sizes without counting, and did not spontaneously recognize the contradiction (i.e., first numerical equivalence and now nonequivalence) as a problem and/or offer an explanation for the unexpected outcome were provided with a prompt. The prompt took the form, "Before you said we both had the same number of buttons. Now I/you have more buttons. Is that all right? Is that okay?" (recognition of contradiction question). A second prompt was provided to children who did not spontaneously explain how the apparent nonconservation could have occurred. This prompt took the form, "How could that happen? How could that be?" (explanation of contradiction question).

Six trials were administered. The trials consisted of both expansion and contraction transformations. The order of administration of the transformations alternated within the series and was counterbalanced across subjects. Four trials involved a surreptitious manipulation as described above. The two other trials did not involve a surreptitious addition or subtraction, and thus the results of counting confirmed a belief in conservation. The purpose of these additional trials was to interfere with children's developing an expectancy that on every trial their counting would be in conflict with their belief in conservation. The standard trials (involving no surreptitious manipulations) were presented in the first and fourth positions. In the interest of time and keeping children motivated to continue with the task, children were not asked to explain their quantitative judgments after counting on these trials. Each child was debriefed at the end of the session and was told not to speak to the other children about the game as doing so would spoil it for them.

Scoring

Although there were six experimental trials, only four trials involved a surreptitious addition or subtraction of an item. It was these four trials that were scored.

The conflict trials were scored on the basis of whether children spontaneously or with prompting recognized and/or explained the contradiction between their belief in conservation and the quantity information they obtained by counting. An adequate explanation included any answer indicating that an item had been either added to or subtracted from one of the rows, that some type of magic had occurred, or that the child had been mistaken about the initial equality. Children were credited with providing an adequate explanation even if they incorrectly attributed the addition or subtraction to the unaltered row. Table 4 contains a list of the five types of responses and the score assigned to each type. Since

Table 4

Scoring Criteria for Conservers on

the Conflict Trials

	Elicited recognition	Elicited explanation	Score
Spontaneous recognition and/or explanation			3
	Yes	Yes	2
	Yes	No	1
	No	Yes	1
	No	No	0

there were four trials, the total reaction-to-contradiction score ranged from 0 to 12.

In order to obtain additional data on the effect of set size on children's performance on number problems, it was decided to score children's quantitative judgments (e.g., equivalence or nonequivalence) following the transformation but prior to their being asked to count. The first conflict trial involving a surreptitious addition or subtraction was excluded in this analysis in order that comparisons between large and small set size conditions would not be influenced by the unique situation on the first trial in the small set size condition. That is, on the first trial in the small set size condition in contrast to the first trial in the large set size condition, a direct perceptual apprehension of the numerosity of the rows could determine the quantitative judgment prior to empirical verification. On the three other trials, the experience of already having obtained cardinal values for the arrays provided children in both set size conditions with comparable quantity information which could have served as a basis for judging numerical equivalence or nonequivalence. On each of the last three trials involving a surreptitious addition or subtraction, children received a score of 1 if they acknowledged inequality between the arrays prior to counting and a score of 0 if they acknowledged equality between the arrays prior to counting. Since there were three trials, each child received three scores.

Results and Discussion

The presentation of the results consists of three analyses. The first analysis compared the total scores of the subject groups across the set size conditions. The second analysis compared the groups on the first trial in which their counting contradicted their belief in conservation for both the small and large set size conditions. The third analysis was a supplementary one in the sense that it was not directly related to the study's primary goal and that it suggested itself during the data collection. This analysis compared children receiving small set size problems with those receiving large set size problems in terms of their quantitative judgment following the transformation but prior to counting.

The means and standard deviations of subject scores in the two set size conditions are presented in Table 5. Planned comparisons were conducted to determine the effects of developmental level and set size on conservers' reactions to counting information that violates their expectancies. Of the four contrasts, only one was significant. Level 1 conservers recognized and/or explained the apparent nonconservation to a greater extent on small set sizes than on large set sizes ($F[1,56] = 4.12$, $p < .05$). A second contrast that did not reach significance was, however, consistent with expectations. Specifically, Level 2 conservers did not differ in their performance across set size conditions. Thus, only the hypotheses relating to set size received support.[1]

It is plausible that repeated trials in which children's counting violated their expectancies about conservation may have actually decreased the incidence of their spontaneous recognition and/or explanation of the apparent nonconservation. Consequently, an analysis of children's

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[1]An analysis using age as the operational definition for developmental level also revealed no significant differences due to developmental level in conservers' reactions to contradictory counting information. The analysis based on age also replicated the present findings with respect to set size.

Table 5

Means and Standard Deviations of Reaction-to-Contradiction Scores across Conditions

Conserver group	Set size			
	Small		Large	
	$\bar{X}$	SD	$\bar{X}$	SD
Level 1	5.46	2.87	3.17	2.62
Level 2	6.00	2.83	4.28	2.93

performance using only the first trial was conducted. Table 6 contains the mean scores on the first trial for the two groups at each level of set size. Statistical analyses (*t* tests) revealed that there were no significant differences in conservers' performance as a function of their developmental level or the set size used. This result is consistent with all but one of the findings based on all four trials, namely, that Level 1 conservers differed significantly in their performance across the two set sizes. This result suggests that the presence of repeated trials did not greatly change the way in which conservers reacted to counting information that violated their belief in conservation.

In order to provide a more detailed picture of the nature of children's performance over the repeated trials, the frequency of each of the reaction-to-contradiction scores for each of the four trials was tallied. The results of this tabulation are presented in Table 7. Inspection of the table reveals that, with one exception, Level 1 and Level 2 conservers reacted essentially the same way on each of the successive trials. Specifically, most of the children in each group were able to recognize and/or explain the evidence of apparent nonconservation when they were questioned. The one exception occurred on the second trial for Level 2 conservers in the small set size condition. On this trial, almost half of the children spontaneously recognized and/or provided an explanation for the apparent nonconservation.

Although the present study was designed to investigate the effect set size has on the way conservers treat contradictory empirical information gained through counting, there was another way in which the number of items influenced children's behavior. Whether children continued to judge

Table 6

Mean Scores on Trial 1 for

Two Groups of Conservers

Conserver group	Set size	
	Small	Large
Level 1	1.54	0.83
Level 2	1.18	1.10

Table 7

Frequency Distribution of Reaction-to-Contradiction

Scores as a Function of Trial and Conserver Group

Conserver group	Trial 1				Trial 2				Trial 3				Trial 4			
	3	2	1	0	3	2	1	0	3	2	1	0	3	2	1	0
Level 1																
Small	4	1	6	2	1	2	8	2	3	2	7	1	1	2	9	1
Large	1	0	7	4	2	0	5	5	0	0	7	5	0	2	6	4
Level 2																
Small	2	1	12	2	8	1	7	1	4	0	12	1	5	0	11	1
Large	1	5	7	5	0	6	6	6	1	4	8	5	1	4	9	4

Note. A score of 3 indicated spontaneous recognition and/or explanation of the apparent nonconservation; a score of 2 indicated elicited recognition and elicited explanation of the apparent nonconservation; a score of 1 indicated either elicited recognition or elicited explanation; a score of 0 indicated that neither recognition nor explanation was elicited.

previously numerically equal rows as still equal following the spatial transformation but prior to being asked to count appeared to be a function of the number of objects used. In other words, children receiving small and large set size problems frequently differed in their judgments as to whether the two rows were numerically equal prior to the time at which the effects of set size were hypothesized to play a role. To determine if these differences were significant, children's quantitative judgments following the transformation but prior to counting were compared. Table 8 contains the number of children within each set size condition who produced equality or inequality judgments on each of the last three trials. As discussed earlier, the first trial was excluded in order that children in both set size conditions would have had the experience of a trial in which they obtained cardinal values, values which could play a role in their quantitative predictions prior to counting on later trials. Chi-square analyses revealed that on each trial children in the small set size condition more often judged the sets to be unequal following the transformation than children in the large set size condition (Trial 2, $\chi^2[1] = 13.44$, $p < .001$; Trial 3, $\chi^2[1] = 29.93$, $p < .001$; Trial 4, $\chi^2[1] = 13.20$, $p < .001$). A Yates correction (Siegel, 1956, p. 110) was used in computing all χ^2 values as n was greater than 40.

In sum, the results of this study did not provide support for the hypothesis that the way conservers react to empirical evidence that contradicts their belief in conservation is a function of their developmental level. That is, more and less advanced conservers did not differ in the extent to which they recognized and/or explained the evidence of nonconservation, within their respective set size condition. In contrast, the

Table 8

Number of Children Producing Each Type of Quantitative Prediction Prior to Counting

Set size	Trial number and quantitative prediction					
	Trial 2		Trial 3		Trial 4	
	Eq	Ineq	Eq	Ineq	Eq	Ineq
Small	10	20	6	24	6	24
Large	25	5	28	2	21	9

Note. Eq = equality; Ineq = inequality.

hypotheses pertaining to set size were supported. Specifically, less advanced conservers were more able to recognize and/or explain the apparent nonconservation on small than on large set size problems. Also, more advanced conservers did not perform differently as a function of set size. Further discussion of these data will take place in the General Discussion (Chapter IV).

Chapter IV
GENERAL DISCUSSION

Two general hypotheses were considered in the present research. The first hypothesis was that the way in which children handle the conflict between information produced through counting and their belief in number conservation is a function of their developmental level with respect to their understanding of conservation. The second hypothesis was that the way that children reconcile contradictory counting information with their understanding of conservation is dependent on the set size used in the conservation problem. In order to provide data relevant to these hypotheses, two studies were conducted. In Study 1, two groups of nonconservers received small or large number conservation problems in which the results of counting indicated conservation. In Study 2, two groups of conservers were administered small or large number conservation problems in which the results of counting indicated nonconservation.

The discussion of the results comprises two sections. In the first section, the significance of the data for models of counting/number conservation relations is considered. In the second section, the implications of the present findings for the general issue of the role empirical information plays in cognitive development are presented.

Implications for Number Development Research

Together the results of the two studies offer some support for the hypotheses that the way children reconcile contradictory empirical information gained through counting with their belief in number conservation is a function of their developmental level and the set size used in the conservation problem. The findings focusing on developmental level will be discussed first. The results of Study 1 revealed that two groups of nonconservers varying in their number knowledge did treat information gained through counting differently when called upon to solve conservation problems. As predicted, developmentally advanced nonconservers, those who could determine numerical equivalence between sets by establishing one-to-one correspondence, changed from judgments of nonconservation to judgments of conservation following counting (on large sets) to a significantly greater extent than nonconservers who could not form one-to-one correspondence. There was additional evidence that the way nonconservers reconcile counting information that violates their belief in nonconservation is dependent upon their developmental level with respect to number knowledge. First, Level 2 nonconservers benefited from the repeated trials involving counting, whereas Level 1 nonconservers did not. This was revealed by a shift to more anticipatory conservation judgments on the last trial in contrast to the first trial for the developmentally advanced nonconservers but not for the less advanced conservers. Second, Level 2 nonconservers produced more mature patterns of conservation judgments across trials than Level 1 nonconservers. More mature patterns were those in which children's conservation judgments followed a developmental progression, that is, once children changed to conservation following counting on a particular trial or anticipated conservation following earlier trials involving counting, they did not revert to nonconservation judgments on any later trial.

These results replicate the findings of Saxe and Cohen (Note 1) and Fuson and her colleagues (in press) by demonstrating that many nonconservers changed to judgments of conservation following counting. The present data are also consistent with those reported by Bearison (1969) in which nonconservers of continuous quantities ranging in age from 5 years 5 months to 6 years 2 months made progress toward conservation after a training procedure involving counting of discrete units of liquid quantity. In the present research it was those nonconservers who could use one-to-one correspondence to determine numerical equivalence (Stage 2 children in Piaget's sytem) who were able to make use of counting information. In the studies of Saxe, Fuson, and Bearison, it was the older nonconservers who benefited from counting. On the basis of the present data, it is likely that the nonconservers in the above studies understood the numerical significance of static one-to-one correspondence.

The results of Study 1 have important implications for theories of the role of counting in the development of number conservation. As counting-based models claim, children were able to use information gained from counting to form number conservation concepts. However, the finding that only some children were able to benefit from counting was not consistent with counting-based models. On the other hand, the finding that less advanced nonconservers were not able to use counting information to inform their conservation judgments is consistent with non-counting-based models. Thus, the present results are not adequately explained by either of these models.

A formulation offered by Saxe (1979a) appears to better account for the present results. According to Saxe, in order for children to use their counting as a means to determine whether number is conserved, they must begin to question whether spatial transformations of a collection affect its number and be willing to verify it. The child's ability to understand the numerical significance of static one-to-one correspondence may be an index of this development, and therefore, we observe Level 2 nonconservers benefiting from their counting to a greater extent than Level 1 nonconservers. Thus, in Saxe's model, the child's developmental level with respect to understanding of conservation determines the extent to which counting information can be used to form conservation concepts.

The model proposed by Fuson and her co-workers (in press) also holds that empirical strategies, such as counting, are used by many nonconservers to establish numerical equivalence between arrays. This model further maintains that the use of empirical strategies to solve conservation problems precedes a mature understanding of conservation as manifested by the production of Piagetian justifications. Fuson hypothesized that in the course of development there is a shift from the use of empirical strategies to the use of Piagetian justifications and that this transition includes a period where the two coexist. The data from Study 2 provided support for Fuson's position by revealing that some children used both empirical counting and Piagetian justifications as explanations for conservation. Siegler (1981) also found that children initially solve number conservation problems by using empirical strategies. As discussed earlier, Piaget (e.g., Inhelder & Piaget, 1963) acknowledged that empirical solutions to the conservation problem precede a true understanding of conservation based on immediate deduction.

A third model in which counting plays a less direct or critical role in the development of number conservation has recently been offered by Gelman (1982). According to Gelman, the experience of counting arrays in one-to-one correspondence allows young children to access an available, although implicit, ability to use one-to-one correspondence to determine numerical equivalence and thereby succeed on number conservation tasks. Following Gelman's model, both groups of nonconservers in the present research should have benefited from their counting on both small and large set size problems. The results, however, do not support her model. Only Level 2 nonconservers changed to judgments of conservation following counting on large set sizes, and there were a number of Level 1 and Level 2 nonconservers who did not change to conservation following counting on small set sizes. Studies by Fuson et al. (in press) and Saxe and Cohen (Note 1) also report findings inconsistent with Gelman's view. They found some nonconservers who were not induced to give conservation judgments following counting. Moreover, there are conceptual ambiguities with Gelman's (1982) argument. For example, Gelman does not explain how counting small arrays in one-to-one correspondence makes explicit the child's implicit understanding of one-to-one correspondence nor why the child does not have access to this knowledge in the first place. Although operating within a nativist framework, Gelman's view that young children's implicit understanding of one-to-one correspondence is not available to them "under most circumstances" (Gelman, 1982, p. 209) raises questions about the degree to which her position is actually a nativist one. To the extent that innate abilities are dependent upon certain conditions (e.g., counting experience) to reveal themselves one could question whether they are in fact innate. It would seem that Gelman's (1982) findings could just as well be explained by Saxe's (1979a) model. Counting information was more helpful to older nonconservers and in fact helped at all precisely because these children had reached the stage in their number development where they understood the numerical significance of static one-to-one correspondence relations and were beginning to question whether transformations of an array affect its number.

Although the finding that some Level 1 nonconservers changed to conservation following counting on small sets was not anticipated, it can be accounted for by Saxe's model. It is plausible that although Level 1 nonconservers could not use one-to-one correspondence to determine numerical equivalence with 8 items (as the assessment trials measured), they may have been able to do so if only 4 items had been used. If this was the case, then those Level 1 children who changed to conservation after counting small sets may have actually been Level 2 nonconservers with respect to small sets and therefore able to use their counting to inform their developing understanding that spatial transformations of an array do not alter its number. Previous studies examining children's ability to use one-to-one correspondence to determine numerical equivalence were limited to large set sizes (e.g., Russac, 1978; Saxe, 1979a), and thus we do not know whether young children understand the numerical significance of static one-to-one correspondence when small sets are used.

The results of Study 2 did not support the hypothesis that the way conservers react to counting information that contradicts their belief in conservation is a function of their developmental level. The percentage of Level 1 conservers who were able to provide an adequate explanation for the apparent nonconservation on three of the four trials was 92% for small set sizes and 58% for large set sizes. The comparable percentages of Level 2 conservers were 94% for small set sizes and 61% for large set sizes. These findings indicate that conservers who gave empirically based explanations for their conservation judgments did not differ in the way they treated contradictory empirical information from conservers who gave more logically based explanations. This result implies that the nature of conservers' justifications is not a sufficient basis for them to perform differently on a task in which their understanding of the concept is involved. Some support for this view that differences among conservers that one would expect to influence performance on a related task may not in fact have the anticipated effect comes from studies comparing natural and trained conservers on measures of extinction. As Miller (1976) pointed out, in only two of eight studies (Amaiwa, 1973; Smedslund, 1961) did natural conservers demonstrate greater resistance to extinction that trained conservers. In a study of children's reactions to violations of their expectancies concerning conservation of weight, Miller (1973) found that older conservers were no more likely to provide explanations for the nonconservation outcome than the younger conservers.

On the other hand, there are methodological reasons that may explain the failure in Study 2 to find significant differences due to developmental level within set size conditions. First, the criterion used to define the two levels of conservers may have been poor. It seemed plausible to consider explanations for conservation that referred to number, to act of counting, or to an action just performed (e.g., "You just moved them.") as reflecting a concrete, more empirically based understanding of conservation. In contrast, explanations referring to the fact that one could rearrange the items to reestablish the equality, to the fact that nothing had been added or taken way, or to the fact that the rows were (numerically) equal initially seemed to reflect a more logical appreciation of conservation. It may be, however, that this categorization of justifications does not reflect any genuine differences in the children's understanding of the concept. In fact, the frequently offered explanation, "You just moved them," may actually have implied the additional idea, "You did nothing else; you didn't add one or take one away." If this notion was implied, then children who offered this explanation would have been considered as having a logically based rather than empirically based understanding of the concept.

Another possible reason for the lack of an effect for developmental level within set sizes relates to the fact that there were four conflict trials. After one or two trials involving a surreptitious addition or subtraction, children were probably not surprised by another occurrence of nonconservation and the likelihood of their producing spontaneous verbalizations of recognition or explanation for the same outcome no doubt lessened across trials. As a consequence, most children did not earn high scores. That many children were able to provide an adequate explanation for the unexpected result when questioned revealed that they did understand how the apparent nonconservation could have occured although they did not offer the explanation spontaneously. A rereading of the extinction studies (following the data collection) revealed that children's elicited explanations rather than spontaneous explanations usually constituted the evidence from which resistance or extinction was inferred.

The results focusing on set size will now be discussed. The results of both studies suggest that the way some children treat contradictory empirical information (primarily gained from counting rather than from matching or subitizing) in the context of solving conservation or conservation-like problems is influenced by the number of items used. In Study 1, less advanced nonconservers were able to use counting information to inform their conservation judgments on small set size problems to a greater degree than on large set size problems. This finding is consistent with the previously reviewed research documenting young children's success on small number conservation problems (Cowan, 1979; Gelman, 1972a; Gelman & Gallistel, 1978; Lawson et al., 1974; Siegler, 1981; Winer, 1974; Young & McPherson, 1976; Zimiles, 1966). Similarly, in Study 2, less advanced conservers were able to recognize and/or explain the apparent nonconservation to a greater extent on small set sizes than on large set sizes. In contrast, the performance of both the developmentally advanced nonconservers and conservers was not influenced by the number of items used. In the first study, the finding that more advanced nonconservers did not benefit from their counting on small sets was not anticipated, and it is not apparent why it occurred. In the second study, on the other hand, the finding that the performance of the more advanced conservers did not differ as a function of set size was consistent with expectations. That is, children who understand conservation as logically necessary were expected to handle contradictory counting information on large set size problems as well as on small set size problems. The present findings imply that number problems involving small and large set sizes present different task demands for children at different stages in their number development.

Children at early stages in their understanding of certain numerical concepts may need problems involving small numbers of items which they can count in order to succeed. In contrast, children whose understanding no longer needs empirical support are not affected by the number of items used.

Considering Study 2 from the point of view of an extinction study, the data indicating that more than 90% of conservers were able to provide an explanation for the apparent nonconservation on small set sizes are consistent with those found in previous extinction of number studies (e.g., Amaiwa, 1973; Strauss & Liberman, 1974). Strauss and Liberman also used small set size conservation problems but, in contrast to the present study, resistance was inferred from children's conservation performance on a delayed posttest rather than from their verbalizations in the face of evidence of nonconservation.

Implications for the Role of Experience in Cognitive Development

The question of the role of external factors or data in children's acquisition of knowledge is one of fundamental concern to researchers in cognitive development. Psychological theories having their roots in an empiricist theory of knowledge maintain that all concepts are derived from the senses. According to this view, we are "given" items of information in experience and we "abstract" concepts from what is given in the environment. The given in experience is the particular, the concrete, and the atheoretical (Weimer, 1973). A serious problem with a "theory of abstraction" (see Cassirer, 1953) is that it cannot explain the acquisition of logical concepts such as conservation because such concepts have no concrete representation in sense data. These concepts pertain to relationships between objects and these relationships are constructed by the individual. Facts or factual data are not pure or objective, simply there to be apprehended. Rather they function as material to be considered by the knower and the way in which they are considered is dependent on the knower's prior conceptual framework.

The results of Study 1 provide support for a constructivist theory of knowledge in that how children interpreted or understood empirical facts (empirical counts) rather than the empirical facts themselves was what was crucial. Only those nonconservers who had attained a certain level in the development of their number concepts used the information gained through counting to form conservation concepts. Additional support for this thesis has been produced by other studies in which children were asked to count in conservation-like tasks. For example, Saxe and Cohen (Note 1) reported that older but not younger conservers tended to change their nonconservation judgments to conservation judgments after counting. Fuson et al. (in press) demonstrated that 5-year-old nonconservers were able to use the information gained through counting to solve conservation problems when this strategy was suggested. On the basis of Saxe's (1979a) formulation, we may assume that the children who benefited from counting information had attained a level of understanding in which they could consider the possibility that spatial transformations of an array do not affect its number and were willing to use their counting to check this possibility.

Conclusion

The present research indicates that the way children reconcile contradictory empirical information gained through counting with their understanding of logical concepts of conservation is, to some extent, a function of the child's developmental level and the number of items used in the conservation problem. On the basis of the results of Study 1, early theories of the role of counting in the formation of conservation concepts do not appear adequate. Instead, the findings support the view that counting-based number evaluations can only be used to help children determine if number is conserved if the child's grasp of number has attained a certain level of development. That is, in order for counting to help children come to understand logical concepts of conservation, children may need to have reached the stage where they begin to entertain the notion that spatial transformations of a collection do not affect its number and be willing to verify it. In addition, the finding that less advanced nonconservers changed to conservation judgments following counting on small but not on larger set size problems suggests that children may at first only be able to use their counting-based number evaluations to understand conservation of small quantities. The data showing that less developmentally advanced conservers were more able to recognize and/or explain the apparent nonconservation on small than on larger number problems provides additional evidence that number problems involving small and larger set sizes make different demands on children at particular stages of development.

Future research on the role information gained through counting plays in children's acquisition of number consrvation concepts should include more extensive measures of cognitive change. In addition to countersuggestion, both immediate and delayed posttests should be used as a means to determine whether changes in performance following trials in which counting information is available reflect genuine developmental progress or represent merely a learned response to a particular stimulus situation.

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