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MOBILITY OF INTUITIVE CORRESPONDENCE, INDUCED PERCEPTUAL ACTIVITY, AND EYE MOVEMENT CRITERIA IN ACQUISITION OF CONSERVATION OF NUMBER

by

© MARY HELEN RICHARDSON

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled MOBILITY OF INTUITIVE CORRESPONDENCE, INDUCED PERCEPTUAL ACTIVITY, AND EYE MOVEMENT CRITERIA IN ACQUISITION OF CONSERVATION OF NUMBER submitted by Mary Helen Richardson in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

The present study examined Piaget's views regarding interaction between existing mental structures and perceptual activity in acquisition of number conservation. A rational was presented for assessing the relative mobility of intuitive correspondence in non-conservers and for attempting to accelerate conservation attainment by inducing coordinating perceptual activity.

Subjects were 94 non-conserving girls aged five and six, who were classified as possessing high or low mobile schemes of intuitive correspondence. The acceleration condition consisted of non-reinforced practice in solution of a series of number conservation tasks in which relevant color cues were progressively diminished. Practice tasks were presented via motion picture film with taped instructions. Post-tests and tests for generalization were administered immediately following treatment and after a two week interval. Criteria were verbal responses which were classified as logical, intuitive or non-conserving. To determine the validity of eye movements as subsidiary criteria of conservation status, visual activity was filmed during solution of delayed generalization tasks for a subsample of grade I girls.

Ordinal interaction between mobility of intuitive correspondence and practice was observed in immediate and delayed post-tests and in five out of seven tests for generalization. Fifty-five percent of girls in the high mobile practice group gave logical responses in all tests. Evidence of permanent change in conservation status was negligible among low mobile practice subjects and among subjects in control groups. Within the eye movement subsample, girls who gave intuitive responses showed the greatest degree of perceptual activity while those who gave non-conserving responses tended to center their fixations on the transformed set. Differences in eye movement patterns were consistent with theoretical assumptions concerning transitional processes in number conservation attainment.

It was concluded that coordinating perceptual activity facilitates attainment of logical conservation of number provided that intuitive correspondence is sufficiently mobile to permit the child to compensate for misleading perceptual cues. In conjunction with verbal responses, eye movement patterns were judged to be useful indices of conservation status. Findings were discussed in relation to operations underlying number conservation and implications for theory, research and education were proposed.

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CHAPTER I

THE PROBLEM

The Concept of Number Conservation and Its Significance in Cognitive Development

As Elkind (1969) notes, concepts may be regarded as belonging to one of two categories; those which define relations between phenomena, and those which concern variations within phenomena. Concepts of the former variety function in the interest of cognitive economy by providing means for classifying information. Concepts of the latter kind assist the individual to distinguish between the real and the apparent by providing rules of invariance which compensate for changes in the appearance of objects or collections.

Certain higher order concepts subsume relations of both kinds. For example, the concept of numerical equivalence defines a particular type of classification based on one to one correspondence and also specifies the conditions under which this relationship is preserved despite changes in the qualitative attributes of sets or of the objects comprising those sets. Conservation of number refers to conceptualization of the invariance of numerical equivalence over spatio-temporal displacements described as transformations.

The child who conserves number logically concludes that two sets, initially judged to contain the same number of objects, remain numerically equal following a transformation which alters the configuration of objects in one set. To the non-conserver change in configuration implies change in quantity. For instance, having verified the numerical equivalence of sets arranged as shown in Figure 1, the non-conserver denies

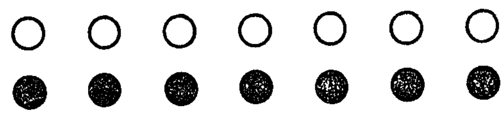

Fig. 1. Numerically equivalent sets before transformation

their equivalence after observing a transformation which results in extension of spatial intervals between objects in one set (see Figure 2). Typically, the transformed row is judged

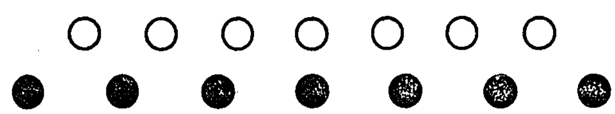

Fig. 2. Numerically equivalent sets following transformation

to contain more objects because it is longer. Increase in length is not compensated by decrease in density because these dimensions remain uncoordinated (Piaget, 1952).

To representatives of the Genevan school, the significance of number, length, distance, substance, area, weight and volume conservation lies in the assumption that in each case conservation implies existence of an internal system of reversible, regulatory actions or operational schemes which allow the child to compensate in advance for dimensional changes which are perceptually misleading.

According to Piaget (1962, 1968a, 1969b), the pre-operational thought of children between the approximate ages of two and seven has a number of characteristics which distinguish it from the sensory-motor adaptations of the first two years of life and from the concrete operational thought of children of approximately seven to twelve. At the pre-operational stage, the child is able to represent reality instead of merely acting upon it; however, representation is characterized by a predominance of static, figural content. As a consequence, thought is irreversible as observed in the fact that the child is unable to integrate information from temporally separate events or to anticipate changes of state. Moreover, because pre-operational thought tends to centre attention upon a single aspect of a given situation to the neglect of other aspects, judgments are subject to perceptual bias.

The sub-period between five and seven years is a period of transition during which children become increasingly capable of representing actions performed on objects. Operations developed at this intuitive stage tend to be semi-reversible and uncoordinated with the result that judgments may not be consistent or logically coherent.

Piaget describes concrete operations as interiorized reversible actions, potentially capable of being performed on material objects and linked with other operations to form integrated structures applicable to a variety of analogous situations. Rules of invariance and systems of classification are regarded as operational structures in this sense.

The Origin of Operations

In summarizing the Genevan position with respect to development of operations, a crucial distinction must be made between Piaget's views and those of developmental realists. As a leading proponent of the latter theory Zaporozhets (1969) asserts that,

> "...the development of mental processes begins with certain external operations performed with objects. Subsequently, given certain conditions, this process acquires an orienting, cognitive function which, once it has undergone a series of changes and becomes contracted, is ultimately converted into an internal operation. Initially, the child needs some external, material prop to help him discriminate which eventually becomes an internalized model." (p. 115)

> "On the basis of experimental facts one can demonstrate that, given a distinct scheme of training in which the child systematically learns certain methods of orientation, he begins to gather and develop types of modelling experience which at a later date will enable him to reproduce certain latent relationships within objects. It is in this way that operations of a strictly intellectual, conceptual nature take place." (p. 117)

Zaporozhets' position closely resembles one attributed to Piaget by Hunt (1961), yet fundamental differences are apparent. Piaget agrees that the transition from intuitive to operational thought comes about gradually as a consequence of the child's activities in interaction with environmental events. In general, he contends that all behavior involves an interplay of assimilation and accommodation, past and present tending toward equilibrium; that is, of assimilation of reality to existing structures and, conjointly, of accommodation of those structures to reality. Piaget thus rejects a "copy" theory of cognitive development in favor of an adaptation model which emphasizes the active role of mental structures in transforming perceptual input. Accordingly, for Piaget, the effect of what Zaporozhets terms orienting or modelling activity is always dependent on the status of schemes in which such activity is incorporated. This distinction appears to carry important implications for the design of experiments aimed at evaluation of training procedures of the type referred to by Zaporozhets.

The Role of Imagery and Its Relationship to Perceptual Activity

In addition to the operative aspect of cognition, Piaget refers to a figurative aspect which includes perception, imitation and mental imagery (Piaget, 1967, 1969b; Furth, 1969). Discussing the development of representation, Piaget (1962) maintains that perceptual activity involving regulations and comparisons is a type of imitation or accommodation which functions to prolong motor adaptation thus giving rise to images. Moreover, just as the products of perceptual activity are always integrated in existing structures which give meaning to the elements and relations analyzed, so images assume the function of signifiers with respect to those relations. In this way images constitute a link between primary perception and verbal communication. The child's verbal judgments reflect the status of his mental schemes via representational imagery re-symbolized in language (Piaget and Inhelder, 1971).

Unlike Bruner (1964) who believes that it is language which structures experience, Piaget (1969b) ascribes to language a role superior to imagery by virtue of its reduced dependence on figural content, but classed together with imagery as a semiotic function, that is, a function which makes thought possible by allowing representative evocation of objects and events not available to immediate perception. In addition, language functions to direct attention. However, as in the case of imagery, language is not thought to be a source of operations but is rather a symbolic system structured by them.

Of central relevance to the present investigation is Piaget's (1969b) view that perceptual activity contributes to the formation of kinetic images. Prior to the onset of mental operations, children demonstrate the capacity to represent the terminal states of transformations but are unable to imagine the processes leading to those states (Piaget and Inhelder, 1971). Once the child is able to represent the successive events which occurred in the course of a transformation, his capacity for anticipating subsequent transformations is enhanced. Furthermore, ability to anticipate assists the child to compensate in advance for misleading perceptual cues and to integrate events which are separated in time. If images are structured by the schemes which support them as Piaget argues, then perceptual activity could be expected to contribute to conservation attainment subject to the limitations imposed by the child's existing mental structures. Conversely, if representational capacities serve to structure mental operations as Bruner and Zaporozhets contend, then for Bruner perceptual activity without accompanying verbal learning would contribute little to change in conservation status, while for Zaporozhets it might play the major role in conservation attainment.

Development of Numerical Equivalence

Piaget (1962) outlines three stages in the development of the equivalence scheme.

The first stage, described as the stage of intuitive global correspondence, is characterized by the child's tendency to base judgments of numerical equality on the configurational attributes of sets to be compared. When required to construct a row of objects parallel and equal in number to a given row, the child produces a row of equal length but disregards numerical properties with the result that one row may contain more or less objects than the other.

During the second stage termed the stage of intuitive one-to-one correspondence, numerical equivalence implies perceived correspondence between analogous parts of a whole. The child is able to construct equivalent sets by a strategy of object-for-object matching; however, although the child subsequently verifies a constructed equivalence in situations where configurational properties of sets are identical, any discrepancy in configuration may result in subsequent denial of equality. For example, the child may correctly match object for object in constructing concentric, numerically equal sets of the type shown in Figure 3. Having completed

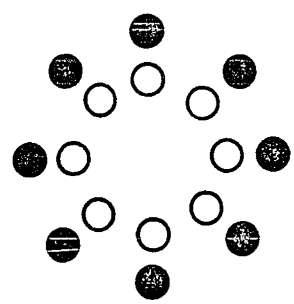

Fig. 3. Numerically equivalent sets arranged in concentric circles

the task, he may deny that these sets contain the same number of objects, presumably because operations are not sufficiently advanced to compensate for perceived differences in circumference. Nonetheless, Piaget describes schemes of the second stage as semi-operational because one-to-one correspondence must be represented before it can be constructed. Clearly, what is missing at this stage are operations permitting coordination of circumference and density.

True quantitative equivalence is recognized at the third stage when correspondence becomes independent of the configuration of sets and the position of their respective elements. At this stage, equivalence is conserved over space and time. Interiorized actions constitute a fully operational structure involving constancy of a set and it is this structure which permits generalization of qualitative correspondence into numerical correspondence in which each element, irrespective of its qualities, is conceived as a unit equal to others and differing from them only by virtue of its temporary position in a series. Conservation is thus implicit in the superordinate operational system of classification and seriation which, according to Piaget, underlies conceptualization of cardinal and ordinal number.

To summarize, development of equivalence, as described in the context of Piagetian theory, appears to reflect increasing mobility of the equivalence scheme. The term mobility is used here in its generic sense to indicate a scheme's range of application (Furth, 1969, p. 62). In the initial stage of global comparison equivalence is exclusively defined by configuration. Although some progress toward quantification is evident in the construction of one-to-one correspondence observed at stage II, mobility is limited since identical configuration remains a qualifying condition. Full mobility is attained at stage III when equivalence is conserved over spatio-temporal displacements which alter both configuration and one-to-one juxtaposition of elements.

The present investigation focuses on conditions of transition from stage II to stage III. Accordingly, it was necessary at the outset to confirm what logically follows from Piaget's (1952) description of sequence; namely, that there is an intermediate stage, prior to conservation attainment, when equivalence is applied in situations where configurations differ but elements remain juxtaposed.[1] This intermediate stage is classed as intuitive since physical correspondence of analogous elements is retained. For present purposes, stage II intuitive correspondence has been sub-divided according to relative mobility of the equivalence scheme. Stage II intuitive correspondence is described as low mobile when limited to situations where sets are identical in configuration, and high mobile when equivalence is recognized in situations where configurations differ. The distinction is pertinent because of the greater degree of operativity presumed to characterize high mobile schemes.

Acceleration of Conservation Attainment

Conservation of number is normally attained, independent of specific pedagogical experience, at approximately seven years of age.

Experimental intervention is a useful method for investigating conditions of conservation attainment. Despite Piaget's

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[1] See Appendix A: Pilot Studies (p. 188).

(1964a) belief that mental structures develop by a process of internal regulation which is minimally affected by experiences designed to direct attention, to exercise memory, or to supply verbal principles, he does concede that:

> "...learning is possible if you base the more complex structure on simpler structures, that is, when there is a natural relationship and development of structures and not simply an external reinforcement." (p. 17)

As for the role of stimulus variables, Piaget (1967) states:

> "An operational system derives its content from a series of abstractions of the subject's actions and not from particular features or properties of objects. But this process of abstraction may be encouraged or obstructed by the material conditions in which various groups of objects are encountered." (p. 84)

In discussing such material conditions, Wohlwill (1966) proposes that stimulus properties may be varied along three dimensions; namely redundancy referring to amount of task-relevant perceptual information; selectivity referring to amount of task-irrelevant perceptual information; and contiguity referring to amount of spatial and temporal separation of informational units. Wohlwill regards the relationship of these variables to concept attainment as two-fold. First, in designing experiences intended to facilitate elaboration of mental structures, the extent to which information can be assimilated by existing structures may depend on the form in which such information is presented. In addition, stimulus properties may influence the extent to which structures tend to be modified by accommodatory activities. The experimental condition employed in this study was planned to incorporate systematic variations in stimulus redundency. Dimensions of selectivity and contiguity were incorporated in design of certain transfer tasks.

Assessment of Conservation

Among issues related to conservation few have engendered more controversy than the problem of assessing conservation status and, in particular, the question of criteria signifying conservation attainment. The problem is not strictly methodological for it is obvious that the criteria selected reflect assumptions about the nature of conservation and its origin.

Braine (1959) supports the use of non-verbal instrumental response criteria as does Zimiles (1963) who contends that conservation training methods can result in establishment of verbal response sets which do not reflect conceptual attainment. Bruner (1964) and his associates accept verbal statements of equality or inequality unaccompanied by explanation, while Inhelder, Bovet, Sinclair and Smock (1966) argue that because the structures underlying conservation are complex, unjustified responses are inadequate indices of conservation status. Smedslund (1961a) requires justifying statements and distinguishes logical conservers from intuitive conservers according to whether justifications are deductive, or empirical in content.

Piaget's (1952) practice of using counter-suggestion to determine the stability of conserving responses has been attacked by Kohnstamm (1967) on the grounds that suggestions emanating from persons in authority may induce anxiety resulting in temporary regression to some earlier form of mental organization. Accordingly, he believes that resistance to counter-suggestion may indeed signify the presence of operational structures but that acquiescence defies interpretation.

With reference to acceptance of justifying statements Kohnstamm observes that such statements are of doubtful validity when they duplicate explanations used by the experimenter in training children to conserve. To Kohnstamm, generalization within the range of the conceptual scheme concerned is an acceptable supplementary criterion. While convincing, generalization to allied schemes, for example from number to area or weight conservation, is not regarded as essential since the latter may involve concepts additional to those under study. Together with logical justification and generalization, Piaget (1964a) insists on retention and mentions two weeks as a minimal interval between testing sessions.

Assessment of number conservation poses a problem which does not arise with respect to other forms of conservation. In the case of number, a subject may determine whether sets are equivalent by counting, thus a primary conserving response provides no indication that invariance has been conceptualized. Smedslund's (1961a) method of differentiating logical and intuitive conservers by analysis of the content of justifying statements seems an appropriate solution. However, more confidence can be placed in the validity of verbal justifications if some more objective criterion is found to correlate with verbal statements. In this regard a study by O'Bryan and Boersma (1971) in which it was shown that eye movements filmed during solution of length, area and substance conservation problems were predictably related to verbal judgments, suggested the desirability of exploring the relation of eye movement patterns to number conservation judgments. Because counting is a strategy based on perceptual evidence and because, by definition, conservation implies decreased dependence on perception, eye movements which are reportedly less subject to conscious influence than verbal reports (Thomas, 1963) were analyzed to determine their potential as supplementary criteria of number conservation status.

Summary and Statement of the Problem

To summarize the theoretical positions reviewed, both Piaget and Wohlwill suggest conditions requisite for acquisition of conservation of number. By implication Piaget postulates the importance of adequate mobility of intuitive schemes of one-to-one correspondence. He further proposes that coordinating visual activity facilitates anticipatory representation of transformations thus providing a basis for compensatory regulations in the presence of misleading perceptual cues as well as a means for integrating information derived from events separated in time. To this set of conditions may be added Wohlwill's contention that qualitative stimulus properties may be systematically manipulated to promote assimilation of the products of perception. Finally, various authors stress the importance of comprehensive, objective criteria in assessing conservation status.

The present investigation was designed to answer three related questions. First, does practice involving coordinating visual activity induced through a combination of verbal questioning and manipulation of task-relevant perceptual cues differentially affect the number conservation status of non-conservers who exhibit high mobility of intuitive correspondence as opposed to non-conservers whose schemes of correspondence are low mobile? Second, assuming that advance in conservation status implies permanent modification of intellectual structures, can such change be demonstrated across multiple criteria; namely, logical verbal justification, retention over time, and generalization to situations involving novel materials, novel transformations, increased irrelevance of perceptual cues, and addition and subtraction of elements? Third, do eye movement patterns recorded during solution of novel conservation tasks differentiate subjects whose verbal justifications are classed as logical, intuitive or non-conserving, and if so, are there differences in the eye movement patterns of conservers exposed to practice and those of conservers not so exposed?

Educational Relevance

Piaget has been reluctant to propose specific applications of his theory to problems of educational methodology and curriculum construction (Hooper, 1968). Nonetheless, while direct extrapolations may be unwarranted at the present stage of research, certain general issues seem particularly pertinent to educational practice.

In Western society, the stage of transition from pre-operational to operational thought coincides with commencement of formal public education for a majority of children. As Genevan studies have clearly shown, this period is marked by comprehensive re-organization of intellectual structures, a re-organization which, potentially, may be facilitated or impeded by experiences to which the child is exposed in school.

The development of what educators normally refer to as pre-number concepts is an acknowledged area of interest that has yielded a substantial body of methodological, curricular and psychological research (Brace and Nelson, 1965). In selecting the problem of number conservation, it was not the author's purpose to determine whether conservation could be taught, to propose ways in which it might be taught, or to supply evidence suggesting that it should or should not be taught. Rather, it is hoped that this investigation will contribute to the aforementioned body of educational research in two ways; first by supplementing previous analyses of sequence in the overall development of the concept of equivalence, and second by identifying factors which affect development of that concept. Though not regarded as directly applicable to the teaching of basic mathematical concepts, film methods and stimulus sequences developed by the author to promote discovery of relationships might conceivably be adapted for classroom use.

CHAPTER II

REVIEW OF RELATED LITERATURE

Analyses of Development of Number Concepts

Certain comprehensive analyses of the development of number concepts include findings relevant to the present investigation which focuses on conservation of numerical equivalence.

Dodwell (1960) and Hood (1962) provide data tending to verify the general sequence of stages in number development proposed by Piaget (1952). Similarly, Wohlwill's (1960) scalegram analysis reveals an initial pre-conceptual stage in which number is responded to solely in perceptual terms, a second stage in which mediating structures commence to reduce dependence on perception, and a final stage in which superordinate structures subsume conservation and coordination of cardinal and ordinal number. Wohlwill reports that ability to count contributes to transition from stage I to stage II, but concludes that the essential factor in abstraction of number appears to be conceptualization of relations.

As part of a more comprehensive study Hood (1962) investigated the possibility that difficulty in conceptualizing relations could be attributed to linguistic deficit. Nonconservers were coached in the use of terms such as "more", "less" and "same" which are commonly employed in presentation of conservation tasks. When tested immediately after coaching, correct conservation responses were elicited but subjects rapidly lapsed into non-conservation suggesting that they had been able to repeat what the experimenter told them to say but had developed little understanding of the conservation problem as a result of verbal explanations. Hood concluded:

> "The concept (of relations) becomes active or operational when the mind can pass in attention from one subject to the other and then back to the first. Unless it has this reversible mobility along with a distinct orientation toward quantity it cannot be truly operational and no comparison of quantity can be made."
>
> "Only mobility can bring about the unifying of two percepts into one larger mental unit or elementary structure thus introducing into thought the possibility of making quantitative comparisons." (p. 19)

Dienes (1959) found that among six year olds global visual attributes were more powerful determinants of quantitative concepts than were perceived relations between parts of a whole. More recently, Siegel (1971) reported that ability to discriminate sequentially presented sets containing "more" or "less" objects occurred at the same time as children exhibited one-to-one correspondence but that both preceded discrimination of "more" or "less" in situations where sets were presented simultaneously with misleading configurational cues. Bryant's (1972) experiments contribute to a growing body of evidence that children younger than five can affirm the invariance of transformed sets in the absence of conflicting perceptual cues.

Acceleration Studies

Despite Piaget's insistence that intellectual development depends on gradual and continuous elaboration of structures, a large number of intervention studies have been reported and those dealing with number conservation may be categorized according to their purpose.

The first suggested category includes studies designed to compare the effectiveness of different treatment conditions or to evaluate the effectiveness of a single condition.

Wohlwill and Lowe (1962) compared three methods: reinforced practice in counting collections of objects; non-reinforced practice in differentiating relevant from irrelevant cues, and non-reinforced practice in addition and subtraction. Results for a sample of kindergarten children were not found to favor one method over others and experimental subjects performed no better than controls on a post-test involving verbal judgment. Experimental subjects did exhibit a moderate degree of improvement when the criterion was instrumental motor response, however no difference was observed between training groups.

For subjects ranging in age from six years, five months to seven years, eight months, Wallach and Sprott (1964) compared responses to a group exposed to non-reinforced reversibility training with those of controls. Training consisted of practice in predicting the results of transformations, followed by verification through manual return of objects to their pre-transformed state. Highly significant differences were reported in favor of the reversibility training group. Conservation judgments resisted counter-suggestion and were retained over a two to three week interval. Wallach, Wall and Anderson

(1967) found that for a group of six and seven year olds reversibility training was more effective than addition-subtraction training. Conservation responses tended to persist over time but transfer was negligible. Working with middle class South American kindergarten children, Roll (1970) found that reversibility training resulted in correct conservation judgments but that subjects could not provide logical justifications for their responses.

Gruen (1965) reports that nursery and kindergarten subjects exposed to addition-subtraction plus verbal pre-training performed significantly better on a post-test of number conservation than did subjects exposed to addition-subtraction training only. Beilin (1965) found that verbal rule instruction of a didactic type was superior to three other methods in eliciting conserving responses in a sample of five year old subjects, but again there was little transfer to analogous tasks.

Postulating the children's failure in conservation tasks is a function of inattention to relevant stimulus attributes, Gelman (1969) compared three methods of conservation training. One group was exposed to oddity training involving "same"-"different" discriminations among toys. Each correct response was rewarded with a trinket. A second group underwent learning set training involving "same"-"different" discriminations among abstract materials with multiple attributes. Discriminations were elicited before and after transformations and reward conditions were identical to those employed for the oddity training group. A control group received learning set training without knowledge of results. Sixteen six trial problems were administered on each of two successive days. On an immediate test of number conservation percentages of subjects giving logically justified conservation responses were 96%, 21% and 1.3% for the learning set, control, and oddity training groups respectively. Similar results were obtained after a three week interval. Transfer to conservation of substance was significantly greater for the learning set group than for other groups and transfer improved slightly over three weeks. Gelman concluded that five year olds can work with quantity if told to do so and if rewarded for doing so. She contends that because they already possess these concepts, quantity and invariance do not have to be defined before children of this age can respond to them. Commenting on Gelman's study, Christie and Smothergill (1970) observed that discrimination training may be more useful in the case of a space-distributed stimulus property such as length than for a property such as number which is not spatially distributed. A partial replication of Gelman's study produced changes in conservation responses but no evidence of transfer.

Winer (1968) demonstrated that pre-training in addition and subtraction of elements induced a tendency to respond to such manipulations when they were performed in conjunction with changes in configuration of sets. Pre-trained subjects gave more conserving responses in a number conservation post-test, a result Winer attributes to set to respond to quantitative rather than qualitative changes. He concluded that response set provides an alternative to the "cognitive conflict" rationale advanced by Smedslund (1961a, 1961b) to account for change in conservation status. Following Smedslund's precedent, Winer's subjects were not provided with knowledge of results. The sample consisted of children who had completed a year in kindergarten but had not yet entered grade I.

The attentional hypothesis was further tested by Blum and Adcock (1969) whose training procedures entailed elicitation of counting plus direction of attention to intervals between objects by the use of cardboard "spacers". Two sets of spacers were employed, a shorter set used to construct sets in their pre-transformed state, and a longer set used in construction of linear transformations. Subjects were asked to predict what would happen to the number of objects in the transformed set when longer spacers were used. In the case of incorrect predictions, the experimenter remarked: "But I'm not changing the number, I'm only changing how low the row is." For a sample ranging in age from five years seven months to eight years three months (two-thirds were over seven), nine out of ten trained, and one out of twelve untrained subjects advanced in conservation status and gains persisted over a three week period. Generalization was not tested.

Halford and Fullerton (1970) postulated that for non-conservers, physical correspondence implies numerical equality while potential correspondence does not. A guided discrimination task sequence was devised to facilitate discovery that a set with the same length and spacing as the transformed set could be matched, object for object, with the non-transformed set. Grade I subjects were required to select the appropriate set from a number of alternative arrays and test their predictions by manual matching. Training sessions were conducted on five successive days and no external reinforcement was supplied at any stage. Eight out of twelve experimental subjects attained conservation as compared to one of twelve controls. Responses resisted counter-suggestion and generalization was demonstrated.

Nursery school children participated in a study by Curcio, Robbins and Ela (1971) who found that subjects "conserved" their own fingers well before the age at which children normally conserve objects. The classic conservation testing procedure was followed using the fingers of each hand as sets to be compared. A transformation consisted of spreading or pressing together the fingers of one hand following an initial judgment based on the numerical equivalence of fingers in a partially spread position. Subjects were trained to conserve objects, first coloured rings located on the fingers and then the same rings removed and placed in front of the subject. Training was successful for subjects who had previously demonstrated counting ability, one-to-one correspondence and awareness of the effect of addition and subtraction on equivalence of sets. Generalization was not tested, but retention was satisfactory and finger training proved superior to addition-subtraction and counting as conservation training procedures.

The majority of acceleration studies have been basically bivariate in design. Some have included chronological age as an independent variable but from the standpoint of psychological explication age x treatment interactions are of limited interest.

A study by Peters (1970) was designed to determine the extent of interaction between conservation training, language comprehension and cognitive style. Subjects were lower socio-economic status kindergarten children with a mean age of five years, five months. Cognitive style was assessed by means of an object sorting task and language assessment included tests for comprehension of comparative terms, past and future tenses of common verbs, and negative forms. Three training methods, namely, unguided discovery, perceptual cue guided discovery (Peters and Rubin, 1969) and verbal didactic instruction, were employed each following the usual procedure for reversibility training (Wallach and Sprott, 1964). On post-test conservation measures all training groups performed better than controls, and gains shown by cue guided and verbal instruction groups were greater than those exhibited by the unguided group. Retention and transfer to similar tasks were demonstrated. Cognitive style and language comprehension both proved to be significant predictors of conservation gains. Contrary to Peters' expectation, verbal instruction was more effective for high analytic subjects with low language comprehension whereas perceptually cued training resulted in greater gains for low analytic subjects with high language scores. Peters concluded that subjects who are inclined toward cue discrimination benefit from a verbal statement of the invariance rule and that those who have better command of the verbal requirements of the task are assisted by cue discrimination training. He regards both verbal mediation and cue discrimination as major factors in the transition from non-conservation to conservation.

Studies which fall into a second category are not designed to evaluate or compare discrete methods but rather to identify some optimum combination which takes the form of a comparatively lengthy teaching sequence. Rothenberg and Orost (1969) investigated whether conservation of number could be taught to kindergarten children when hypothesized steps requisite for attainment of this concept were trained to learning criteria. Subjects were exposed to reinforced counting (Wohlwill and Lowe, 1962), reinforced addition-subtraction (Gruen, 1965), reversibility training (Wallach and Sprott, 1964), and verbal pre-training (Gruen, 1965). Finally, older children were used as "assistant teachers" in situations designed to elicit cognitive conflict (Smedslund, 1961a). Significant training effects were reported. Gains were retained over a three month period and transfer to conservation of discontinuous substance was demonstrated.

To summarize, there remains little doubt that acquisition of conservation of number can be accelerated, possibly by a year and a half or more, though longitudinal studies may be required to confirm what could be an artifact of sampling in some of the studies reviewed. Nonetheless, two trends seem evident. Conservation training has been more successful with older as opposed to younger subjects, Gelman's (1968), Rothenberg's and Orost's (1969) and Curcio's, Robbins' and Ela's (1971) studies being exceptions in this regard, and training has been more effective with longer as opposed to shorter training periods. The role of verbal instruction, reinforcement and cognitive conflict remain equivocal. Methods involving direction of attention and empirical discovery seem promising yet available evidence fails to clarify the nature of subject-object interaction responsible for structural change. Specifically, Piaget's own argument that the status of relevant structures is a determinant of learning gains does not appear to have been tested with respect to number conservation.

An acceleration study which does focus on development of prerequisite structures is reported by Sigel, Roeper and Hooper (1966) and is considered relevant despite the fact that it concerned acquisition of conservation of discontinuous quantity rather than number. Over a five week period demonstration plus questioning were used for the purpose of advancing subject's understanding that objects have multiple characteristics; that characteristics may be combined in various ways to produce new categories, and that categories may be re-organized to permit return to some previous form of organization. Using small samples the original study (N = 7) and a replication (N = 10) indicated moderate success in inducing conservation judgments in four year olds. A significant degree of generalization to continuous substance and weight conservation was observed. The authors concluded that conservation *per se* need not be taught directly since children who possess the prerequisite concepts may discover a conservation principle which may subsequently be applied to substance, number, weight and volume.

Perceptual Activity

The function of perceptual orienting activity in development of representation of static objects is well documented in Soviet literature (Zaporozhets, 1969; Zaporozhets and Zinchenko, 1966). With respect to representation of movement including changes of state occurring through transformation, Inhelder (1965) has shown that representation of the result of transformations chronologically precedes representation of the actual trajectory of objects during transformation. Her findings suggest that representation of movement does not arise independent of operations. Inhelder concludes that the image of a transformation becomes adequate only when directed by operations in the course of being structured; at the same time, she regards image formation as facilitating in elaboration of operational structures. The postulated interdependence of images and operations is particularly relevant to the present research in view of Piaget's belief, together with Soviet evidence, that imagery evolves from reproductive assimilation, that is, from imitative perceptual activity. If this is so, visual tracking of moving objects should promote image formation, hence in the case of transformation of a set of objects, sequential rather than simultaneous movement is suggested as is reduction of the speed at which elements are normally moved in presentation of conservation tasks. Similarly, visual coupling of elements in the transformed set with their counterparts in the non-transformed set may be described as a form of imitation or approximate visual motor reconstruction of the trajectory of objects during transformation. The experimental treatment condition used in this study incorporates presentation of sequential transformations at reduced speeds as well as induced visual coupling.

Piaget's (1969a) extensive studies of perceptual development reveal the function of perceptual activity in correcting illusions which have their origin in field effects. Direct extrapolation of these findings to problems of concept formation is unjustified within the Piagetian framework since Piaget denies that intellectual development derives from perception through extension of the latter to increasingly more complex situations. In support of his view that perceptual activity is not a sufficient condition even for recognition of relations, Piaget (1968a) briefly cites a Genevan study in which parallel rows each containing four objects were exposed for intervals short enough to preclude counting. Under a condition where rows were unequal in length but where cues designed to elicit one-to-one matching were extremely salient, only subjects who had previously demonstrated representation of one-to-one correspondence succeeded in reporting that rows were equal in number.

Criteria of Conservation Attainment

The literature includes a number of studies in which commonly used conservation criteria have been employed to assess subjects' responses in tasks which are not conservation tasks according to Genevan standards. The following discussion is limited to assessment of conservation of numerical equivalence at a conceptual level. Tasks which include an initial judgment of equivalence of sets followed by a transformation which is witnessed by the subject and results in disparate configuration of sets are regarded as true conservation tasks. Tasks which depart from this general paradigm, namely, perceptual discrimination tasks (Calhoun, 1971; Green and Laxton, 1970), tasks in which the transformation and/or the results of the transformation are concealed (Gelman, 1972), and tasks which are modified to remove potentially misleading configurational cues (Strauss and Langer, 1970; Bryant, 1972) may test related abilities but do not qualify as tests of conservation as it is defined by Genevan investigators.

Depending on the criteria selected, some investigators have found ability to conserve in five year olds (Braine and Shanks, 1965a, 1965b; Frank, 1966), whereas Smedslund (1961a) has not identified conservers below the age of seven. Gruen (1966) compared the Bruner-Frank primary response criterion with Smedslund's criterion of logical justification. Significantly fewer conservers were identified using the latter procedure but Gruen is of the opinion that Smedslund's method is more appropriate to assessment of conservation as Piaget defines it.

In search of a criterion less susceptible to social interactional forces than verbal report, O'Bryan and Boersma (1971) reasoned that cognitive processes associated with stages in conservation development should be reflected in eye movement patterns recorded while subjects were engaged in solution of conservation problems. Accordingly, it was postulated that non-conservers would tend toward exclusive fixation of the element judged to be greater in quantity after transformation, and that transitional conservers would demonstrate more visual search for information than conservers in the interval between completion of transformation and response to the conservation question. Analysis of eye movements filmed during solution of length, substance and area problems strongly confirmed predictions. Among a sample of grade I and II girls, non-conservers exhibited a high degree of visual centration on the element judged to be greater, while transitional conservers (subjects who contradicted a primary response when questioned in Piagetian clinical fashion) showed a more equitable distribution of fixations on transformed and non-transformed elements but made fewer shifts from one to the other than did conservers. Conservers, that is, subjects whose primary responses were logically justified, reached solution with fewer fixations than other groups and exhibited a negligible degree of visual centration. Particularly convincing was evidence of horizontal décalage (Flavell, 1963). Individuals who conserved some properties but not others, for example length but not area, tended to exhibit eye movement patterns consistent with their verbal judgments in each case.

In a subsequent study Wilton and Boersma (1973) found that eye movement patterns distinguished non-conservers who had been exposed to Gelman's (1968) training methods from untrained non-conservers. During solution of length, continuous and discontinuous quantity and number conservation tasks, trained subjects exhibited more couplings (shifts of fixation between transformed and non-transformed elements), more runs (successive fixations on the same element), shorter mean length of runs, shorter mean length of fixations and fewer fixations than untrained subjects. Untrained non-conservers showed more runs and fixations of longer duration on the element judged to be quantitatively greater after transformation. For trained subjects the duration of runs and fixations on transformed and non-transformed elements was balanced with no evidence of centration on either element. These relationships were demonstrated in a sample of grade I and II pupils and in a sample of educable mentally retarded children. Similar differences were observed in natural (untrained) conservers and non-conservers. "Surprise reactions" defined using variables which included galvanic skin response, blood volume, pulse and heart rate distinguished natural conservers and trained non-conservers from untrained non-conservers in tasks involving violation of conservation principles. Physiological indices reflecting "surprise" characterized responses of natural conservers and trained subjects to problems involving violation whereas non-conservers registered significantly less "surprise" in these situations. In general, verbal conservation judgments were positively correlated with eye movement patterns and physiological responses.

Effects of Stimulus Properties and Types of Transformations

While Piaget emphasizes the role of cognitive structures in directing perception, Wohlwill (1966) argues that because there is constant interaction between perception and cognition, conceptual processes may be influenced by the nature of information in a given stimulus field. In support of this contention he found that as amount of relevant information increased and as amount of irrelevant information decreased in the stimulus display, younger as opposed to older children made more errors and took longer to respond in an oddity discrimination task.

Uzgiris (1964) found that the type of material used in substance, weight and volume conservation tasks was related to conservation behavior and that variation across materials was greatest for subjects who were in the course of transition from non-conservation to conservation. In discrimination tasks involving number comparisons Baker and Sullivan (1970) found that materials with high interest value facilitated accuracy in comparing sets of four or five objects but had no apparent effect when sets contained seven to nine objects.

Peters and Rubin (1969) investigated the effects of variations in transformation and stimulus attributes on conservation of number responses in kindergarten children. Type of transformation had no effect on performance but a condition in which objects were color-matched to emphasize one-to-one correspondence between sets was observed to facilitate conservation judgments for some children. The authors concluded that stimulus attributes appeared to interact with subject differences. The study was not designed to reveal what these subject differences might be. Rothenberg (1969) reports that type of transformation, specifically, linear versus non-linear, was not related to proportion of correct number conservation responses among a sample of four and five year olds. No difference was observed in the proportion of conservers identified when materials had properties which accentuated one-to-one correspondence than when such properties were absent. Neither Peters' and Rubin's nor Rothenberg's findings can be regarded as inconsistent with Piaget's (1952) clinical observations that correspondence provoked through the use of complementary materials; eggs and egg cups, for example, had no effect on number conservation judgments before the stage when requisite structures were presumed to be adequately mobile.

Film Presentation of Conservation Tasks

Clear advantages attend standardized presentation of conservation tasks. Singh (1968) demonstrated that presentation via motion picture film had no differential effect on conservation responses when compared with conventional presentation involving manipulation of objects by the experimenter. Furthermore, O'Bryan and Boersma (1971) provide data indicating that when film is used it makes little difference whether materials are depicted two or three dimensionally. Motion picture film was used for presentation of conservation tasks by O'Bryan and Boersma (1971) and by Wilton and Boersma (1973).

Postulating that experience in manipulating objects might not be necessary for conservation attainment, Sullivan (1967) produced a film designed to induce conservation of substance. Content consisted of sequences where one adult (the questioner) transformed materials and asked questions and a second adult (the model) replied to those questions. Two versions were prepared, one in which the model gave no explanation of his conservation responses and one in which responses were explained in terms of logical principles. Conservation was successfully induced in a sample of grade I children and generalization was demonstrated. There was no difference between responses of subjects in the Verbal Principle and No Principle groups. Sullivan concluded that success of the film-modelling technique contradicted Piaget's claim that conservation arises from actions performed on concrete objects. Sullivan's modelling rationale was derived from social learning theory (Bandura and Walters, 1963) and consequently differs from a rationale based on functions of perceptual activity.

CHAPTER III

RATIONALE, DEFINITIONS, POSTULATES AND HYPOTHESES

Rationale

The present study constituted an enquiry into the nature of transitional processes in attainment of number conservation. Conceived within the context of Genevan theory, the study was designed to examine the validity of two general premises as they appeared to apply to conservation of number. The first premise is that perceptual activity may assist the child to compensate for misleading perceptual cues which tend to infirm his prior judgments concerning the numerical equivalence of sets. The second, or qualifying premise is that the mobility of the child's existing mental structures is a determinant of the extent to which perceptual activity can be expected to facilitate compensation.

In the case of number conservation, the most relevant of existing mental structures was assumed to be the scheme of intuitive correspondence. Intuitive correspondence refers to comparison of the numerical properties of sets in which constituent objects are arranged in one-to-one physical correspondence. To Piaget, mobility of a scheme is defined by the range of objective situations in which it is applied; consequently intuitive correspondence was inferred to be less mobile when equivalence judgments were limited to displays in which there was both physical correspondence of analagous objects and identical configuration of sets, than when equivalence judgments extended to situations in which sets differed in configuration.

The literature shows that number conservation can be accelerated by means of training and the most effective training methods seem to have involved a considerable amount of perceptual activity induced by verbal and perceptual cues. On the other hand, it has been argued that readiness is the crucial issue in conservation attainment since children already on the threshold of operational thought might benefit from each of a variety of training methods. Recent multivariate studies provide some indication of the complexity of subject x treatment interactions, yet in the domain of number, interaction of training methods with what Piaget regards as the predominant subject variable, namely mobility of mental schemes, has not been investigated. This study was designed to reveal the degree of interaction between mobility of intuitive correspondence and treatment which took the form of cue-guided practice in solving a series of number conservation tasks.

Because there is clear evidence that non-conservers tend to base their judgments on configurational cues, initial tasks in the practice series were designed to reduce the perceptual salience of configurational differences by using colour cues to emphasize one-to-one correspondence. In order to lessen the probability of dependence on colour cues, these were gradually phased out over the practice series. For all practice tasks verbal instructions directed the subject to engage in visual activity linking corresponding objects. Instrumental responses were required as evidence of such activity. No external reinforcement was provided since it was desired to avoid formation of purely verbal response sets.

The literature reveals discrepancies in the conceptual analysis of conservation, varying degrees of control in the administration of conservation tasks, and differences in criteria used to assess conservation. For the present study, number conservation was regarded as a higher order concept involving inferential processes. Accordingly, all tasks required the subject to make two judgments about the numerical equivalence of sets, one before and one after a visible transformation which altered the configuration of one set. Through the use of film and tape recorded instructions the experimenter attempted to standardize the treatment procedure and to lessen the probability of differential cueing during administration of conservation tests. Stringent criteria were applied to assessment of conservation status and structural change was inferred only when logical justification, generalization and retention were demonstrated. In this respect it was deemed important to distinguish three classes of conservation response. Subjects were classed as non-conservers when they judged sets to be unequal after transformation, regardless of the reason given. Subjects who gave a correct primary response but justified this response on empirical grounds, for example by reference to counting, object for object matching, or some other strategy designed to yield empirical evidence of numerical equivalence, were classed as intuitive conservers. True conservation implying conceptualization of invariance across spatial transformations was inferred when a correct primary response was given logical justification as, for example, in cases where a subject referred to the initial equivalence of sets and the fact that nothing had been added or subtracted, or explained that change in length was compensated by change in density. Subjects whose responses fell in this category were termed logical conservers.

It has been shown that eye movement patterns filmed during solution of conservation tasks serve to distinguish non-conservers, intuitive conservers, and logical conservers in length, substance and area tasks, and that they distinguish trained from untrained grade I and II subjects in number conservation tasks. Accordingly, it was decided to explore eye movement patterns as a possible supplementary criterion of number conservation status in a sub-sample of grade I girls. Eye movements were regarded as a potentially convincing criterion since they are less susceptible to external influence than verbal reports. On theoretical grounds, non-conservers could be expected to exhibit relatively little perceptual activity; to centre visual fixations on one set - probably the set judged to be greater because of its perceptual salience, and to demonstrate relatively few shifts of fixation between sets. Subjects whose verbal judgments are justified on intuitive rather than logical grounds should exhibit active visual search patterns reflecting intuitive strategies such as matching and counting, and should take relatively longer to achieve solution. Logical conservers should require less time than intuitive conservers to reach solution and should display little evidence of centration or visual search.

Subject Variables

(1) High Mobile Intuitive Correspondence

Ss defined as high mobile (HM) were girls who reported that the constructed set was equal in number to the given set in each of three trials administered during the test for mobility of intuitive correspondence. Girls whose responses were not consistent over three trials were excluded from the sample.

(2) Low Mobile Intuitive Correspondence

Ss defined as low mobile (LM) were girls who reported that the constructed set had more or less objects than the given set in each of three trials administered during the test for mobility of intuitive correspondence.

(3) Mobility Control Group

The mobility control (MC) group consisted of twenty grade I Ss mean age six years, seven months selected by random procedure from a sample of grade I non-conserving girls with stage II intuitive correspondence. The MC group was exposed to the conservation screening test, color discrimination test, conservation pre-test, immediate conservation post-test, four tests for immediate generalization, delayed conservation post-test, and three tests for delayed generalization.

(4) High Mobile Experimental Group

The high mobile experimental (HME) group consisted of twenty HM Ss (fifteen grade I, five kindergarten) with a mean age of six years, five months, who were randomly assigned to the experimental (practice) condition. The HME group was exposed to the conservation screening test, color discrimination test, test for mobility of intuitive correspondence, conservation pre-test, practice series, immediate conservation post-test, four tests for immediate generalization delayed conservation post-test, and three tests for delayed generalization.

(5) Low Mobile Experimental Group

The low mobile experimental (LME) group consisted of seventeen LM Ss (five grade I, twelve kindergarten) with a mean age of six years, one month randomly assigned to the experimental (practice) condition. The LME group was exposed to the same tests as the HME group.

(6) High Mobile Placebo Group

The high mobile placebo (HMP) group consisted of twenty HM Ss (fifteen grade I, five kindergarten) with a mean age of six years, seven months randomly assigned to the placebo (placebo film) condition. The HMP group was exposed to the same tests as the HME group.

(7) Low Mobile Placebo Group

The low mobile placebo (LMP) group consisted of seventeen LM Ss (five grade I, twelve kindergarten) with a mean age of five years, nine months randomly assigned to the placebo (placebo film) condition. The LMP group was exposed to the same tests as the HME group.

Eye Movement Variables

(1) Configurational Boundaries

Configurational boundaries were arbitrarily determined for purposes of EM scoring. The configurational boundaries for a set were defined as hypothetical lines bounding a reacangular area enclosing the set, and fixed 1" from the outer edges of objects in that set (see broken lines in Figure 12). Configurational boundaries allowed a recording error tolerance approximately 2X the reported accuracy of the instrument (Mackworth, 1967), a tolerance assumed to accommodate slight degrees of calibration loss during recording.

(2) Fixations

A fixation was defined as one or more successive, scoreable, 16 mm motion picture frames in which the corneal reflection spot fell within the same circular area subtended by fifteen degrees of arc in the stimulus field.

(3) Complete Frames

Complete frames refer to 16 mm motion picture frames exposed at the rate of ten per second, showing non-blurred corneal reflection spots falling within the configurational boundaries of either of two sets of stimulus objects.

(4) Interpolated Frames

Interpolated frames were defined as ten or less successive 16 mm motion picture frames, exposed at the rate of ten per second, in which no corneal reflection spot was visible or in which the reflection spot was blurred. Since the reflection spot may vanish as a consequence of blinking or may appear blurred as a result of rapid eye movement, such frames were scored as follows. If the number of frames (n) was even, n/2 frames were attributed to the fixation occurring prior to disappearance or blurring and n/2 frames to the fixation occurring after re-appearance of a well defined spot. If n was uneven, n/2 + 1/2 frames were attributed to the shorter, and n/2 - 1/2 frames to the longer of two fixations occurring before and after disappearance or blurring.

(5) Scoreable Frames

Scoreable frames were defined as the sum of complete frames and interpolated frames.

(6) Runs

A run was defined as two or more successive fixations falling within the configurational boundaries of the same set of stimulus objects.

(7) Couplings

A coupling was defined as a shift from a fixation falling within the configurational boundaries of one set of stimulus objects to a fixation falling within the configurational boundaries of a different set of stimulus objects.

(8) Total Exposure Time

Total exposure time, expressed in seconds, was defined as 1/10X the number of scoreable frames recorded during the interval between completion of transformation (cessation of motion of the last object in the transformed set) and permanent disappearance of the corneal reflection spot resulting from an eye closure response signifying S's readiness to respond to the conservation question.

(9) First Three Seconds of Exposure Time

The first three seconds of exposure time was defined as the first thirty scoreable frames recorded after completion of transformation; that is, after cessation of motion of the last object in the transformed set.

Criterion Variables

(1) Conservation Response Classification

For the immediate conservation post-test, immediate generalization tests numbers one and four, the delayed conservation post-test, and each of three tests for delayed generalization.

S's verbal responses were classified as logical, intuitive or non-conserving if in the unanimous opinion of E and two independent judges they satisfied one of the following criteria proposed by Piaget (1969b, p. 98):

(1) Logical conserving response (LC)

S judged sets to be equal in number after transformation and provided a justifying statement reflecting one or more of the following operations:

(a) Simple identity; for example: "They're the same things. They just moved apart a bit."

(b) Additive identity; for example: "You didn't add any" or "None went away."

(c) Reversibility by inversion; for example: "They could go back where they were before."

(d) Compensation or reversibility by reciprocal relationship; for example: "This row is longer than that one but the things have bigger spaces between them."

(2) Intuitive conserving response (IC)

S judged sets to be equal in number after transformation and provided a justifying statement which was empirical rather than logical. Intuitive justifications centred on the transformed state of sets without reference to the transformation; for example: "There are nine here and nine here", or "I counted." Also classed are intuitive were indefinite justifications such as: "I just know"; "I can tell";

"John told me."

(3) Non-conserving response (NC)

S judged sets to be unequal in number after transformation regardless of justification.

In the case of immediate generalization tests numbers two and three (subtraction and addition), a response classed LC indicated that sets were unequal in number and referred to the fact of subtraction (or addition) by way of justification. As for other tests, IC responses were those classed as empirical. A response was classed NC if S judged sets to be equal, or if a judgment of inequality was followed by reference to configuration; for example: "This one has more... because its longer."

(2) Terminal Conservation Status

A non-conserver was defined as a subject who gave NC responses in one or more of the conservation post-tests or test for generalization.

An intuitive conserver was defined as a subject who gave no NC responses but gave one or more IC responses in conservation post-tests or tests for generalization.

A logical conserver was defined as a subject who gave LC responses for both immediate and delayed conservation post-tests and for all tests for generalization both immediate and delayed.

(3) Practice Errors

Practice errors were defined as verbal judgments indicating inequality of transformed and non-transformed sets, given by HME and LME Ss in response to conservation questions presented at the conclusion of each of eight tasks comprising the practice series. Total practice errors referred to the sum of practice errors over eight tasks.

(4) EM Criteria

(1) Exclusive centration was defined as zero couplings implying that in a given period of exposure time all fixations fell within the configurational boundaries of one set of stimulus objects.

(2) Number of couplings was defined as the sum of couplings occurring in a given period of exposure time.

(3) Couplings per second in total exposure time was defined as the ratio of number of couplings occurring in total exposure time to total exposure time in seconds.

(4) Solution time was defined as total exposure time.

(5) Number of fixations in total exposure time refers to the sum of fixations occurring in total exposure time.

(6) Mean length of run, expressed in seconds, was defined as the ratio of the number of runs made to 1/10X the number of scoreable frames in a given period of exposure time.

Postulates and Hypotheses

(1) Mobility-Treatment Interaction

If high mobility of stage II intuitive correspondence represents a greater degree of operativity of the equivalence scheme than does low mobility, and if perceptual activity facilitates elaboration of structures which are already semi-operative, then the interaction of mobility level and induced perceptual activity should be manifest in the conservation responses of high and low mobile non-conservers exposed to induced perceptual activity during solution of number conservation problems.

Postulate I: Interaction of treatment and mobility level will be evident in the proportion of LC responses given by HME, HMP, LME and LMP Ss in conservation post-tests and tests for generalization.

Hypothesis 1: Multiple contingency analysis of proportions of LC responses given by HME, HMP, LME and LMP groups in the immediate conservation post-test, delayed conservation post-test, and each of four immediate and three delayed tests for generalization will reveal a significant ordinal interaction between mobility and treatment.

(2) Conservation Post-Test Performance

If high mobility plus practice in visual matching are conditions which combine to facilitate advance in conservation status and if this combination is superior in effect to alternative conditions; namely; low mobility plus practice, and no practice irrespective of mobility, then pre-test - post-test change in conservation responses should be more frequent among HME Ss than among other groups.

Postulate II: The proportion of Ss who change from pre-test NC responses to post-test LC responses will be greater among Ss in the HME group than among Ss in the HMP, LME, LMP and MC groups.

Hypothesis 2a: The proportion of Ss who give LC responses in the immediate conservation post-test will be significantly higher for the HME group than for the HMP, LME, LMP and MC groups respectively.

Hypothesis 2b: The proportion of Ss who give LC responses in the delayed conservation post-test will be significantly higher for the HME group than for the HMP, LME, LMP and MC groups respectively.

(3) Generalization

If generalization is a necessary criterion of conservation attainment and if high mobility of intuitive correspondence we practice in visual matching is superior to other conditions in facilitating advance in conservation status, then high mobile Ss exposed to practice should exhibit a greater degree of generalization than other groups.

Postulate III: The proportion of Ss who give LC responses in generalization tests will be greater among Ss in the HME group than among Ss in the HMP, LME, LMP and MC groups.

Hypothesis 3a: The proportion of Ss who give LC responses will be significantly higher for the HME group than for the HMP, LME, LMP and MC groups respectively in each of immediate generalization tests numbers 1, 2, 3 and 4.

Hypothesis 3b: The proportion of Ss who give LC responses will be significantly higher for the HME group than for the HMP, LME, LMP and MC groups respectively in each of delayed generalization tests numbers 1, 2 and 3.

(4) Terminal Conservation Status

If adequate criteria of conservation attainment include logically justified conservation responses, retention over time, and generalization to novel number conservation tasks, and if high mobility of intuitive correspondence and practice in visual matching combine to facilitate advance in conservation status, then high mobile subjects exposed to practice should demonstrate superior performance on all criteria combined.

Postulate IV: The proportion of Ss who attain terminal status of logical conserver will be greater among Ss in the HME group than among Ss in the HMP, LME, LMP and MC groups.

Hypothesis 4: The proportion of Ss who give LC responses in both the immediate and delayed conservation post-tests and in all of four immediate and three delayed tests for generalization will be significantly higher for the HME group than for the HMP, LME, LMP and MC groups respectively.

(5) Practice Errors

If assimilation of the products of perceptual activity is dependent on mobility of relevant structures, then, after practice in visual matching, Ss whose schemes of stage II intuitive correspondence are more mobile should make fewer errors than Ss whose schemes are less mobile when required to judge the numerical equivalence of transformed and non-transformed sets.

Postulate V: HM Ss will make fewer errors in the practice series than will LM Ss.

Hypothesis 5: Mean practice errors will be significantly higher for the LME group than for the HME group.

(6) Visual Centration During Solution of Delayed Generalization Tasks

If eye movement patterns are related to number conservation status in grade I girls and if non-conservers tend to direct their attention to one set of elements to the neglect of the other set during solution of delayed generalization tasks, then, in the first few seconds after completion of a transformation, Ss who judge sets to be unequal should exhibit a greater degree of exclusive visual centration than Ss who give logically justified conserving responses assumed to reflect decentration of thought and conceptualization of relations. Similarly, over longer time intervals non-conservers should display fewer couplings between sets than logical conservers and fewer couplings than Ss who justify their conserving responses by reference to counting, visual matching, or some other empirical strategy employed to compare the number of objects in transformed and non-transformed sets.

Postulate VI: Exclusive visual centration during the first three seconds after completion of a transformation will be more characteristic of Ss who give NC responses than of Ss who give LC responses.

Hypothesis 6: The proportion of Ss who exhibit exclusive visual centration (zero couplings) in the first three seconds of exposure time will be significantly higher for Ss who give NC responses than for Ss who give

LC responses, in each of three delayed generalization tests.

Postulate VII: Ss who give NC responses will exhibit a lower rate of coupling during total exposure time than will Ss who give IC or LC responses.

Hypothesis 7: The sum of ranks for couplings per second in total exposure time will be significantly lower for Ss who give NC responses than for Ss who give LC or IC responses in each of three delayed generalization tests.

(7) Solution Time and Number of Visual Fixations During Solution of Delayed Generalization Tasks

If Ss who supply intuitive explanations search for empirical evidence of numerical equivalence after transformations are completed, this tendency should be reflected in eye movement patterns. Ss whose responses are classed as intuitive should exhibit more fixations than logical conservers in total exposure time, and should take longer to reach solution than logical conservers or non-conservers.

Postulate VIII: Ss who give IC responses will demonstrate more fixations than Ss who give LC or NC responses in total exposure time.

Hypothesis 8: Mean number of fixations in total exposure time will be significantly higher for Ss who give IC responses than for Ss who give LC or NC responses respectively in each of three delayed generalization tests.

Postulate IX: Ss who give IC responses will demonstrate a longer solution time than Ss who give LC or NC responses.

Hypothesis 9: Mean number of seconds solution time will be significantly higher for SS who give IC responses than for Ss who give LC or NC responses respectively in each of three delayed generalization tasks.

(8) Distribution of Visual Fixations During Solution of Delayed Generalization Tasks

If non-conservers centre their attention on one set to the neglect of the other, then an imbalance in the distribution of successive visual fixations on transformed and non-transformed sets should be apparent. Moreover if configuration is the prime determinant of equivalence judgments of non-conservers and if they centre their attention on the set ultimately judged to be greater in number, this tendency should be reflected in eye movement patterns.

If the judgments of logical conservers are independent of the qualitative features of sets, then they should demonstrate a relatively equitable distribution of successive fixations between transformed and non-transformed sets. Finally, if intuitive conservers employ empirical strategies for comparing the number of objects in transformed and non-transformed sets, then they should demonstrate a relatively equitable distribution of successive fixations.

Postulate X: Ss who give NC responses will exhibit greater mean length of run on one set than on the other set in the first three seconds and in total exposure time, and mean length of run will be greater on the set judged to contain the greatest number of objects after transformation. Ss who give LC or IC responses will exhibit no difference in mean length of run on transformed and non-transformed sets in the first three seconds and in total exposure time.

Hypotheses: During the first three seconds of exposure time and during total exposure time in each of three delayed generalization tasks:

10a: Ss who give NC responses will exhibit a significant difference between mean length of run on the transformed set and mean length of run on the non-transformed set.

10b: Ss who give NC responses will exhibit significantly greater mean length of run on the set judged to be greater than on the set judged to be lesser in number.

10c: Ss who give LC responses will exhibit no significant difference between mean length of run on the transformed set and mean length of run on the non-transformed set.

10d: Ss who give IC responses will exhibit no significant difference between mean length of run on the transformed set and mean length of run on the non-transformed set.

CHAPTER IV

PROCEDURE

The Population

The population sampled in this study was assumed to consist of middle class western Canadian kindergarten and grade I girls of normal intelligence whose understanding of numerical equivalence had reached the stage II intuitive level but had not extended to conservation of number.

The Sample

The sample consisted of 94 girls, 60 registered in regular grade I classes in four Edmonton Public Schools, 22 enrolled in two privately operated kindergartens, and 12 in regular attendance at a subsidized Day Care Center operated under the jurisdiction of the City of Edmonton Department of Social Service. Selection of institutions was planned to yield a sample presumed to be balanced with respect to socio-economic status. All Ss resided in districts ranging from predominantly upper to predominantly lower middle class.

At the time of testing, the mean age of kindergarten Ss was 5 years 7 months (S.D. 4.11 months) and the mean age of grade I Ss was 6 years, 7 months (S.D. 4.40 months). Ages ranged from 5 years, 3 months to 6 years, 4 months for kindergarten Ss and from 6 years, 1 month to 8 years, 2 months for grade I Ss. All kindergarten Ss were qualified by age to enter grade 1 the following fall.

Ss were selected if they qualified on each of the following criteria:

(1) Initial conservation status of non-conserver.

(2) Demonstration of stage II intuitive correspondence.

(3) Ability to discriminate relevant colors as determined by the color discrimination test.

(4) Freedom from severe visual, auditory or speech defects as determined from institutional records.

(5) Parental permission for participation.

(6) Classification as HM or LM as determined by the test for mobility of intuitive correspondence, with exception of Ss assigned to the MC group.

Among 166 girls tested, the following numbers were excluded for the reasons indicated.

Parental permission withheld	14
Initial status of conserver	53
Stage I intuitive correspondence	3
Unclassified (inconsistent responses) in test for mobility of intuitive correspondence	1
Absence on date of delayed testing	1

The EM Subsample

The EM subsample consisted of 34 grade I Ss for whom complete EM data were obtained for one or more of three delayed generalization tasks. Data for all three tasks were obtained for 20 Ss.

With the exception of Ss who regularly wore corrective lenses (N=2), all grade I Ss in HM, LM and MC groups (N=58) were brought to the laboratory for EM recording. 24 Ss were excluded for the reasons indicated below.

Refusal to accept bite bar	2
Mouth too small to accommodate bite bar	1
Failure to achieve calibration	6
Unscoreable data (see Appendix B)	14
Malfunction of camera	1

Selection and Classification Tests

(1) Initial Conservation Status

Non-conservers were defined as Ss who reported that one set contained more elements than the other following transformation in both the conservation screening test and the conservation pre-test. Conservers, that is, girls who reported that sets were equal in number following transformation in either or both of these tests were excluded from the sample.

(2) Conservation Screening Test

The conservation screening test consisted of presentation of parallel rows, equal in length, each containing eight blue plastic counters 1" in diameter. S was asked: "Do both rows have the same number of chips or does one row have more chips than the other?" When S replied that both rows had the same, she was directed to: "Watch what I do." E then performed a linear transformation extending the intervals between counters in the row closest to S from 1/4" to 3/4". E then asked: "Now do both rows have the same number of chips or does one row have more chips than the other?" S's response was recorded as C (conserver) or NC (non-conserver) on a checklist.

(3) <u>Test for Stage II Intuitive Correspondence</u>

The test for stage II intuitive correspondence consisted of presentation of a row of nine blue plastic counters 1" in diameter with 1/2" between counters, and a box containing 14 red counters of the same size. Instructions were: "This time, I want you to make a row of red chips along here (E traced a line between S and the given row parallel to the given row and 1 1/2" below it, with her finger) and make it so there are just the same number of red chips as there are blue ones." S's response was recorded as correct (equal row) or incorrect (unequal row) on a checklist.

(4) <u>Color Discrimination Test</u>

The color discrimination consisted of presentation of a box containing 1" square plasticized color samples, two squares representing each of the colors (red, blue, green, yellow, magenta, orange) which would subsequently appear as attributes of some object or stimulus figure used in testing or film-mediated practice. S was told: "I want you to pick out one square of each different color. Try to find all the different colors and put the ones you pick out over here." (E pointed to a clear area in front of S). S's response was recorded as correct or incorrect on a checklist.

(5) <u>Test for Mobility of Stage II Intuitive Correspondence</u>

The test for mobility of stage II intuitive correspondence consisted of three trials, each involving presentation of a set of plastic counters arranged in a circle, and a heap containing four to six counters in excess of the number required to construct an equivalent set. All counters were 7/10" in diameter. S was told: "I want you to make a circle of... (color name) ones around here (E traced the circumference of the circle to be constructed with her finger) and make it so there's a... (color name for set to be constructed) to go with every... (color name of given set)." No comments were interjected if S correctly matched counter for counter to produce an equivalent set. In cases of incorrect construction, if an insufficient number of counters had been used, E said "Let's see, that one goes with that one, and that one with that one, (E continued to point to pairs adjusting physical correspondence when necessary, to equate intervals between counters). Is there one to go with this one?" The same procedure was followed when an excessive number of counters had been used, except that E pointed to extra counters asking: "Do you need that one?" When S had amended construction errors, E said: "Now, here in the circles, are there more ....'s (color name of given set) or more ....'s (color name of constructed set), or just the same number of ....'s as there are ....'s (color names)?" For each trial, S's response was recorded as correct (sets judged equal) or incorrect (sets judged unequal) on a checklist. On completion of three trials, S was classified and recorded as HM (all trials correct) LM (all trials incorrect) or unclassified (some trials correct, some incorrect).

Trials 1, 2 and 3 differed with respect to (a) colors of sets; (b) distance between counters in the given set; and (c) location of the constructed set (greater or lesser diameter; i.e., outside or inside the given set). Colors, spacing and location of given and constructed sets are shown in Figure 4.

(6) Conservation Pre-Test

The conservation pre-test consisted of a number conservation task involving presentation, via 16 mm colored motion picture film, of two parallel 4 1/2" rows spread 3/10" apart, each row containing eight circular yellow flowers 1/5" in diameter, spaced 3/10" apart. Flowers were displayed on a flat black ground. (All dimensions refer to projected size).

Tape recorded instructions were delivered by E via remote control. S was first asked: "Do both rows have the same number of flowers or does one row have more flowers than the other?" When S had replied, instructions directed her to: "Watch what happens." A transformation occurred in which flowers in the transformed set moved sequentially to form a longer (6") row with 1/2" between flowers (see Figure 5).

S was asked: "Do both rows have the same number of flowers or does one row have more flowers than the other?"

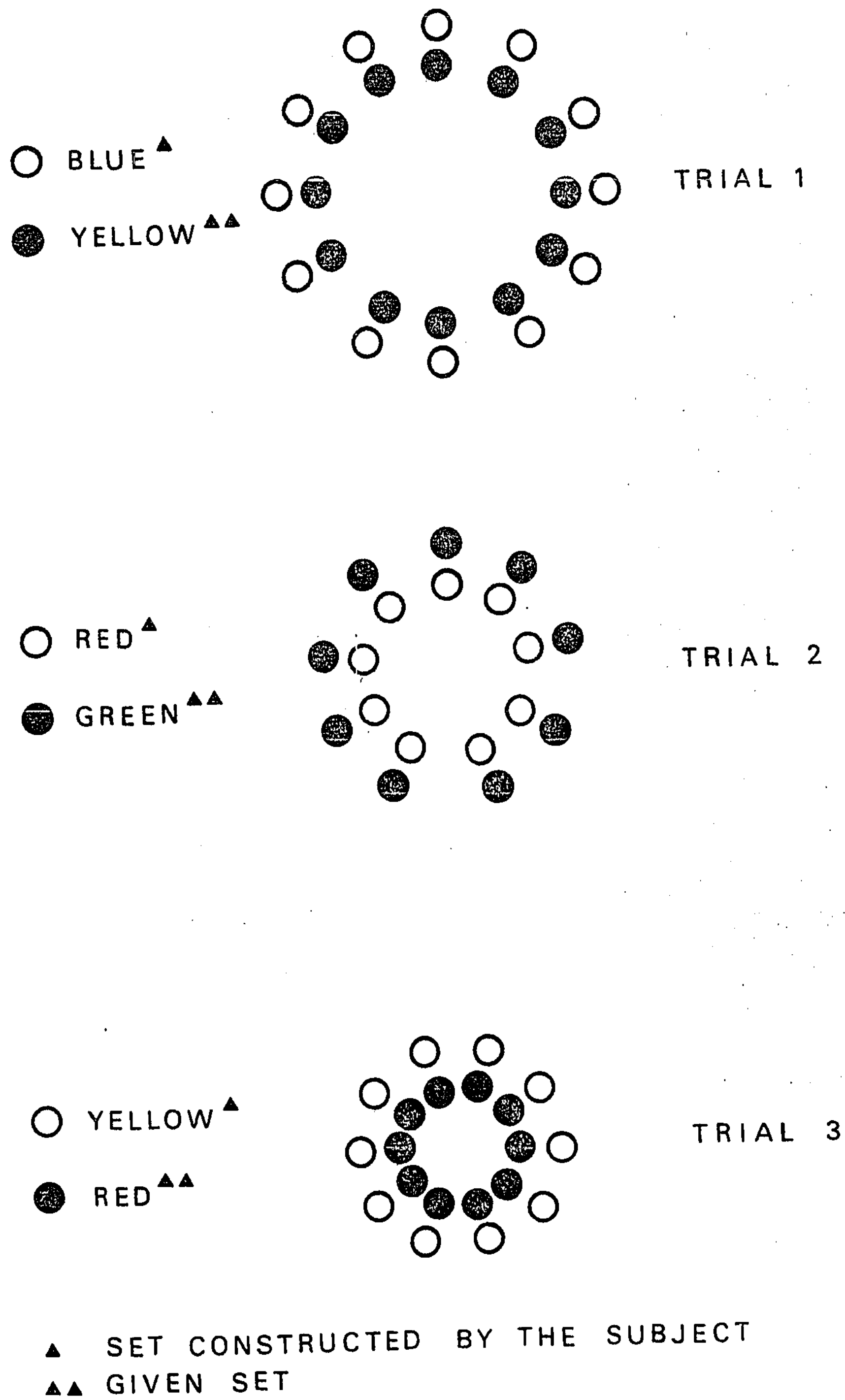

Fig. 4. Colors and arrangement of materials for each of three trials in the test for mobility of intuitive correspondence

S's response was recorded on a checklist as C (conserver) or NC (non-conserver).

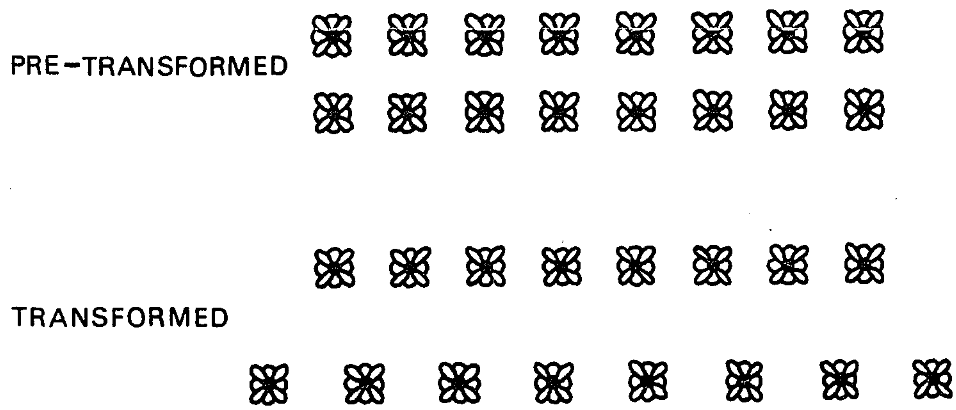

Fig. 5. Stimulus figures in pre-transformed and transformed states for the conservation pre-test. (Reproduced to scale: 1/2 x projected size.)

Overview of Experimental Design and Procedure

A screening test for conservation of number and a test for stage II intuitive correspondence was administered to 45 kindergarten and 121 grade I girls. From grade I girls identified as non-conservers with stage II correspondence, 20 were randomly selected and designated as the mobility control (MC) group. Remaining Ss were tested for mobility of intuitive correspondence. 40 Ss classified as high mobile (HM) and 34 Ss classified as low mobile (LM) were identified.

To confirm that all Ss were non-conservers at the outset of treatment, a pre-test of number conservation was administered by means of colored motion picture film and tape recorded instructors to HM, LM and MC groups.

Ss in HM and LM groups were randomly assigned to one of two treatment conditions. 37 Ss (20 HM; 17 LM) designated as HME and LME groups were exposed to the experimental condition consisting of guided practice in solution of a series of eight number conservation tasks (practice series), presented by way of colored motion picture film accompanied by tape recorded instructions. Tasks in the practice series were arranged in decreasing order of redundancy relative to amount of task-relevant information (color cues) provided. For each of the first six tasks instructions were designed to elicit visual coupling of color-corresponding objects between transformed and non-transformed sets. The last two tasks involved homogeneously colored objects providing no perceptual basis for one-to-one matching. For each task a verbal judgment was elicited with respect to the numerical equivalence of transformed and non-transformed sets. Responses were tape recorded and an error score (practice errors) was computed for each S.

37 Ss (20 HM; 17 LM) designated as HMP and LMP groups were exposed to placebo treatment consisting of viewing a colored language film of approximately the same length as the practice film. The tapescript accompanying the placebo film included questions which S was expected to answer vocally.

Immediate and delayed post-tests of conservation identical to the conservation pre-test were administered to all groups. The immediate post-test was administered following treatment and the delayed post-test after an interval of 13 to 15 days from the date of pre-testing.

All groups were exposed to seven tests for generalization. Tests for immediate generalization consisted of four number conservation tasks involving, respectively, use of color as an irrelevant attribute, use of color as a misleading attribute, subtraction of an element from the transformed set, and addition of an element to the transformed set. After a 13 to 15 day interval, three novel number conservation tasks were administered by way of black and white motion picture film. Differences among delayed generalization tasks related to spatial orientation of sets, and not to the number, size or shape of objects, which were constant over all three tasks.

For grade I Ss in all groups, eye movements were filmed during solution of delayed generalization tasks. Eye movement (EM) data were analyzed relative to the number of couplings between sets, the total number of fixations, the time taken to reach solution and the distribution of successive fixations (mean length of run) between transformed and non-transformed sets. Analyses were performed on each of these variables over total exposure time and, in the case of couplings and mean length of run, over the first three seconds of exposure time.

All testing and treatment was administered individually. Screening, pre-testing, treatment, immediate post-testing, and immediate testing for generalization was carried out in a single half-hour session conducted in S's school or kindergarten. Delayed tests were administered in the EM laboratory at the university for grade I Ss, and in their respective institutions for kindergarten Ss.

Except for verbal reinforcement of matching activity in tasks one and two of the practice series, no material rewards or verbal reinforcements including knowledge of results were provided by the experimenter at any stage of testing or treatment.

A schematic outline of design and procedure is presented in Figure 6 below.

Schedule for Data Collection

Data collection commenced in mid-January, 1970 and was completed by the end of May. Except for school holidays and contingencies related to school or classroom schedules, testing was conducted each weekday within regular school hours. First and second sessions for kindergarten Ss and first sessions for grade I Ss were distributed between mornings and afternoons. All testing conducted in the EM laboratory took place in the morning. Within each institution first sessions were completed for all girls in one classroom before testing began for girls in the next class. Girls were tested in the order in which they were released by their teacher and E had no prior knowledge of this order. Testing was completed in one institution before it commenced in another.

Teachers, administrators and parents were made aware of the general purpose of the study, explicitly that it was an investigation of how normal children acquire certain basic

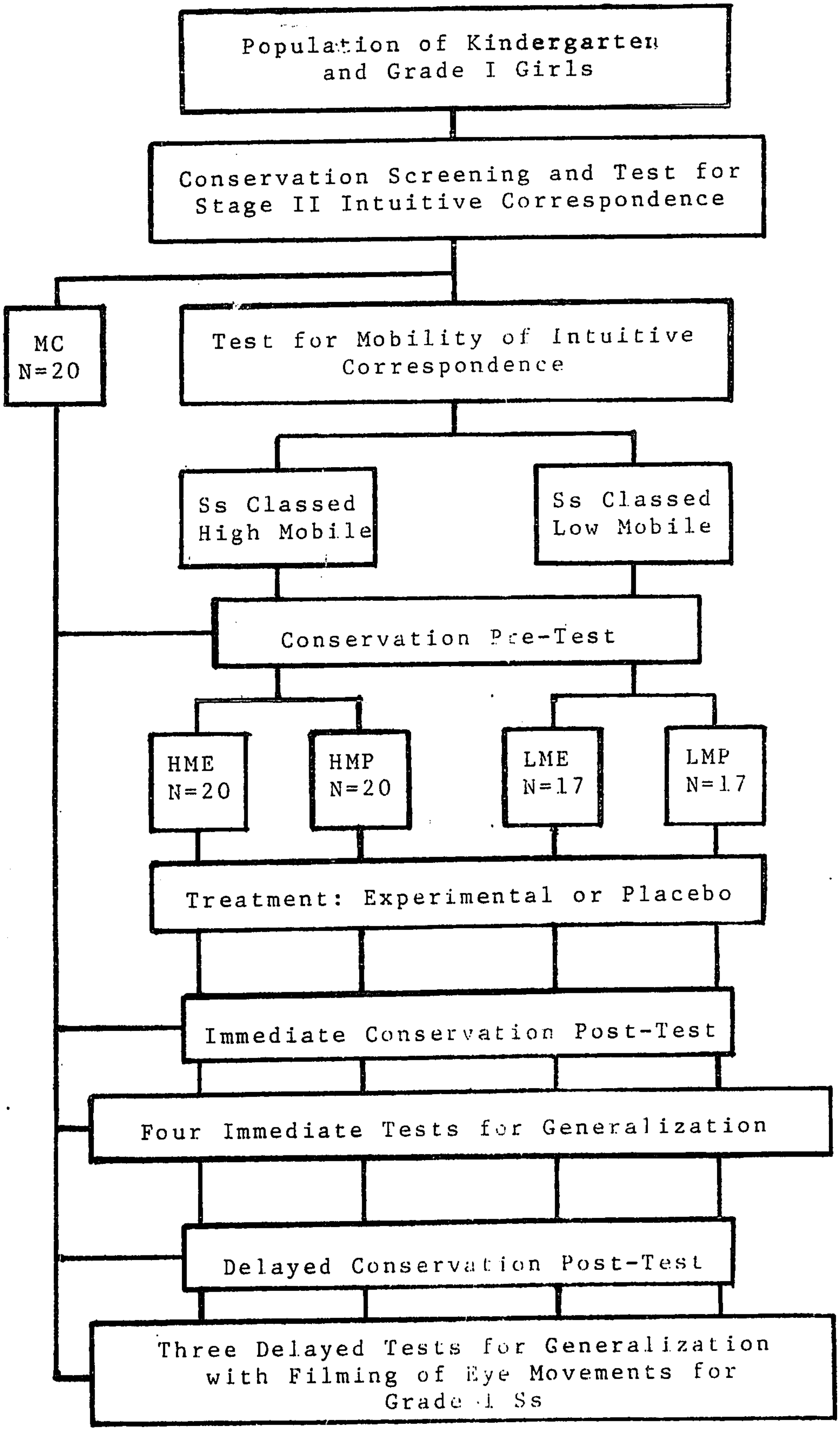

Fig. 6. Outline of experimental procedure

ideas about number. Teachers who expressed interest were invited to view the practice film after treatment had been completed for Ss in the school concerned. Parents and school personnel were not aware of the design of the experiment, hence few anticipated treatment differences and none knew the particular treatment conditions to which individual pupils were exposed. No information concerning intelligence test scores, readiness test scores, school achievement or socio-economic status of individuals was solicited by E. Coöperation of administrators, teachers and parents was excellent in all institutions visited.

Treatment Conditions

(1) Pilot Studies

Two pilot studies were undertaken in order to make a preliminary assessment of the effect of cue-guided practice on conservation status and the relationship of mobility of intuitive correspondence to practice effects. Procedure and results of these studies are reported in Appendix A. The practice series employed in pilot studies was similar to the series described below with respect to task sequence and color cues.

(2) Practice Series

The practice series consisted of eight conservative number conservation tasks each involving presentation, via 16 mm colored motion picture film, of a 4 1/2" row containing outline figures of seven girls spaced 2/5" apart, and a parallel row 3/5" below the row of girls, containing seven balls spaced the same distance apart as girls. Figures were displayed on a flat black ground.

Color cues were provided through correspondence between the color of each girl's dress and the color of the ball directly beneath that girl in the pre-transformed display. All instructions were tape recorded and delivered by E by remote control.

An introductory film sequence accompanied by tape commentary, showed balls (amorphously arranged) moved to correspond spatially and in color with girls in order to show that there were: "...enough balls so that every girl can have one." Prior to transformation S was directed to answer two questions; namely: "Is there a ball for every girl?" and "Are there more balls than girls or less balls than girls, or just the same number of each?" The form of the latter question varied somewhat from task to task. Responses were tape recorded.

Following transformation of balls in tasks one to six inclusive, a red arrow appeared above the figure at the left hand end of the row of girls. Instructions directed S to: "Point to the ball that belongs to this girl." The same directive, in a variety of forms, was repeated as the arrow moved left to right from figure to figure allowing an average of seven seconds for S to respond. Intervals allowed for pointing decreased slightly in length from earlier to later tasks in the series. In the event that a pointing response was not made within the interval allowed by the film, E switched the movie projector to stop-action until S had pointed to one of the balls in the transformed set. Incorrect pointing responses were not acknowledged or corrected by E. For tasks one and two the words: "Right" and "Good" respectively were included in the tapescript and delivered immediately after S had pointed to the ball judged to correspond with the figure at the right hand end of the row of girls; that is, upon completion of matching activity. These were the only reinforcing terms employed in the practice series. Matching activity was not elicited in tasks seven and eight which provided no differential color cues relative to girl-ball correspondence. The arrow did not appear in these tasks.

Following disappearance of the red arrow in tasks one to six and following completion of transformation in tasks seven and eight, S was directed to answer two questions; namely: "Is there a ball for every girl?" and "Are there more balls than girls or less balls than girls or just the same number of each?" Again the form of the latter question varied from task to task. The response interval allowed by the film averaged ten seconds for each question. Stop-action was used in the event that S had not replied within that interval. S's verbal responses were tape recorded.

A complete transcript of taped instructions delivered during the practice series is presented in Appendix A.

Figure 7 shows the form and color of stimuli (reproduced three times the projected size) and Figures 8 to 11 inclusive illustrate color attributes and post-transformed configurations for each of eight tasks. It may be noted that task sequence provided for change in color attributes or in transformation, but that both were not altered concurrently.

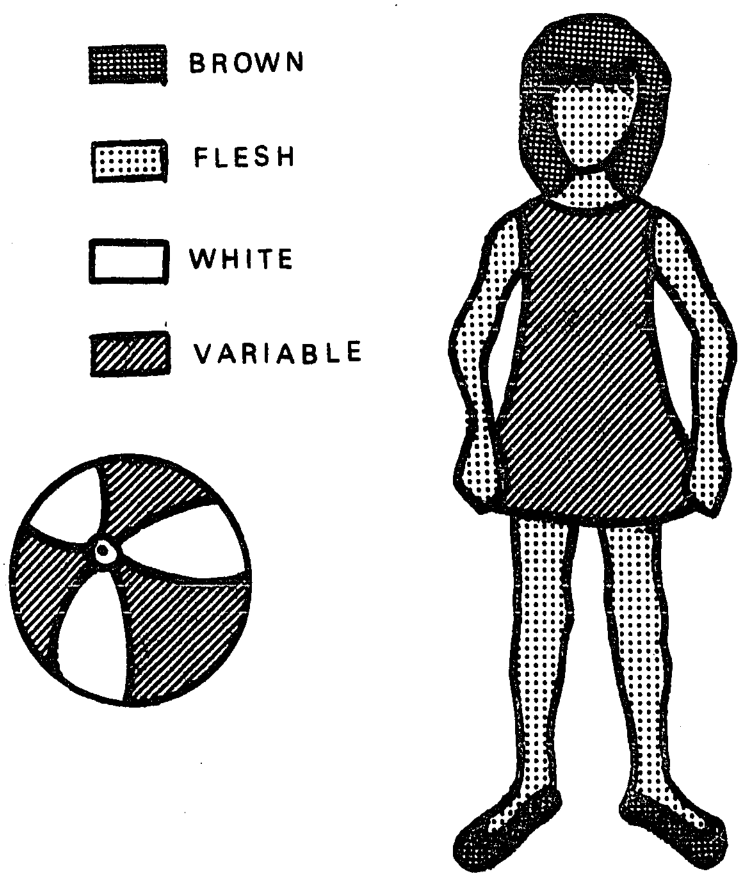

Fig. 7. Stimulus figures for the practice series. (Reproduced to scale: 3 x projected size.)

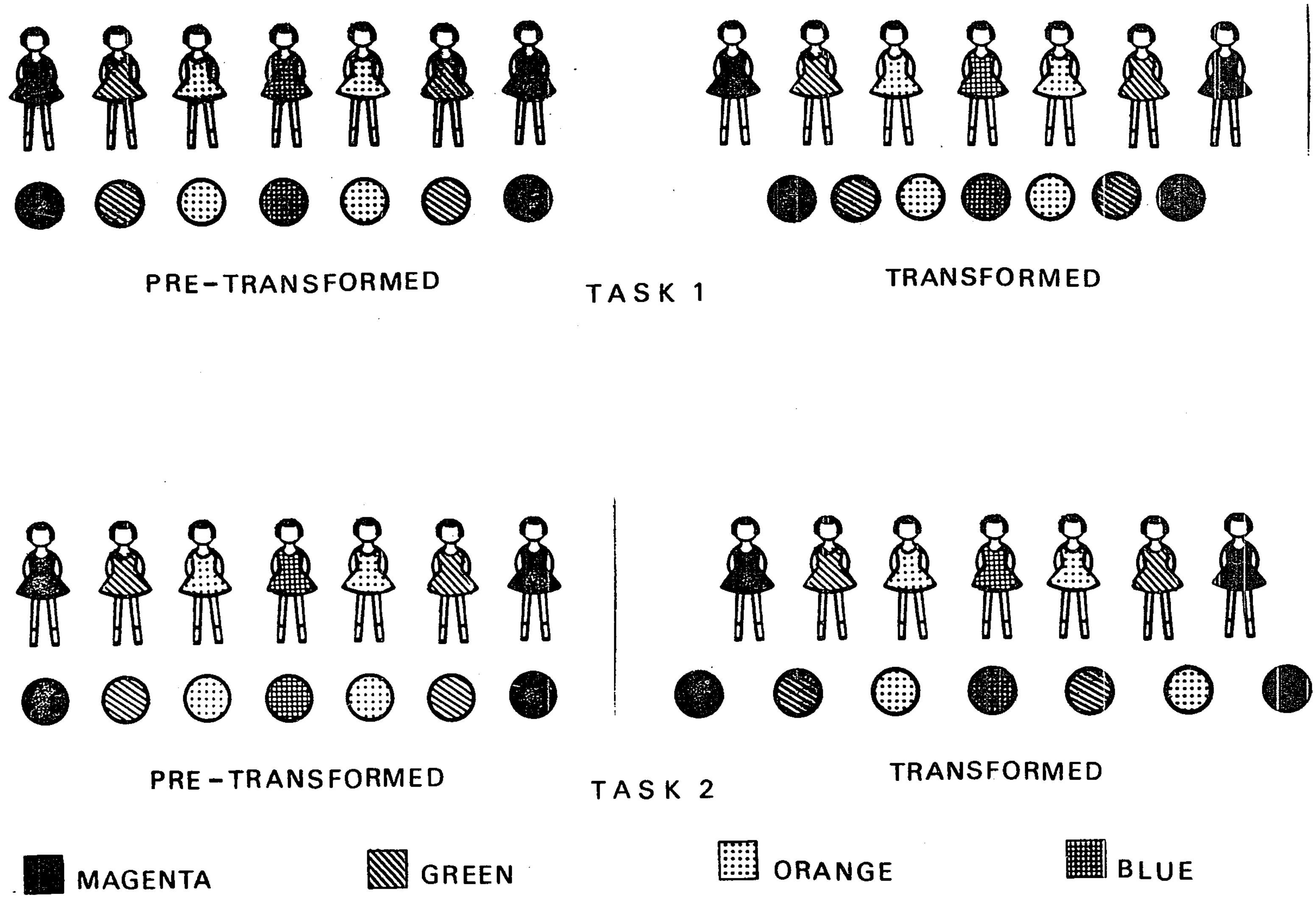

Fig. 8. Colors and arrangement of stimuli for tasks 1 and 2 of the practice series

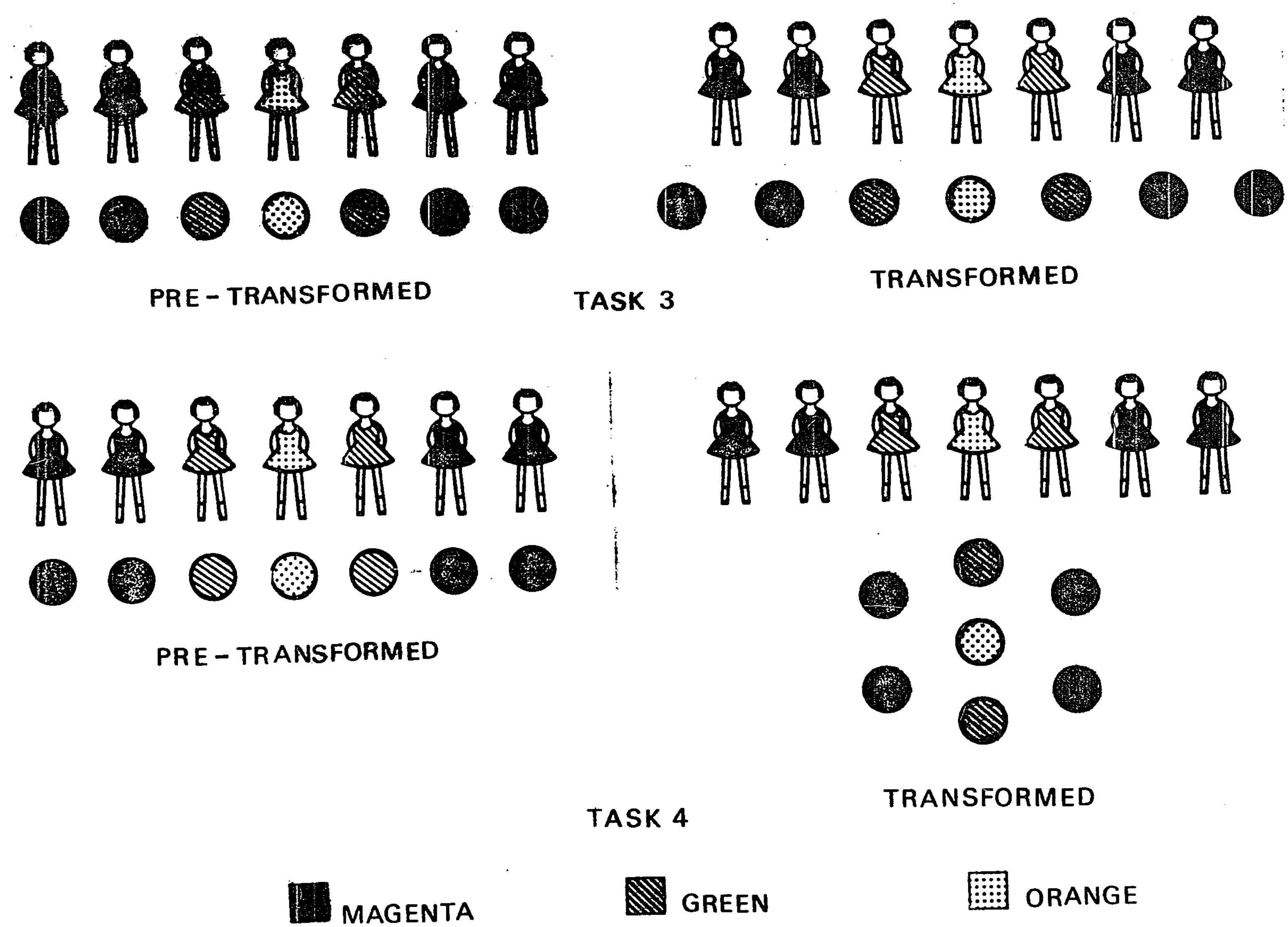

Fig. 9. Colors and arrangement of stimuli for tasks 3 and 4 of the practice series

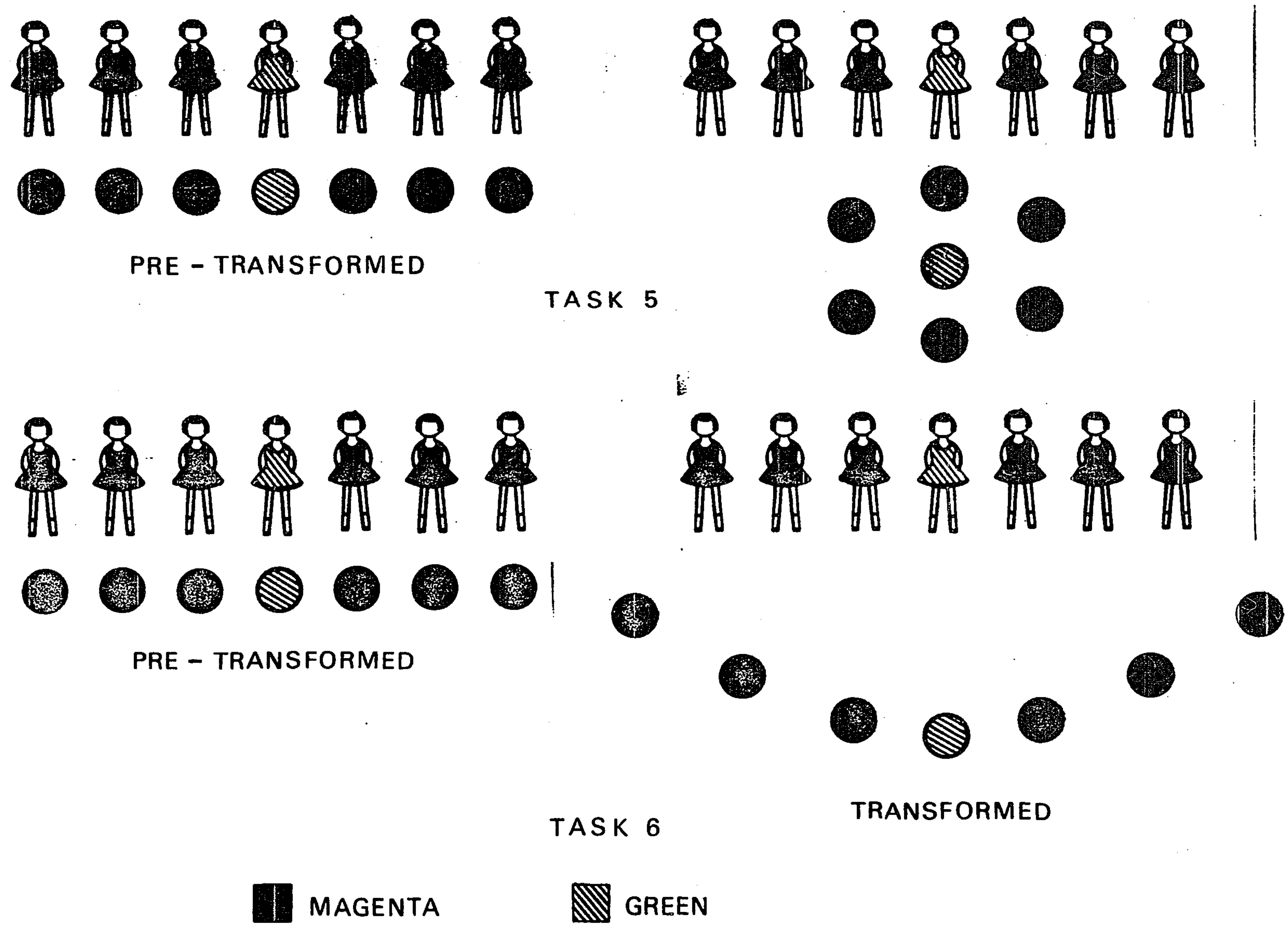

Fig. 10. Colors and arrangement of stimuli for tasks 5 and 6 of the practice series

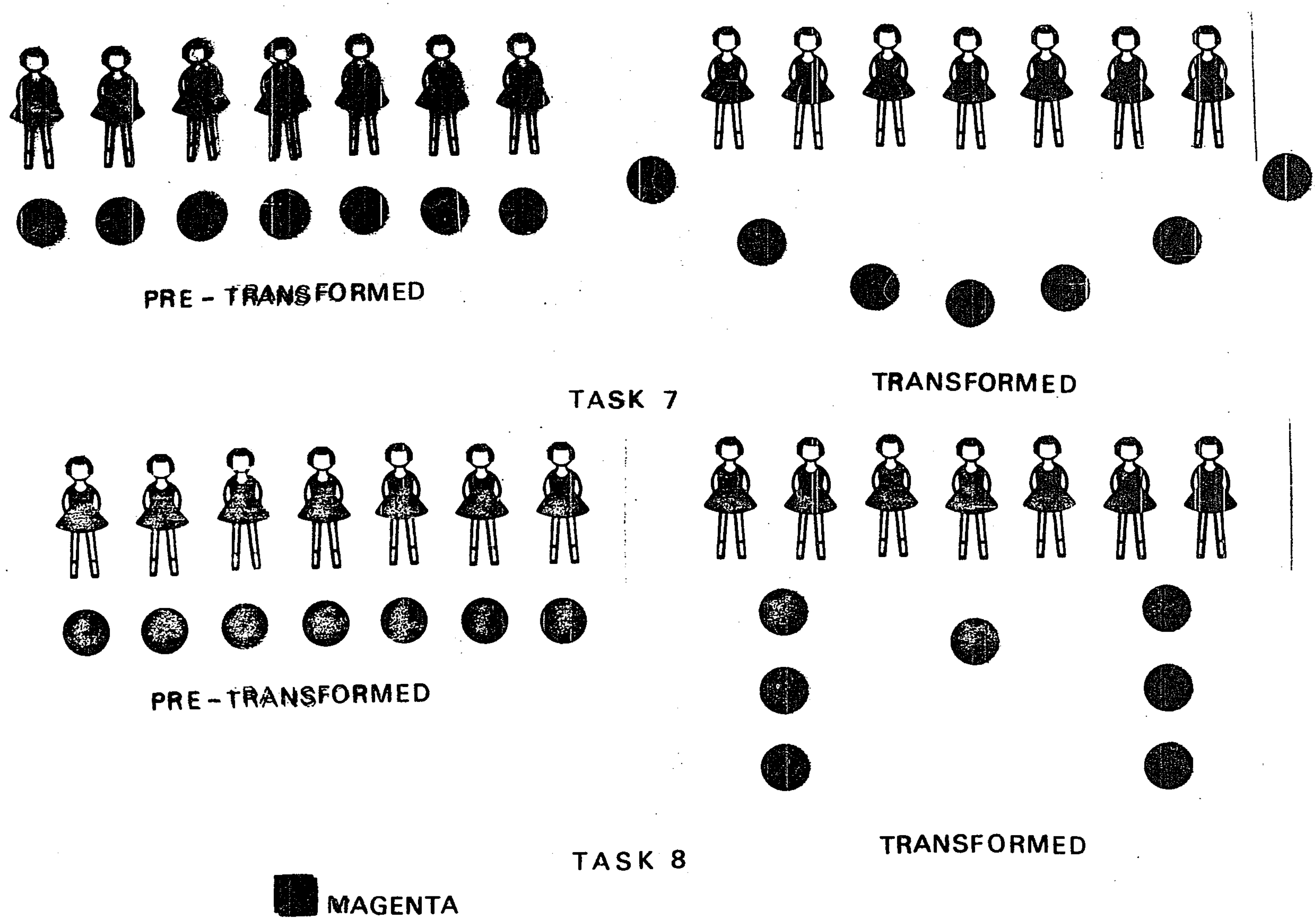

Fig. 11. Colors and arrangement of stimuli for tasks 7 and 8 of the practice series

All transformations were sequential and averaged 22 seconds in duration at a projection speed of 24 frames per second. Order of transformation was constant over all tasks commencing with the ball at the left hand end of the pre-transformed set and continuing left to right until the ball at the right hand end was in place in the transformed configuration. At no point were two balls in motion simultaneously. Total projection time at 24 frames per second for the full practice series, excluding stop-action intervals, was 11 minutes, 20 seconds.

Tape recorded responses were used to compute a practice error score for each S. Responses indicating that sets were unequal in number after transformation were scored as errors irrespective of S's response to the question preceding the conservation question; namely, "Is there a ball for every girl?" Error scores for the series thus ranged from 0 to 8.

(3) Placebo Treatment

The placebo treatment condition consisted of presentation of a commercially produced colored motion picture film entitled "Andy's Animal Alphabet" (March of Time Films, Inc., 1950). This film, intended for educational use in primary language programs, follows "Andy", a young orangutan, and his keeper on a trip around the zoo where they find animals whose names begin with letters of the alphabet. Each sequence commences with a picture of a large block bearing a single letter. Subsequently one or more animals beginning with that letter are shown in the zoo setting.

Tapescripts prepared by E were substituted for the regular sound track. For grade I girls, instructions directed S to name each letter shown, and, if possible, to name the animals; for example "What is this letter?" "If you know this animal, tell me what it's called." Names of common animals; for example, "bear", "camel", "deer", "elephant", "frog" were not provided. In the case of less familiar animals; for example, "antelope", "hippopotamus" and "jaguar", a name was provided, for example; "Do you know what this is?" (pause) "It's called a rhinoceros, ...R for rhinoceros." In the event that S was unable to name a letter within time limits allowed by the film, stop-action was used to extend the response interval. Errors were not acknowledged or corrected, and the script contained no words such as "right" or "good" which could be construed as reinforcing.

An adapted script which omitted questions relating to letter names was used for kindergarten Ss; for example, "Here's a block with B on it. ... What's this animal? (pause for S's response) Bear begins with B." Stop-action was not used for kindergarten Ss. Otherwise, conditions were the same as for grade I Ss.

Total viewing time, exclusive of stop-action intervals, was ten minutes.

Number Conservation Criterion Tests

(1) Immediate Conservation Post-Test

Except for an additional question, the immediate conservation post-test was identical to the conservation pre-test and was administered immediately after task eight of the practice series for HME and LME groups, immediately after the placebo film for HMP and LMP groups, and after 1/2 hour of regular school activity for the MC group. After S had responded to the conservation question: "Do both rows have the same number of flowers or does one row have more flowers than the other?", S was asked: "How do you know?" Responses were tape recorded and transcribed verbatim.

(2) Immediate Tests for Generalization

Four tests for immediate generalization were administered, upon completion of the immediate conservation post-test, in the order in which they are described below. Materials for generalization tasks one and two were plastic counters 7/10" in diameter in four colors: red, yellow, green and blue. Materials used in generalization tasks three and four were, respectively, mauve candies and green candies ("Smarties", 1/2" in diameter).

(1) Immediate Generalization Task One consisted of presentation of two parallel rows, each containing ten counters colored as shown in Figure 12 below. E asked S: "Do both rows have the same number of chips or does one row have more chips than the other?"

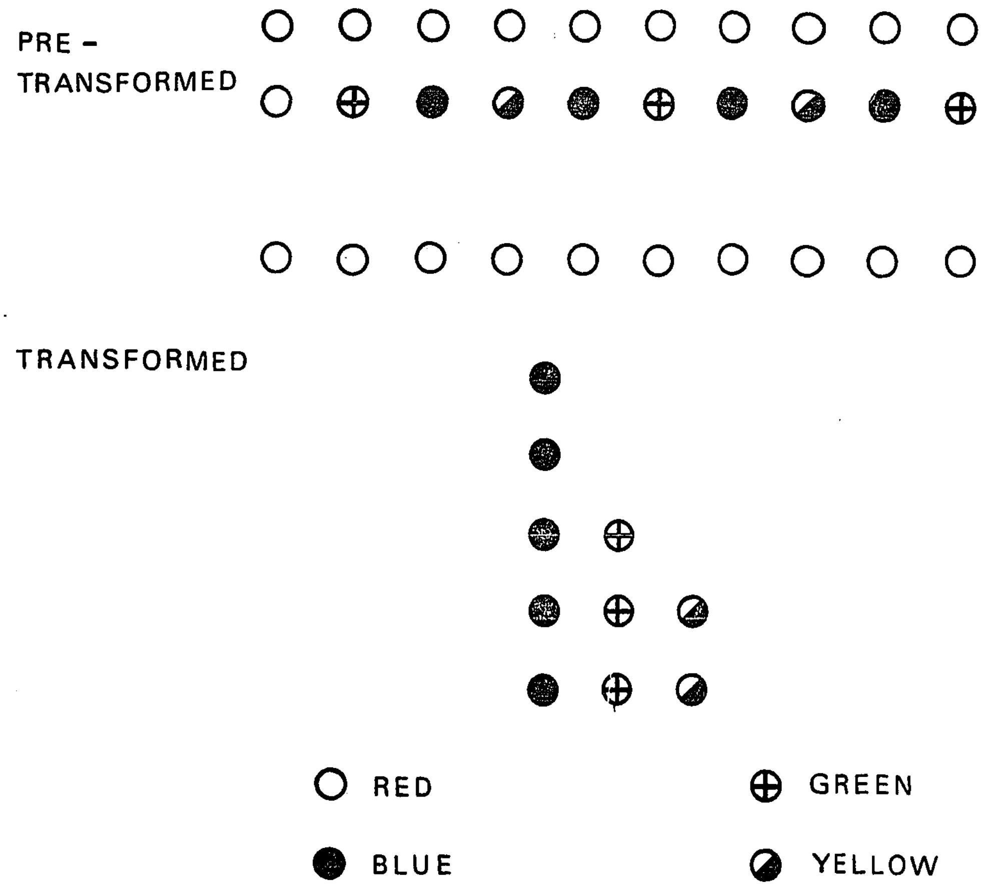

Fig. 12. Colors and arrangement of stimulus materials for immediate generalization test no. 1

When S indicated that rows were equal, E performed a sequential transformation first placing all blue counters, then all green counters and finally all yellow counters in three respective columns as illustrated in Figure 12. E then asked S: "Are there more chips here (E pointed to the non-transformed row) or more chips here (E made an encompassing gesture indicating the whole grouping of transformed objects) or are there the same number here (E indicated the transformed set) as there are here (E indicated the non-transformed set)?" After S had replied, E asked: "How do you know?" Responses were tape recorded and transcribed verbatim.

(2) Immediate Generalization Task Two consisted of presentation of two parallel rows, each containing eight counters colored as shown in Figure 13 below. E asked S: "Do both rows have the same number of chips or does one row have more?" When S indicated that rows were equal, E performed a linear, simultaneous transformation (two counters in motion at a time commencing at the extremities and working toward the centre of the set) resulting in extension of intervals between counters as shown in Figure 10. E asked S: "Does one row have more chips than the other or do they both have the same number?" When S had replied, E asked: "How do you know?" Responses were tape recorded and transcribed verbatim.

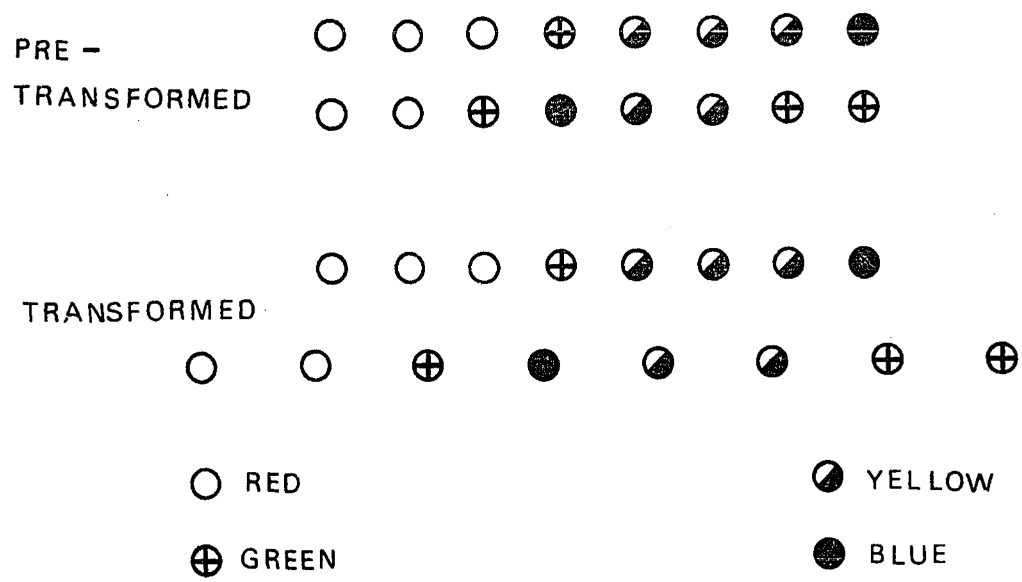

Fig. 13. Colors and arrangement of stimulus materials for immediate generalization test no. 2

(3) Immediate Generalization Task Three consisted of presentation of two parallel rows, each containing nine mauve candies. E asked S: "Do both rows have the same number of Smarties or does one row have more?" When S indicated that rows were equal, E said "Watch carefully what happens", and performed a sequential transformation resulting in the configuration shown in Figure 14. E then picked up and ate the candy indicated by the arrow in Figure 14. E asked "Are there more Smarties here (indicating the non-transformed set) or more here (indicat-

ing the transformed set) or just the same number here (non-transformed set) as there are here (transformed set)?" When S had replied, E asked "How do you know?" Responses were tape recorded and transcribed verbatim.

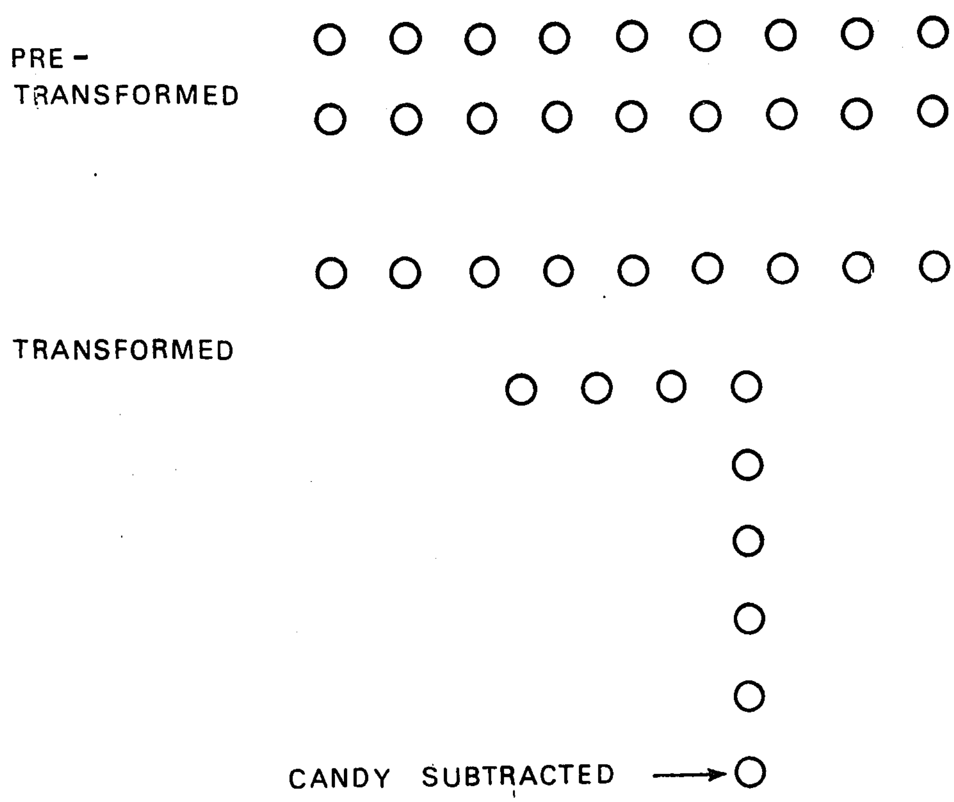

Fig. 14. Arrangement of stimulus materials for immediate generalization test no. 3

(4) Immediate Generalization Task Four consisted of presentation of two parallel rows, each containing eight green candies, and a box containing eight to

ten identical candies located 6" above the top row. E asked: "Do both rows have the same number of Smarties or does one row have more?" When S indicated that rows were equal, E said "Watch what happens", and performed a sequential transformation resulting in the configuration shown in Figure 15. E then took a candy from the box and placed it in the position indicated by the arrow in Figure 15. E asked: "Are there more Smarties here (indicating the non-transformed set) or more here (indicating the transformed set) or just the same number here (non-transformed) as there are here (transformed)?" When S had replied, E asked: "How do you know?" Responses were tape recorded and transcribed verbatim.

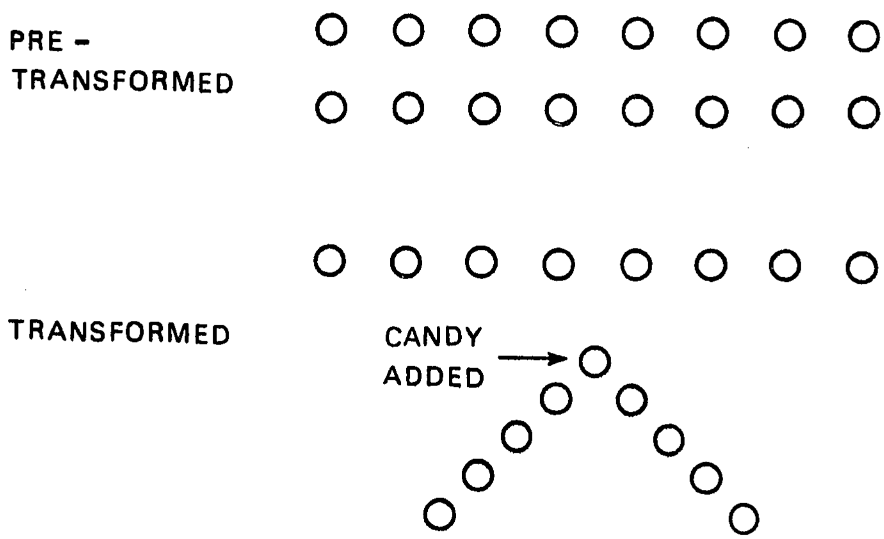

Fig. 15. Arrangement of stimulus materials for immediate generalization test no. 4

(3) Delayed Conservation Post-Test

The delayed conservation post-test was identical to the immediate conservation post-test and was administered 13 to 15 days after the conservation pre-test.

(4) Delayed Tests for Generalization

Three tests for delayed generalization were administered, immediately after the delayed conservation post-test, in the order in which they are described below. Stimuli for each task were eight 2/5" black squares and eight black circles 2/5" in diameter (projected size) displayed on a light grey ground and presented via 16 mm black and white motion picture film. Accompanying instructions were tape recorded and delivered by E via remote control. For each task, S's responses were tape recorded and transcribed verbatim.

(1) Delayed Generalization Task One consisted of presentation of parallel rows, the top row containing eight squares and the bottom row containing eight circles (see Figure 16). Instructions were: "Here are two groups of things. See, the things in one group are squares and the things in the other group are circles. Tell me, do both groups have the same number of things or does one group have more things than the other?" When S indicated that groups were equal, a sequential transformation of circles occurred resulting in the circular configuration shown in Figure 16. Duration of the transformation was 15

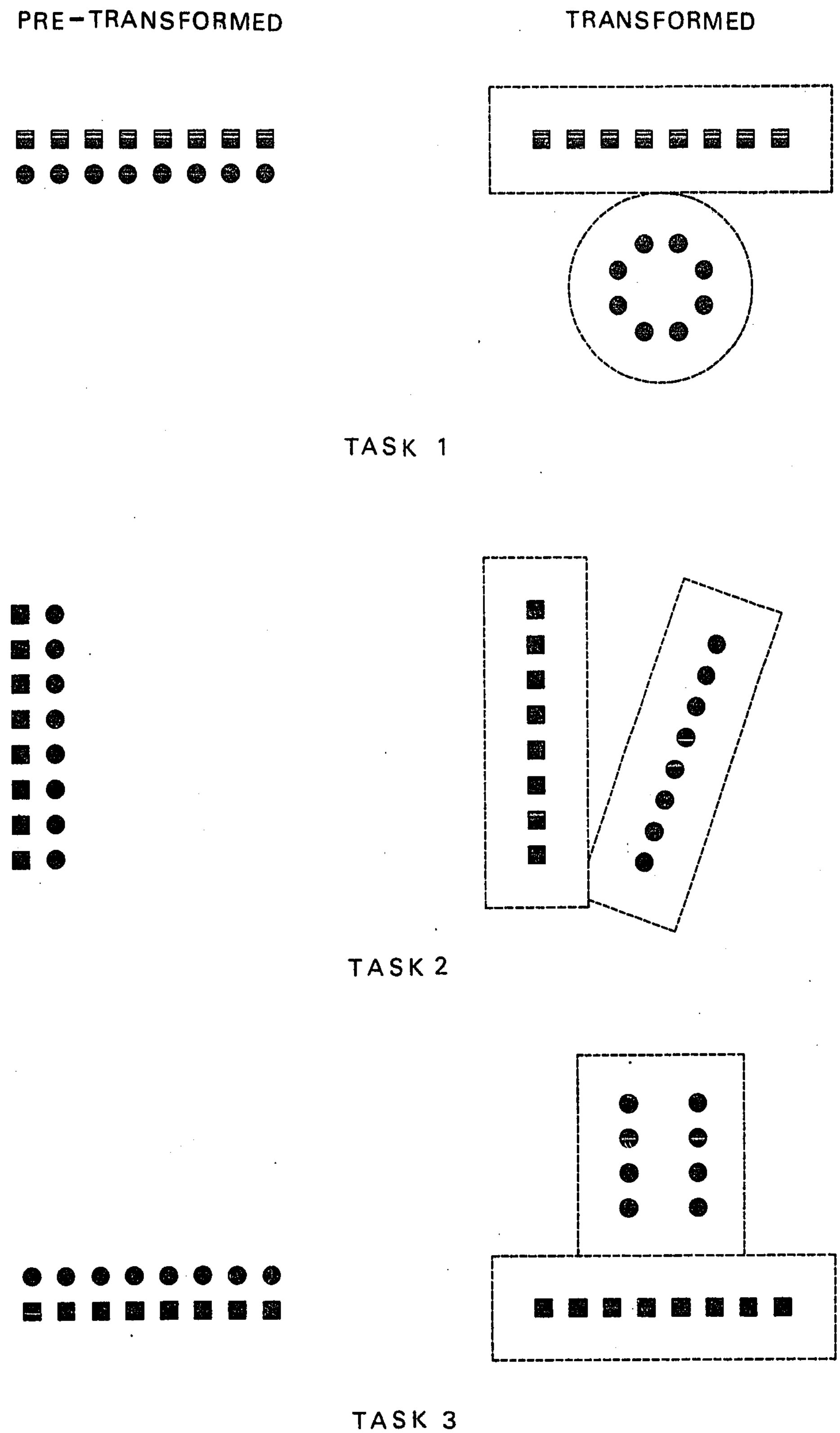

Fig. 16. Arrangement of stimuli for each of the three delayed generalization tests

seconds. Taped instructions asked: "Do both groups have the same number of things or does one have more?", and, after S had replied: "How do you know?"

(2) Delayed generalization Task Two consisted of presentation of parallel columns, the left hand column containing eight squares and the right hand column containing eight circles (see Figure 16). Instructions were: "See these two groups of things? Tell me, do both groups have the same number of things or does one group have more things than the other?" When S indicated that groups were equal, a sequential transformation of circles occurred resulting in the diagonal configuration shown in Figure 16. Duration of the transformation was 12 seconds. Taped instructions asked: "Do both groups have the same number of things or does one group have more?", and after S had replied, "How do you know?"

(3) Delayed Generalization Task Three consisted of presentation of parallel rows the top row containing eight circles and the bottom row containing eight squares (see Figure 16). Instructions were: "See these two groups of things?" Tell me, do both groups have the same number of things or does one group have more things than the other?" When S indicated that groups were equal, a sequential transformation of circles occurred resulting the two-column configuration shown in Figure 16. Dura-

tion of the transformation was 19 seconds. Taped instructions asked: "Do both groups have the same number of things or does one group have more?", and, after S had replied, "How do you know?" Stimuli in Figure 16 are drawn to scale, 1/3 times projected size.[1]

Apparatus and Procedure

(1) Production of Testing and Practice Films

For the conservation pre- and post-test film, the practice series film and the film presenting delayed generalization tasks, stimulus figures were cut from stiff cardboard and mounted on 1/2" x 3/4" x 1/8" magnets backed with felt. Contact between stimulus figures and a vertically mounted cardboard background screen was maintained by means of magnets, placed in corresponding position, on the rear surface of the screen. Stimulus motion was achieved by manual manipulation of magnets on the rear surface according to patterns pre-drawn on that surface. A flat black ground was used for the pre- and post-test film and for the practice film. A light non-reflective grey ground was used for delayed generalization tasks. Task-relevant colors used in the practice film were standard, namely Truprint (Schmidt Printing Inks, Montreal)

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[1] Broken lines bounding each set were not part of the stimulus display in delayed generalization tasks. These boundaries enclose areas defined for the purpose of EM scoring (see p. 41).

151TP blue; 110TP orange; 140TP green, and 120TP magenta printed on Wellington offset 140M layout paper.

An 8 mm version of the practice series film was produced without technical assistance to assess the general feasibility and effectiveness of the film medium and to evaluate colour selection, timing of stimulus presentation and clarity of instructions. This series was administered to three grade I girls. Observation suggested that time intervals allowed for verbal responses could be reduced from an initial estimate and that instructions related to pointing did not need to be repeated in full for each task since Ss readily learned to attend to the arrow signal and, without further prompting, to point to appropriate objects in the transformed set.

Professional cinematographers were engaged for production of 16 mm films used in the study. Kodak Tri-X reversal film was used for black and white and Kodak Ektachrome (professional type) for color production. Films were exposed at 16 frames per second and later projected at the standard rate of 24 frames per second to compensate for the slowness of stimulus movement necessitated by manual manipulation of magnets.

(2) Testing and Treatment Sessions

The initial testing-treatment session was conducted in a private room in the S's school or kindergarten and averaged 30 minutes in duration. The second session (delayed post-test and tests for delayed generalization) was conducted in the Ss institution for kindergarten children and in the EM laboratory for grade I Ss. Duration of the second session averaged five minutes for kindergarten Ss and approximately 20 minutes for grade I Ss including time required to prepare Ss for EM recording.

In order to sustain interest under conditions precluding knowledge of results, verbal praise or presentation of rewards throughout both sessions, E adopted a consistent practice of involving S in conversation and activity to achieve continuity of rapport and to facilitate transition from one task to the next. For example, at the conclusion of the conservation screening test in session one, E customarily said:

> "Now we're through with these (blue counters), and here's the box they go in. I keep my things in different colored boxes so I can remember where everything is. The blue chips go in the blue box. Do you want to put them in? .... Thank you. Now we need the yellow box. What do you think is in it? .... Look and see. .... What I want you to do with these is to pick out...."

In rare instances when S asked directly if her response was correct, E turned the question back with a reply of the following type: "I think you can tell if it's right, can't you?" On the whole, Ss seemed to have considerable confidence in their own judgments and did not seek confirmation from E.

(3) Administration of Tests Involving Concrete Materials

During administration of the conservation screening test, test for stage II intuitive correspondence and tests for immediate generalization, S was seated opposite E who manipulated materials on a table covered with low-reflective light grey cardboard.

(4) Administration of Film-Mediated Tasks

For the conservation pre-test and immediate post-test, the practice series, the placebo film, and, in the case of kindergarten Ss, the delayed conservation post-test and delayed tests for generalization, S was seated facing a ground glass table screen (Hudson Photographic Industries Telescreen table model 605 designed for side projection) with a viewing area 6 1/2" x 5 1/2". The centre of the screen was located approximately four inches below eye level at a sufficient distance to permit S to touch the glass surface when her arm was three-quarters extended. To prevent S from dislodging the screen during pointing, screen legs were adhesive taped to the table.

A Bell and Howell 16 mm autoload motion picture projector was located 24 inches to the left of the screen. Standard intensity of projected film colors was obtained under conditions where overhead room lighting was retained but side lighting was reduced by use of regular window blinds.

Instructions were administered via a portable casette tape recorder located behind and six inches to the left of the screen. Tape recorder controls were operated by E by remote switch. A second casette tape recorder used for recording responses was located behind and six inches to the right of the screen. The microphone for this recorder was situated beside the screen.

E was seated behind and to the left of S, opposite the projector. E could reach projector controls by leaving her chair and leaning forward, but when seated, could not be seen by S unless S turned approximately 150 degrees.

Before testing commenced, S was familiarized with the purpose of each item of equipment, and, if she indicated lack of familiarity with tape recorders, was permitted to record and listen to a playback of her own voice. None of the Ss tested expressed concern about the fact that their responses were being recorded. It was observed that many Ss were familiar with tape recorders but that few understood the principle of motion picture projection. The number of Ss who turned to look at E at any point during film presentation was negligible, however, a number did attempt to locate what they apparently presumed to be actual moving objects by looking in the open left end of the projection screen box. This occurred despite the fact that Ss had been previously shown that the pictures they were going to see were on a reel of film. In general, Ss appeared well motivated by the opportunity to view what E referred to as "...your own private movie." Attention and participation were as well if not better sustained among kindergarten Ss as among grade I girls. Whereas a small number of the latter exhibited a degree of inattention in later trials of the practice series, the former, for whom the experience was possibly more novel, showed no decrement in attention over the full series. Neither group displayed a decrement in matching activity and it was rarely necessary to use stop-action in order to extend verbal response intervals.

(5) Eye Movement Recording

Before commencement of data collection, all aspects of EM recording procedure were tested on adults and children and full procedure was carried out for a group of six grade I girls who were not included in the sample. Procedural modifications included reduction in the usual length of the conservation question in order to minimize the possibility that verbal stimuli introjected during filming would elicit head movement resulting in loss of calibration. It was felt that the final form of the question; namely, "Do both groups have the same number of things or does one have more?" would be correctly interpreted in view of S's experience in responding to longer forms of the same question; for example: "Do both rows have the same number of flowers or does one row have more flowers than the other?" Other modifications pertained to elimination of extraneous sources of visual and auditory stimulation and improved support for S's back. An original plan for presentation of taped instructions via headphones was abandoned when it was observed that lack of familiarity and/or discomfort of the headset resulted in more head movement than did presentation via a speaker located out of S's view mid-way between her head and the viewing screen. Initial difficulties in obtaining film records of adequate quality were resolved by changing from Tri-X (ASA 200) to 4-X (ASA 320) film and by adding a specialized lens to the camera.

An effective procedure was devised for training Ss to close their eyes as a signal of readiness to respond to the conservation question. First, a number of verbal trials were administered in which S listened to a question asked by E, then closed her eyes and kept them closed until E said "Now open your eyes and tell me the answer." When S performed reliably in the verbal situation, she was placed on the bite-bar of the EM recorder. Taped instructions were delivered as follows: "In a minute, you are going to see a picture. I want you to look at the picture, and listen to the question, then, when you're sure you know the answer, close your eyes." A 35 mm slide depicting children engaged in some activity was then projected on the screen of the EM recorder. After a five second interval recorded instructions of the following type were delivered: "Here are some children playing in the snow. What do you think the children are making?" All questions required some degree of inference. When S had closed her eyes, she was told to come off the bite-bar and give her answer. Correct eye closure responses were verbally reinforced. Training continued with a different slide for each trial, until S emitted a correct eye closure response on three successive trials. A total of three trials was sufficient for criterion performance by the majority of Ss.

Eye closure training was conducted under conditions closely approximating those existing during EM recording and transfer to the recording situation proved satisfactory for all Ss. A tendency for anticipatory eye closure; that is, closing of the eyes before or during presentation of the question occurred for some Ss in earlier stages of training but no

EM data was lost as a consequence of premature eye closure. Recording procedure commenced immediately after eye closure training.

(6) Procedure for Eye Movement Recording

A Polymetrics Eye Movement Recorder, model V-1164-1, employing the principle of corneal reflection was used to obtain photographic records of EMs. Detailed information concerning this instrument may be found in the manufacturer's manual and in a report by Mackworth (1967). Briefly, a light spot from a remote source is reflected by mirror onto the cornea of the left eye. The camera, aligned with the left eye, records on film the moving corneal reflection spot superimposed on mirror image of whatever stimulus material is projected, from the rear, onto a ground glass viewing screen or presented on cards set in a holder immediately in front of the screen. Controls permit balancing of all light sources so that S experiences no discomfort from excessive contrasts. Figure 17 shows the design of the recorder used.

A Photo Optical 16 mm data analyzer (model 224-A) with remote hand controls was used for rear projection of motion picture stimuli on a screen with a viewing area 7.8" x 7.8". The screen was situated at a fixed distance of 26.5" ± 2" from S's eyes, variation in distance resulting from adjustment of a padded headrest to head size and slope of S's forehead. Instructions were delivered via a casette tape recorder situated out of the line of vision, between S and the viewing screen.

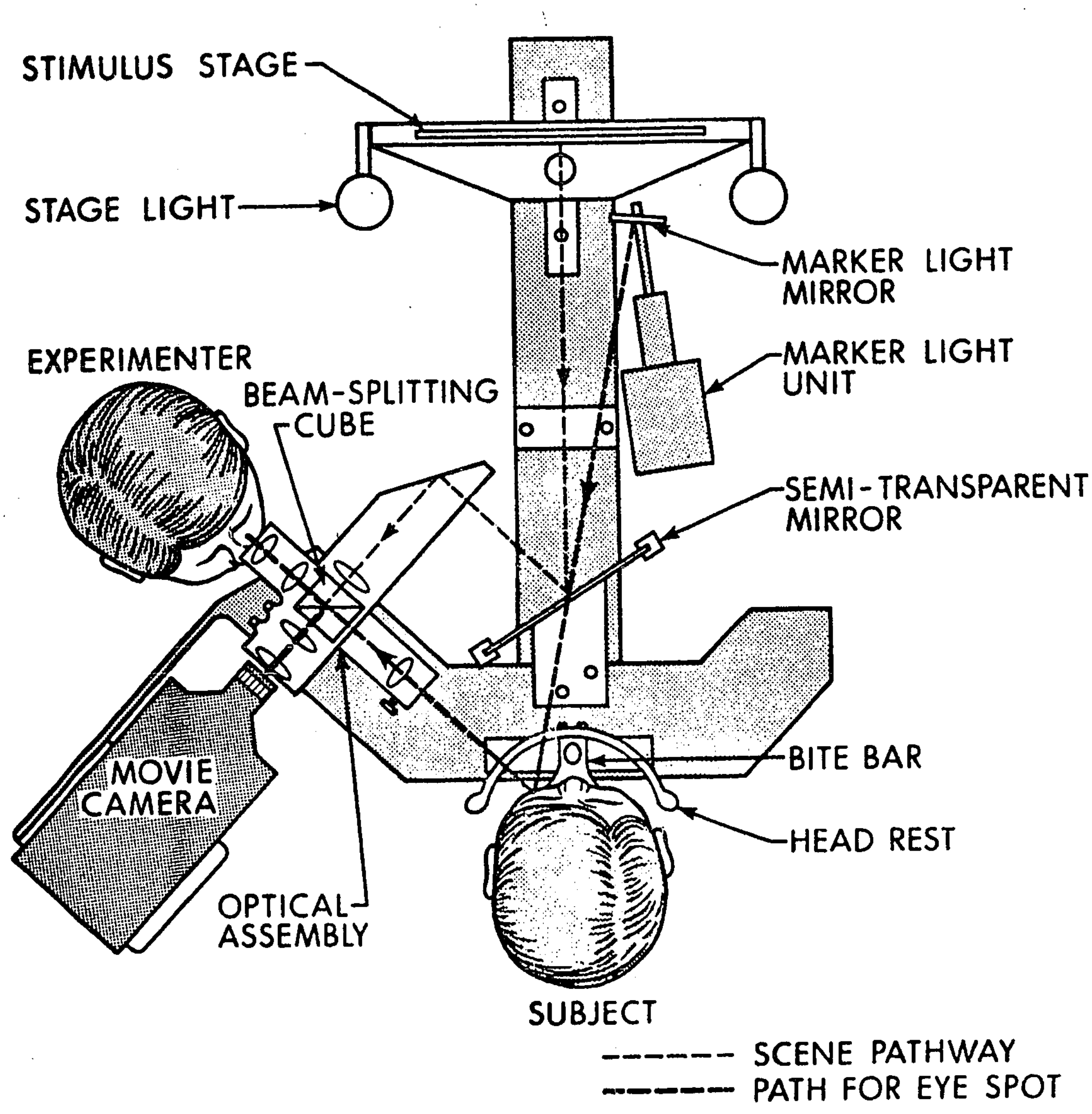

Fig. 17. Schematic view of the eye movement recorder.

Presentation of visual material was controlled by an assistant concealed from S's view and E, partially concealed from view by the structure of the EM recorder, operated the camera and remote hand controls for the tape recorder. The microphone for a second tape recorder used to record S's responses was located six inches to the right of S's head and out of her line of vision.

S was seated in a padded chair hydraulically elevated to correct viewing height. The S's back was firmly supported by supplementary padding so that little effort was required to maintain an upright sitting position. Supplementary side padding was used to discourage lateral body movement. In addition to the forehead support, a bite-bar was used to prevent head movement during filming. The bar consisted of a sterilized, U-shaped metal plate entirely covered to a depth of 1/4" in the back and 1/2" in the front with dental compound. Preparation of the bite-bar entailed softening the compound by immersion in warm water. The bar was then attached to the recorder directly in front of S's mouth and she was asked to bite on the compound in order to make a simultaneous impression of upper and lower teeth. The compound was then allowed to harden, and during EM recording, S engaged her teeth in the prepared impression.

Following recommendations suggested by Boersma and O'Bryan (1970) for EM recording with young children, a simply designed target stimulus was used for calibration purposes. A cardboard calibration card inserted in front of the viewing screen displayed an accurately centred outline of a daisy-shaped flower 3/4" in diameter. S was instructed to sit very still and "keep looking right at the pink spot (1/4" in diameter) in the middle of the flower." Continual verbal reinforcement proved helpful in sustaining fixation on target while the corneal reflection was located, brought into focus, and centred by horizontal and vertical adjustments of the camera. To permit subsequent assessment of the accuracy of calibration some film was exposed showing the reflection spot superimposed on the calibration card.

Grade I Ss were transported to the university in groups of two or three, by taxi. At the request of school authorities E accompanied children to and from school and this contact proved advantageous in terms of rapport. While waiting their turn in the EM laboratory Ss were supervised by a female assistant in a playroom provided with toys and drawing materials. Before entering the laboratory Ss were told that they were going to see some pictures and that "we're going to take some movies of your eye while you're watching." Upon entering the laboratory S was introduced to E's assistant and given an opportunity to examine all items of equipment. S was reminded that the projector and tape recorders were "just like the ones we used last time in school." Since camera adjustments were potentially distracting during the calibration phase, it proved particularly important to show S how the camera could be adjusted in three planes so that E could "see your eye through this tiny hole." Ss became familiar with the sound of the camera motor by watching while E made "a movie of" S's name. Before being seated, S was shown the bite-bar made by the previous S, often a classmate who could be referred to by name. It was explained that S would make her own bite-bar to help her keep her head steady. Most children appeared to know that movement resulted in blurred snapshots and this analogy was used to convey the necessity of "keeping still for eye movies." S was then seated and her bite-bar prepared. The delayed conservation post-test was administered while the bite-bar was hardening. Eye closure training, initial calibration and presentation of delayed generalization test number one followed in that order. Recalibration was required prior to presentation of delayed generalization tests numbers two and three respectively. For each test filming commenced at completion of calibration and continued without interruption until eye closure.

(7) Problems in EM Recording

As previously reported (p. 58) complete EM records were not obtained for all grade I Ss and for some Ss, no scoreable EM data were recorded. A discussion of problems associated with EM data loss is presented in Appendix A.

Scoring Procedures

(1) Classification of Verbal Responses

All justifying statements made by Ss who judged transformed and non-transformed sets to be equal in number were typed verbatim, randomly ordered within task groups, and classified independently by E and two judges acknowledged to be highly familiar with Piagetian developmental theory. Tasks were described in detail and judges were requested to adopt Piaget's (1969b, p. 98) criteria in assessing statements. Three categories were provided; namely logical justification, intuitive justification, and classification uncertain. Unanimous agreement was obtained in classification of 94.6 per cent of statements. Classification was determined by majority rule for the remainder. Two judges made no use of the uncertain category and agreed on classification of seven statements rated uncertain by the third judge. Judges did not meet to discuss classification of any items. A sample of justifying statements, together with classifications, is presented in Appendix B.

(2) Scoring of Eye Movement Data

EM data were hand scored using an analyst projector with single frame controls. A reliability coefficient of .92 was obtained for a random sample of six Ss whose complete EM records were scored and re-scored after a ten day interval.

Statistical Analysis

(1) Analysis of Verbal Response Data

The basic design for analysis of verbal conservation responses in post-tests and tests for generalization (Hypotheses 1 through 3b, pp. 47-49) consisted of a 2 x 2 x 2 model with two levels (high and low) of Factor A (mobility of intuitive correspondence); two types (experimental and placebo) of Factor B (treatment), and two classes (conserver and non-conserver) of Factor C (response class). Factors A and B were defined as fixed and Factor C as random.

In the case of Factor C, responses were dichotomized as follows. Responses designated conserver consisted of LC responses and responses designated non-conserver consisted of IC and NC responses which were summed to obtain cell values. This procedure was regarded as justified since for all comparisons the dependent variable was the proportion of LC responses.

Following Sutcliffe's (1957) method of multiple contingency analysis (mixed model) chi-square was partitioned as follows:

Source	df
χ^2(AC)	(a-1)
χ^2(BC)	(b-1)
χ^2(ABC)	(a-1)(b-1)(c-1)
χ^2(Total)	(ab-1)(c-1)

Values of chi-square were calculated as follows: where o refers to observed and e to expected cell values.

$$\chi^2(AC) = \sum_{i=1}^{a} \sum_{k=1}^{c} \left(\frac{o_{ik} - e_{ik}}{e_{ik}}\right)^2$$

$$\chi^2(BC) = \sum_{j=1}^{b} \sum_{k=1}^{c} \left(\frac{o_{jk} - e_{jk}}{e_{jk}}\right)^2$$

$$\chi^2(ABC) = \sum_{i=1}^{a} \sum_{j=1}^{b} \sum_{k=1}^{c} \left(\frac{o_{ijk} - e_{ijk}}{e_{ijk}}\right)^2 - \chi^2(AC) - \chi^2(BC)$$

$$\chi^2(Total) = \sum_{i=1}^{a} \sum_{j=1}^{b} \sum_{k=1}^{c} \left(\frac{o_{ijk} - e_{ijk}}{e_{ijk}}\right)^2 .$$

The expected value for a given cell was defined as N times the probability of an observation falling in that cell; that is $N \cdot p_{ijk}$.

For the mixed model $\chi^2(AC)$ and $\chi^2(BC)$ were interpreted as main effects of mobility and treatment respectively, and $\chi^2(ABC)$ was regarded as an expression of mobility-treatment interaction. Where interaction was inferred, all simple main effects were tested. Hypothesized simple effects were tested regardless of the significance of the interaction term.

Comparisons between pairs of groups (simple effects) were tested by means of chi-square tests for differences between independent proportions (Siegel, 1956, pp. 104-110). Yates' correction for continuity (Ferguson, 1959, pp. 171-172) was applied in all cases where expected values were less than five.

A chi-square test for association (Ferguson, 1959, p. 165) was applied to determine whether terminal conservation status was associated with mobility-treatment grouping. Comparisons between pairs of groups in proportion of Ss attaining a terminal status of logical conserver (Hypothesis 4, p. 50) were tested by means of chi-square tests for differences between independent proportions (Siegel, 1956, pp. 104-110). Yates' correction was applied in the case of expected frequencies less than five.

Finally, Hypothesis 5 (p. 50) concerning the difference between HME and LME groups in number of errors made in solution of tasks in the practice series was tested by means of Welch's test for difference between means for independent samples (Winer, 1962, pp. 36-39). The use of Welch's t' statistic was regarded as appropriate since assumptions could not be met with respect to homogeneity of variance in practice errors.

(2) Analysis of EM Data

(a) Comparisons between Groups

Hypotheses 6 and 7 (pp. 51-52) concerned comparison of verbal response groups in degree of visual centration during solution of each of three delayed generalization tasks.

Chi-square tests for association (Ferguson, 1959, p. 165) were used to determine whether verbal conservation response class (LC, IC, NC) was associated with exclusive centration (zero couplings) in the first three seconds of exposure time. Chi-square tests for difference between independent proportions (Siegel, 1956, pp. 104-110) were applied to compare pairs of response groups in proportion of Ss exhibiting zero couplings (Hypothesis 6).

Kruskal-Wallis one-way analysis of variance by ranks (Ferguson, 1959, pp. 270-272) was used to test for differences among response groups in rate of coupling (number of couplings per second) in total exposure time. Mann-Whitney U tests (Ferguson, 1959, pp. 268-269) were applied to compare pairs of response groups (Hypothesis 7).

Differences between response groups in number of fixations in total exposure time (Hypothesis 8, pp. 52-53) and differences in solution time (Hypothesis 9, p. 53) were tested by analysis of variance and Newman Keuls tests on ordered means (Winer, 1962, pp. 80-85).

(b) Comparisons within Groups

Hypotheses 10a, 10b, 10c and 10d (pp. 54-55) concerned differences in the distribution of successive fixations (mean length of run) between transformed and non-transformed sets. Correlated t tests (Winer, 1962, pp. 39-43) were used for these comparisons which were carried out within LC, IC and NC response groups respectively.

CHAPTER V

RESULTS AND DISCUSSION

Post-Test Performance Data

It was hypothesized that mobility of intuitive correspondence and treatment would interact in their effect on Ss' verbal conservation responses in immediate and delayed post-tests (Hypothesis 1) and that in each case the HME group would exhibit a higher proportion of LC responses than the HMP, LME, LMP or MC groups respectively (Hypotheses 2a and 2b).

Table 1 shows the proportions of LC, IC, NC and IC plus NC responses for immediate and delayed post-tests. Table 2 summarizes the results of multiple contingency analyses (main effects and interactions), and Table 3 presents results of group comparisons including the MC group.

Results showed significant mobility-treatment interaction in both immediate and delayed post-tests and examination of proportions of LC responses (Table 1) indicated that interaction was ordinal in nature. Main effects of treatment and mobility level were also significant.

The HME group exhibited a significantly higher proportion of LC responses than each of the other groups in the immediate and in the delayed post-tests supporting Hypotheses 2a and 2b respectively.

Post hoc comparisons indicated that there were no differences in proportions of LC responses among HMP, LME, LMP and

TABLE 1

PROPORTIONS OF LC, IC AND NC RESPONSES GIVEN BY GROUPS IN IMMEDIATE AND DELAYED CONSERVATION POST-TESTS

Proportion	Test	Group				
		HME	HMP	LME	LMP	MC
LC	Immed.	.75	.05	.23	.00	.05
	Del.	.75	.10	.18	.00	.10
IC	Immed.	.05	.00	.00	.00	.00
	Del.	.10	.00	.18	.06	.00
NC	Immed.	.20	.95	.76	1.00	.95
	Del.	.15	.90	.71	.94	.90
NC + IC	Immed.	.25	.95	.76	1.00	.95
	Del.	.25	.90	.89	1.00	.90

TABLE 2

SUMMARY OF MULTIPLE CONTINGENCY ANALYSES FOR IMMEDIATE AND DELAYED CONSERVATION POST-TESTS

Source	df	Immed. Post-Test χ^2	Del. Post-Test χ^2
Mobility	1	7.43*	6.79*
Treatment	1	22.20**	19.52**
Mobility x Treatment	1	5.04*	4.19*
Total	3	34.67	30.50

* $p < .05$
** $p < .001$

TABLE 3

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF LC RESPONSES BETWEEN GROUPS FOR IMMEDIATE AND DELAYED POST-TESTS

Groups Compared	Immed. Post-Test χ^2	Delayed Post-Test χ^2
HME-HMP	20.42**	17.29**
HME-LME	9.87*	7.69*
HME-LMP	21.44**	21.44**
HME-MC	20.42**	17.29**
HMP-LME	2.03	1.17
HMP-LMP	.07	.37
HMP-MC	.53	.28
LME-LMP	2.55	1.46
LME-MC	2.03	1.17
LMP-MC	.07	.37

* $p < .05$
** $p < .0005$

MC groups in either post-test.

Since retention over time was specified as one criterion of conservation, it was of interest to observe whether proportions of LC responses differed between immediate and delayed post-tests. Inspection of Table 1 shows that the difference did not exceed .05 (one subject) for any group. These differences, being of a magnitude not amenable to meaningful statistical analysis, were considered negligible hence it was inferred that on the basis of LC responses, retention was satisfactory over the two-week interval between the immediate and the delayed post-test.

It was also pertinent to assess the stability of individual post-test responses over time, to determine whether response changes were located in particular groups, and to analyze the nature and direction of such changes. A chi-square test of differences among groups in the proportion of Ss whose response classification differed in immediate and delayed post-tests showed that significant differences were present ($\chi^2 = 11.79$; df = 4; $p < .05$). Proportions of Ss whose response classification changed were, within each group respectively: HME .35; HMP .05; LME .11; LMP .06 and MC .05. In conjunction with these observed proportions, results of chi-square tests reported in Table 4 indicate that post-test responses were less stable in the HME group than in the HMP, LMP and MC groups respectively, but that there were no significant differences in response stability among the HMP, LME, LMP and MC groups.

TABLE 4

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF IMMEDIATE-DELAYED POST-TEST RESPONSE CHANGES BETWEEN GROUPS

Groups Compared	χ^2
HME-HMP	5.62*
HME-LME	2.69
HME-LMP	4.59*
HME-MC	5.62*
HMP-LME	.56
HMP-LMP	.01
HMP-MC	.00
LME-LMP	.36
LME-MC	.01
LMP-MC	.56

* $p < .05$

Of the seven HME Ss whose response classification differed in immediate and delayed post-tests, three changed from NC to LC; two changed from LC to IC; one changed from LC to NC, and one changed from IC to NC. Interpreting these data in terms of the direction of change, three Ss were classed as having advanced and four as having regressed in performance. Using the binomial test (Siegel, 1956, pp. 36-39) the difference was not significant ($p = 1.00$) suggesting that there was no clear evidence of improvement or regression in the post-test performance of HME Ss whose responses changed over time.

Immediate Generalization Performance Data

Proportions of LC, IC, NC and IC plus NC responses for four immediate generalization tests are shown in Table 5. Table 6 summarizes the results of multiple contingency analyses and Table 7 presents results of individual group comparisons.

Analyses indicate that Hypothesis 1 was supported for immediate generalization Task One where color was introduced as an irrelevant attribute and for immediate generalization Task Two where color was a potentially misleading attribute. Inspection of cell proportions indicated that interaction was again ordinal in nature. Significant main effects of treatment and mobility were observed for both Task One and Task Two.

Hypothesis 1 was rejected in the cases of immediate generalization Task Three (transformation followed by subtraction of an object) and Task Four (transformation followed by addition of an object) where interaction was non-significant.

TABLE 5

PROPORTIONS OF LC, IC AND NC RESPONSES GIVEN BY GROUPS IN THE FOUR TESTS FOR IMMEDIATE GENERALIZATION

Proportion	Test		Group				
			HME	HMP	LME	LMP	MC
LC	Imm. Gen.	1	.75	.10	.23	.00	.20
		2	.80	.10	.24	.06	.10
		3	1.00	.70	.59	.23	.60
		4	.95	.45	.41	.06	.50
IC	Imm. Gen.	1	.20	.35	.24	.24	.20
		2	.15	.10	.00	.06	.05
		3	.00	.00	.06	.12	.20
		4	.05	.05	.12	.12	.15
NC	Imm. Gen.	1	.05	.55	.53	.76	.60
		2	.05	.80	.76	.88	.85
		3	.00	.30	.35	.65	.20
		4	.00	.50	.47	.82	.35
IC + NC	Imm. Gen.	1	.25	.90	.77	1.00	.80
		2	.20	.90	.76	.94	.90
		3	.00	.30	.41	.77	.40
		4	.05	.55	.59	.94	.50

TABLE 6

SUMMARY OF MULTIPLE CONTINGENCY ANALYSES FOR IMMEDIATE GENERALIZATION TASKS

Source	df	Imm. Gen. No. 1 χ^2	Imm. Gen. No. 2 χ^2	Imm. Gen. No. 3 χ^2	Imm. Gen. No. 4 χ^2
Mobility	1	8.05*	7.89*	15.45**	15.88**
Treatment	1	19.21**	19.21**	8.54*	13.84**
Mobility x Treatment	1	4.35*	4.85*	.08	.38
Total	3	31.61	31.95	24.07	30.10

* $p < .05$
** $p < .001$

TABLE 7

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF LC RESPONSES BETWEEN GROUPS FOR THE FOUR IMMEDIATE TESTS FOR GENERALIZATION

Groups Compared	Imm. Gen. No. 1 χ^2	Imm. Gen. No. 2 χ^2	Imm. Gen. No. 3 χ^2	Imm. Gen. No. 4 χ^2
HME-HMP	17.21**	19.79**	3.63*	11.90**
HME-LME	9.74*	11.79**	7.65*	12.43**
HME-LMP	21.44**	20.32**	23.57**	29.38**
HME-MC	12.33**	19.79**	8.56*	10.16*
HMP-LME	1.24	.46		
HMP-LMP	.35	.02		
HMP-MC	.19	.28	.44	.10
LME-LMP	2.55	.94		
LME-MC	.02	.46	.00	.29
LMP-MC	2.02	.02	4.98*	8.56*

* $p < .05$
** $p < .0005$

Significant main effects were observed for both tasks indicating that conservation responses were influenced by effects of treatment and mobility acting independently.

Hypothesis 3a, namely that the proportion of LC responses would be higher in the HME than in each of the HMP, LME, LMP and MC groups was supported for all immediate generalization tasks. No significant differences were found among HMP, LME and LMP groups in Tasks One and Two, and post hoc comparisons between these groups were regarded as unjustified for Tasks Three and Four where significant mobility-treatment interaction was absent. Comparisons involving the MC group revealed no differences in the case of Tasks One and Two, however in Tasks Three and Four respectively MC Ss demonstrated a significantly higher proportion of LC responses than the LMP group.

Inspection of Table 6 suggested the possibility of differences among immediate generalization tasks. Accordingly, task differences were tested over the full sample using Cochran's Q test (Siegel, 1956, pp. 161-166). A significant Q value of 69.51 ($p < .0001$) was obtained. Since it was established that task differences existed, the next question of interest was whether task differences were present within groups. Table 8 summarizes results of Cochran's Q tests for task differences in proportion of LC responses across groups. Analyses suggested that type of task had no differential effect on responses of LMP Ss but that further analysis to determine the location of task effects was justified for other groups.

TABLE 8

Q TESTS FOR WITHIN GROUP TASK DIFFERENCES
IN PROPORTION OF LC RESPONSES ON
IMMEDIATE GENERALIZATION TASKS

Group	Value of Q	df
HME	9.27*	3
HMP	27.41**	3
LME	8.57*	3
LMP	7.72	3
MC	18.00**	3

* $p < .05$
** $p < .001$

Table 9 shows that between-task differences in proportion of LC responses were confined to the LME, HMP and MC groups. In conjunction with proportions reported in Table 5, results indicate that HMP Ss exhibited a significantly higher proportion of LC responses in Task Three (subtraction) and in Task Four (addition) than in either of Tasks One and Two which involved no change in the quantitative properties of the transformed set. The LME group and the MC group both displayed a higher proportion of LC responses in Task Three (subtraction) than in either of Tasks One and Two.

Analysis of task differences suggested that absence of mobility-treatment interaction in Tasks Three and Four could be largely explained in terms of the performance of the HMP and LME groups relative to that of the HME group. A number of alternative explanations for this performance pattern are proposed and discussed on pp. 129-133.

Delayed Generalization Performance Data

Proportions of LC, IC, NC and IC plus NC responses for the three delayed generalization tests are presented in Table 10. Table 11 summarizes results of multiple contingency analyses and Table 12 shows results of individual group comparisons.

Significant mobility-treatment interaction was observed in each of the three delayed generalization tasks (Table 11) and proportions (Table 10) revealed that this interaction was once again ordinal. Hypothesis 1 was thus supported for de-

TABLE 9

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF LC RESPONSES BETWEEN PAIRS OF IMMEDIATE GENERALIZATION TASKS FOR HME, HMP, LMP AND MC GROUPS

Tasks Compared	HME χ^2	HMP χ^2	LME χ^2	MC χ^2
Imm. Gen. 1 and 2	.00	.00	.00	.00
Imm. Gen. 1 and 3	3.20	6.12*	4.50*	6.12*
Imm. Gen. 1 and 4	2.25	5.14*	1.78	3.20
Imm. Gen. 2 and 3	2.25	10.08**	4.16*	7.11**
Imm. Gen. 2 and 4	.80	5.14*	1.80	3.12
Imm. Gen. 3 and 4	.00	3.20	1.50	1.33

* $p < .05$
** $p < .01$

TABLE 10

PROPORTIONS OF LC, IC AND NC RESPONSES GIVEN

BY GROUPS IN THREE TESTS FOR DELAYED GENERALIZATION

Proportion	Test		Group				
			HME	HMP	LME	LMP	MC
LC	Del. Gen.	1	.70	.10	.23	.06	.20
		2	.85	.15	.29	.18	.25
		3	.80	.20	.29	.06	.25
IC	Del. Gen.	1	.20	.40	.18	.12	.20
		2	.10	.35	.29	.12	.15
		3	.10	.20	.18	.18	.15
NC	Del. Gen.	1	.10	.50	.59	.82	.60
		2	.05	.50	.42	.70	.60
		3	.10	.60	.53	.76	.60
IC + NC	Del. Gen.	1	.30	.90	.67	.94	.80
		2	.15	.85	.71	.82	.75
		3	.20	.80	.71	.94	.75

TABLE 11

SUMMARY OF MULTIPLE CONTINGENCY ANALYSES FOR DELAYED GENERALIZATION TASKS

Source	df	Del. Gen. No. 1 χ^2	Del. Gen. No. 2 χ^2	Del. Gen. No. 3 χ^2
Mobility	1	5.78*	5.47*	6.09*
Treatment	1	14.42**	14.73**	15.18**
Mobility x Treatment	1	4.59*	6.56*	5.03*
Total	3	24.79	26.76	26.30

* $p < .05$
** $p < .001$

TABLE 12

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF LC RESPONSES BETWEEN GROUPS FOR THE THREE DELAYED TESTS FOR GENERALIZATION

Groups Compared	Del. Gen. No. 1 χ^2	Del. Gen. No. 2 χ^2	Del. Gen. No. 3 χ^2
HME-HMP	15.00**	19.60**	14.40**
HME-LME	7.94*	11.72**	9.58*
HME-LMP	15.67**	16.79**	17.83**
HME-MC	10.42**	14.55**	12.13**
HMP-LME	.44	.43	.08
HMP-LMP	.02	1.05	1.06
HMP-MC	.24	.14	.00
LME-LMP	.94	.16	1.82
LME-MC	.02	.00	.00
LMP-MC	.59	.02	1.26

* $p < .05$
** $p < .0005$

layed generalization tasks as was Hypothesis 3b which predicted a higher proportion of LC responses in the HME group as compared to each of the remaining groups (Table 12). No significant differences were found among the HMP, LME, LMP and MC groups in proportion of LC responses.

Inspection of cell proportions did not clearly preclude the existence of task differences, therefore a Cochran Q test for differences in proportions of LC responses among the three delayed generalization tasks was applied over the full sample. Because the value of Q approached significance (Q = 5.63; df = 2), task differences were tested across groups. None of the Q values obtained (HME 5.39; HMP 2.25; LME .59; LMP 4.08; MC .90) were significant indicating that type of task did not differentially affect the proportion of LC responses given by any group in delayed generalization tests. Absence of task effects in these tests was interpreted as further evidence of the discrepant nature of immediate generalization Tasks Three (subtraction) and Four (addition).

Terminal Conservation Status

A terminal status of logical conserver was attributed to Ss who gave LC responses in the immediate and delayed posttests and in all seven tests for generalization. By groups, proportions of Ss attaining logical conserver status were: HME .55; HMP .00; LME .12; LMP .00, and MC .00. The existence of excessively low expected frequencies for all groups except HME was regarded as justification for collapsing cells

(Ferguson, 1959, p. 171) and comparing the proportion of logical conservers in the HME group with the proportion in all other groups combined. Hypothesis 4 was strongly supported ($\chi^2 = 36.13$; $p < .0001$) and this finding provided convincing evidence of the greater incidence of permanent change in mental structures among members of the HME group. Two HME Ss (10%) gave LC responses in all but one of the criterion tests and the sum of IC and NC responses ranged from two to six over nine tasks for the remaining 35% of Ss.

Practice Errors

The experimental condition involved guided practice in solution of eight consecutive number conservation tasks comprising what was termed the practice series. For each task in this series any verbal judgment which denied the numerical equivalence of transformed and non-transformed sets was recorded as an error. Hypothesis 5 stated that the mean number of practice errors would be significantly higher for the LME group than for the HME group. This Hypothesis was strongly supported ($\bar{X}$ LME = 3.06, S.D. = 2.94; $\bar{X}$ HME = .20, S.D. = .68; $t' = 3.92$; df = 17.45; $p < .0005$).

Practice error means fail to reflect the error patterns in the two groups concerned. In the HME group 18 Ss (90%) made no errors whereas in the LME group seven Ss (41%) had error scores of zero. This difference proved significant ($\chi^2 = 9.99$; $p < .01$). In the case of the 12 Ss (ten LME and two HME) whose error scores ranged from one to eight, it seemed relevant to determine whether the proportion of errors changed over the eight tasks in the practice series. A test for changes among tasks yielded a significant Q value of 33.90 (df = 7; $p < .001$) and examination of error totals for each task (Tasks One through Eight, in order: 11, 10, 10, 9, 8, 3, 2, 7) revealed a systematic decrease in errors from Task One to Task Seven with a reversal of this trend in the final item of the series.

Findings regarding practice errors lend support to the argument that color-guided visual matching activity facilitates recognition of the numerical equivalence of transformed and non-transformed sets when intuitive correspondence is sufficiently mobile to permit assimilation of information derived from such activity. However, despite the fact that high mobile Ss made fewer errors, findings suggest that practice also had a facilitating effect on the judgments of low mobile Ss. Induced perceptual activity in conjunction with gradual withdrawal of task-relevant color cues provided what could be termed an errorless learning situation for 35% of Ss exposed to practice while the remaining 65% who made errors nevertheless displayed some evidence of learning.

Analysis of Intuitive Response Data

Intuitive (IC) responses were not considered to be conserving responses since the latter implied logical justification of conservation judgments. Nonetheless, intuitive responses reflect a less global and more analytic approach to conservation problems than do non-conserving responses and for this reason, it could be argued that Ss who gave IC responses showed some measure of advance in conservation status. In connection with the present investigation, it seemed important to determine whether mobility level, treatment, or interaction of two affected the proportion of intuitive responses observed in post-tests and tests for generalization. Table Bii (Appendix B) shows results of multiple contingency analyses on responses dichotomized as IC: LC + NC. In no instance was there justification for inferring that mobility or treatment influenced the proportion of IC responses.

A second question concerned the possibility of systematic increase or decrease in the proportion of IC responses over time. Neither trend was observed when IC responses in the immediate and delayed post-tests were compared ($\chi^2 = 1.88$; df = 1; $p = .17$). With regard to tests for generalization, the presence of differences among tasks was confirmed ($Q = 29.50$; df = 6; $p < .001$). Table Biii in Appendix B shows results of comparisons between generalization tasks. The proportion of IC responses proved significantly lower in immediate generalization tests two, three and four than in immediate generalization test one and delayed generalization tests one and two respectively. Thus, while there was no evidence of increase in IC responses in post-test performance, results were moderately suggestive of increase in the case of generalization tests. In view of the obviously distinctive nature of immediate generalization tests three and four (subtraction and addition), this trend was not considered to provide definitive evidence of learning and may simply reflect the general increase in LC responses in the subtraction and addition items.

Effect of Educational Level

In a study which dealt with one aspect of the development of number concepts, it appeared reasonable to expect that Ss who had been exposed to the grade I curriculum for several months might perform better than kindergarten Ss of the same mobility level under the same treatment conditions. To investigate the possibility of confounding due to effects of educational level, Fisher's exact probabilities (Siegel, 1956, pp. 96-104) were calculated to test the null hypothesis of independence between educational level and conservation response classification within the two groups (HME and HMP) where grade I Ss constituted a three-quarters majority. Exact probabilities are shown in Table Bi of Appendix B. In no instance could the null hypothesis be rejected, therefore it was inferred that educational experience was not a factor differentially affecting verbal conservation judgments within the HME and HMP groups.

Discussion of Findings Relative to Verbal Response Data

Table 13 summarizes decisions based on tests of Hypotheses 1 to 5 inclusive. With the exception of the generalization tests involving subtraction and addition which merit

TABLE 13

RESULTS OF TESTS OF HYPOTHESES RELATING TO VERBAL CONSERVATION JUDGMENTS

Hypotheses			Description	Findings
1:	Mobility-Treatment Interaction		Immediate post-test	S[a]
			Delayed post-test	S
			Imm. Gen. test 1	S
			Imm. Gen. test 2	S
			Imm. Gen. test 3	NS[b]
			Imm. Gen. test 4	NS
			Del. Gen. test 1	S
			Del. Gen. test 2	S
			Del. Gen. test 3	S
2:	Post-Test Performance	a	Imm. post-test	S
		b	Del. post-test	S
3:	Generalization	a	Imm. Gen. tests 1, 2, 3, and 4	All S
		b	Delayed Gen. tests 1, 2, 3	All S
4:	Terminal Cons. Status			S
5:	Practice Errors		Practice series error scores	S

[a] Supported.

[b] Not supported.

separate discussion, the criterion performance level of all groups was relatively constant over a two week period and over a sequence of criterion tasks which varied with respect to the number, color and form of objects, and the spatial orientation and configuration of sets. Neither exposure to successive tasks nor time *per se* appear to result in conservation gains during the post-treatment period in which data was collected, hence observed changes in conservation status were regarded as attributable to experimental factors.

Results showed a clear and consistent difference between the performance of the HME group and other groups in all tests except the subtraction and addition problems. Apparently girls who were able to compensate for configurational disparities in the mobility test situation were better prepared to profit from the practice condition than their counterparts whose mobility test decisions were predicated on configurational data. Girls exposed to a period of activity similar to the practice condition in length and general format but unrelated to number concepts failed to show appreciable gains in conservation status regardless of their mobility classification. Overall, the performance of the MC group closely resembled that of the HMP group and differed only from that of the HME group. This suggests that exposure to testing for mobility of intuitive correspondence did not affect performance in criterion tasks. Educational level appeared to have no differential effect. Intuitive responses reflecting transitional conservation status were comparatively infrequent and relatively constant across tasks suggesting that gains in conservation status could be adequately described by referring to LC response criteria.

According to the most stringent of criteria, namely terminal conservation status, over half of the girls in the HME group could be said to have acquired number conservation. Thus, for a convincing proportion of girls initially classified as high mobile, one twelve minute period of guided but non-reinforced practice proved sufficient to produce unequivocal evidence of structural change. In the absence of evidence concerning possible effects of increasing the number or duration of practice periods it is impossible to determine whether additional factors interacting with practice and mobility level serve to influence the rate of number conservation attainment. An acknowledged limitation of the present study is its modest contribution to identification of factors which can be used for predictive purposes. Why some HME Ss did not acquire number conservation remains to be explained.

Because they may bear on the process of conservation attainment, the qualitative characteristics of LC and NC responses warrant description. As previously stated (p. 44), Piaget recognizes four types of logical justification; namely, simple identity, additive identity, reversibility by inversion, and compensation. Seventy-two per cent of all LC responses fell in the simple identity category. The following example is typical: "They were the same number to begin with and those just went up in two lines so they're still the same number." Twenty-five per cent of LC responses conveyed the fact that objects in the transformed set could be returned to their original position (reversibility by inversion). Less than two percent could be categorized as indicative of compensation; that is, that changes in configuration of the transformed set are compensated by change in the spacing between objects. LC statements tended to be expressed in a narrative form in which S referred first to the pre-transformed state and then proceeded to describe the dynamics of the transformation. Ninety-five per cent of all LC responses included use of the past tense. Possibly this was due to the fact that most transformations were sequential, though the narrative form predominated equally strongly in tasks which involved simultaneous displacement of objects. In any event, there appeared little doubt that Ss who gave LC responses were able to represent both static states and the physical course of transformations. In contrast, 84% of all NC justifications were phrased exclusively in the present tense and most referred to configurational attributes. Examples of justifying statements are presented in Appendix B.

The unanticipated increase in LC responses given by HMP Ss and to a lesser extent by LME and MC Ss in addition and subtraction tasks merits thorough discussion. Addition and subtraction tasks were included for the purpose of assessing possible effects of verbal response set. In all other tasks a correct response indicated that sets contained the <u>same</u> number of objects after transformation. Despite the fact that Ss were given no information concerning the correctness of their responses, silence on E's part could have been interpreted as verification producing simple instrumental effects on the frequency of "same" responses. Had performance deteriorated in addition and subtraction problems, verbal set might have been suspected. Instead, performance improved for three groups in the only tasks where "same" was an incorrect answer. Clearly, this phenomenon could not be interpreted as an artifact of set to judge transformed and non-transformed elements unequal since Ss whose performance improved in addition and subtraction tasks provided what were classed as logical explanations in support of their judgments.

One feature which distinguished the tasks in question was the nature of materials which, for these problems and these problems only, were candies. Pilot investigations revealed that removal of an object from a set was interpreted by some Ss as a form of transformation. Whether the object removed was held by E or placed out of sight some Ss continued to regard it as part of the transformed set reporting that sets were still equal in number because all the objects in the transformed set had been moved and one had been moved twice. This problem was resolved by using candy which E could convincingly delete from the transformed set by consuming it. Although no candy was given to Ss, its presence, together with E's behavior, could have altered motivational conditions by arousing expectation of candy rewards. However, as an explanation for performance differences, this interpretation fails to account for Ss' ability to justify their judgments logically or for the fact that LME and MC groups exhibited improved performance in the subtraction task but not in the addition problem when candies were used in both cases. Nonetheless, the possibility of interaction between type of material, treatment, and mobility level cannot be discounted.

Assessment of responses in addition and subtraction tasks poses problems which do not arise in conventional conservation tasks. Ostensibly, reference to the fact of addition or subtraction as an explanation for the inequality of previously equivalent sets may be accepted as evidence of number conservation. This inference is valid only when S answers the actual conservation question which requires a judgment concerning the relative quantity of objects in two sets. If the child interprets the conservation question as meaning that he is to report whether the transformed set contains more objects than it did initially, he may supply what appears to be a correct primary response, (e.g., "There are more here") supported by an apparently logical explanation (e.g., "...because you put another candy in."). In the present study, no attempt was made to verify Ss' interpretations of the conservation question, consequently observed proportions of LC responses in addition and subtraction problems may be inflated by inclusion of pseudo-logical explanations. In the case of conventional problems, misinterpretation of the conservation question is normally apparent in the child's explanatory statement. Possibly, misinterpretation is more probable when two successive events, namely the transformation and the addition or deletion of an object intervene between initial and final judgments, and this may be especially true of non-conservers who characteristically base their judgments on recent as opposed to remote events. In summary, a plausible explanation for the performance pattern of HMP Ss is that the cognitive complexity of the addition and subtraction tasks resulted in misinterpretation of the conservation question which in turn produced pseudo-logical responses.

The performance pattern of LME Ss may be interpreted by referring to the configurational properties of transformed sets in the addition and subtraction problems. As shown in Figures 14 and 15 (pp. 82-83) transformations in both tasks resulted in configurations Ss could be expected to perceive as "smaller" in the absolute as well as the relative sense. Ordinarily, non-conservers rely on configuration to explain what they believe to be the numerical inequality of sets. Their previous responses suggested that this was generally true of the LME group. In the subtraction problem, removal of an object would yield results consistent with a tendency to perceive the transformed set as "smaller". Under such conditions, particularly if subtraction was emphasized by E's action of eating a candy, non-conservers might declare that sets were unequal and refer to the act of subtraction by way of explanation. Under conditions of conflict engendered by disparity between perceptual data and global notions concerning the effects of addition, decisions and explanations might remain dominated by configurational cues. Obviously, such an interpretation is tenable only with the additional assumption that treatment effects enabled LME Ss to partially disregard configurational cues in the favorable situation presented by the subtraction task. LMP Ss showed no significant degree of improvement in either of the addition or subtraction items.

A parsimonious, if less than satisfactory interpretation of performance trends is simply that the particular characteristics of the addition and subtraction tasks engendered cognitive conflict of a kind which facilitated correct conservation judgments. Under this assumption all LC responses could be regarded as valid evidence of operational thought. Successful resolution of cognitive conflict implies structural change. Because there was no indication of transfer to subsequent tasks, explanations involving postulated pseudo conservation were preferred.

Analysis of Eye Movement Data

Eye movements were filmed during solution of delayed generalization tasks one, two and three for the purpose of assessing their value as subsidiary conservation criteria. For this portion of the study, verbal response classification was compared with visual behavior recorded during the interval between completion of the transformation and eye closure signalling the S's readiness to respond to the conservation question. Comparisons were made between groups and within groups.

The EM subsample consisted in total of 34 grade I girls for whom scoreable EM data were available on one or more of the three generalization tasks. Because complete EM records were obtained for 20 Ss only, the composition of the EM subsample was not constant across tasks and this fact precluded comparisons among tasks. For tasks one, two and three, NS were 28, 29 and 27 respectively. Table Biv in Appendix B shows the composition of the EM subsample by mobility-treatment classification.

Comparisons Between Verbal Response Groups

It was postulated that in the brief period immediately following completion of a transformation, evidence of visual centration would be manifest in complete absence of shifts of fixation (couplings) between transformed and non-transformed sets. Hypothesis 6 predicted that the proportion of Ss exhibiting zero couplings in the first three seconds of exposure time would be higher for Ss who gave NC responses than for those who gave LC responses. Table 14 shows that there were significant differences among groups in tasks one and two where the proportion of Ss exhibiting zero couplings was higher in the NC group than in the LC or IC groups. No significant differences were observed in task three.

With respect to evidence of visual centration during total solution time, Hypothesis 7 stated that the rate of coupling would be lower for Ss who gave NC responses than for

TABLE 14

COMPARISON OF NC, IC AND LC RESPONSE GROUPS IN PROPORTION OF Ss EXHIBITING EXCLUSIVE VISUAL CENTRATION IN THE FIRST THREE SECONDS OF EXPOSURE TIME

Task		Response Group			χ^2	Group Comparisons χ^2 df = 1		
		LC	IC	NC	df = 2	NC-LC	NC-IC	LC-IC
1	n =	10	9	9	5.24[a]	4.33*	3.60*	.16
	prop. 0 couplings	.30	.33	.77				
2	n =	9	9	11	9.94**	3.03*	9.89*	2.49
	prop. 0 couplings	.44	.11	.82				
3	n =	9	7	11	2.28			
	prop. 0 couplings	.33	.71	.54				

[a] $p = .057$

* $p < .05$

** $p < .01$

those who gave LC responses. Table 15 shows that the direction of the relationship was as predicted but that rejection of the null hypothesis was unjustified. In Task One, Ss who gave IC responses showed a higher rate of coupling than Ss whose responses were classed NC, and in Task Three rate of coupling was slower for IC than for LC Ss.

Results of analyses of couplings suggest that during the early stage of the solution process in Tasks One and Two NC Ss exhibited a comparatively strong tendency to centre their attention on one set exclusively. Relative to other groups this tendency was less pronounced during total solution time. Coupling patterns, especially those exhibited by the IC group, may have been influenced by the arrangement of objects in the transformed sets. In Task One objects formed a circle and in Task Two they were aligned in a diagonal. Hypothetically, neither of these arrangements would lend themselves to counting, or to number recognition by grouping, as readily as the arrangement in Task Three where the transformed set consisted of two parallel columns each containing four objects. The comparatively rapid rate of coupling among IC Ss in Task One could reflect empirical matching activity whereas their tendency toward centration in Task Three could indicate efforts to enumerate objects in a single set.

Ss who give IC responses are commonly described as transitional conservers who have not yet conceptualized the constancy of the equivalence relationship over transformations and must therefore seek empirical evidence to substantiate

TABLE 15

ANALYSIS OF VARIANCE BY RANKS AND MANN-WHITNEY TESTS ON COUPLINGS PER SECOND IN TOTAL EXPOSURE TIME

Task	N	Group n's			H	Groups Compared		
						LC > NC	IC > NC	IC > LC
		LC	IC	NC	df = 2	z	z	z
1	28	10	9	9	5.81[a]	1.14	2.42*	.12
2	29	9	9	11	3.51	1.21		
3	27	9	7	11	5.69[b]	1.17	-1.08	-2.28*

[a] $p = .053$

[b] $p = .055$

* $p < .05$

their judgments of relative number. It was hypothesized that the IC group would exhibit a greater number of fixations than other groups in total exposure time (Hypothesis 8) and would take longer to reach solution (Hypothesis 9). Table 16 shows results of analysis of variance on number of fixations. No differences were found among groups in Tasks One and Three, and in the case of Task Two homogeneity assumptions of the analysis of variance model could not be met. Group means and standard deviations are presented in Table 17. Differences in variances were tested and it was found that the variance for the IC group was significantly greater than for the LC group ($F = 13.65$; $df = 8,8$; $p < .001$) and that variance in the NC group exceeded variance in the LC group ($F = 5.19$; $df = 10,8$; $p < .01$). Analysis of variance by ranks (Kruskal-Wallis in Siegel, 1959, pp. 184-193) revealed no differences among response groups in number of fixations recorded over total solution time in Task Two ($H = 4.41$; $df = 2$; $p = .11$).

Analysis of variance on solution time in seconds indicated that homogeneity assumptions could not be fulfilled (Table 18). When variances were compared between groups it was found that in every task solution time was significantly less variable for LC than for IC or NC Ss. Furthermore, in Tasks Two and Three the variance in solution time was significantly greater for IC than for NC Ss. Results of tests for differences in variance are shown in Table 19.

When solution time data were ranked, analysis (Kruskal-Wallis) suggested that differences among groups occurred only

TABLE 16

ANALYSIS OF VARIANCE ON NUMBER OF FIXATIONS IN TOTAL EXPOSURE TIME

Task	Source	df	Mean Square	Fmax	F	p
1	Between	2	6.38	3.30	1.59	.21
	Within	25	4.00			
2	Between	2	11.73	13.65*		
	Within	26	6.70			
3	Between	2	1.84	3.29	.09	.91
	Within	24	20.60			

* $p < .005$

TABLE 17

MEAN NUMBER OF FIXATIONS IN TOTAL EXPOSURE TIME

Task	Response Group					
	LC		IC		NC	
	M	*SD*	*M*	*SD*	*M*	*SD*
1	8.60	4.08	13.66	7.41	10.00	6.18
2	8.55	3.21	14.88	11.85	8.90	7.33
3	7.92	3.89	8.31	6.42	7.40	3.53

TABLE 18

ANALYSIS OF VARIANCE ON SOLUTION TIME IN SECONDS

Task	Source	df	Mean Square	Fmax
1	Between	2	4.05	10.66*
	Within	25	1.88	
2	Between	2	7.11	25.83**
	Within	26	2.62	
3	Between	2	31.60	20.44**
	Within	24	8.03	

* $p < .01$
** $p < .001$

TABLE 19

TESTS ON DIFFERENCES IN TOTAL SOLUTION TIME VARIANCES BETWEEN RESPONSE GROUPS

Task	Groups Compared	Means	Variances	df	F
1	NC	8.72	19.20	8	5.73*
	LC	6.36	3.35	9	
	IC	10.48	35.78	8	10.68**
	LC	6.36	3.35	9	
	IC	10.48	35.78	8	1.86
	NC	8.72	19.20	8	
2	NC	7.24	10.44	10	3.89*
	LC	6.30	2.68	8	
	IC	11.53	69.36	8	25.88***
	LC	6.30	2.68	8	
	IC	11.63	69.36	8	6.64**
	NC	7.24	10.44	10	
3	NC	5.89	4.26	10	3.73*
	LC	6.07	1.14	8	
	IC	9.46	23.51	6	20.62**
	LC	6.06	1.14	8	
	IC	9.46	23.51	6	5.51*
	NC	5.89	4.26	10	

* $p < .05$
** $p < .01$
*** $p < .001$

in Task Two. Hypothesis 9 was supported for Task Two where solution time was significantly greater for the IC group than for either the LC or NC groups (Table 20).

Number of fixations in total solution time was shown to be unrelated to response classification. Because the IC group exceeded other groups in the time taken to reach solution in Task Two, it might be inferred that in this task IC Ss demonstrated fixations of longer duration. In view of the extreme variability in solution time among IC Ss, this inference was regarded as unwarranted as was any generalization concerning the behavior of IC Ss as a group. During each period following completion of a transformation some IC Ss appeared to have engaged in considerable perceptual activity while others reached solution relatively quickly. Variability in solution time was consistent with variability in the explanatory verbal statements given by Ss whose responses were classed IC. The following list consists of justifying statements given by IC Ss in Task One. Corresponding solutions times are quoted.

S. No.	Justifying Response	Solution Time in Seconds
61	"Because there's a circle."	9.0
88	"Because I counted."	8.0
89	"I counted them and they both had seven."	11.8
34	"Because the bottom one went around."	5.5
30	"Because, um, there's not more than the other."	5.9

TABLE 20

ANALYSIS OF VARIANCE BY RANKS AND MANN-WHITNEY

TESTS ON SOLUTION TIME IN SECONDS

Task	N	Group n's			H	Groups Compared		
						IC > LC	IC > NC	LC > NC
		LC	IC	NC	df = 2	z	z	z
1	28	10	9	9	4.24			
2	29	9	9	11	7.65*	2.07*	2.08*	.45
3	27	9	7	11	3.56			

* $p < .05$

S. No.	Justifying Response	Solution Time in Seconds
6	"Because there's three and three there and two makes eight; then I know there was three and three in the circle and two more made eight."	5.8
29	"Because you put them in a circle and the other ones are lines."	8.9
28	"I looked at them. It just looks like it."	24.0
27	"It looks like it."	15.3

Depending on a variety of factors including individual strategies for comparing sets, some Ss may have derived sufficient information to form a judgment during the interval preceeding completion of the transformation. Speed of transformations was thought to preclude reliable counting by young children, however some may have attempted to count objects as they moved. Use of empirical strategies was not implicit in the verbal responses of more than half the IC group in any task.

The relative homogeneity of solution time among LC Ss provides convincing evidence of the distinctiveness of this group, especially in comparison with the IC group, but also in comparison with the NC group. If IC Ss employed a variety of strategies including counting to determine the number of objects in each set, and if NC Ss tended to look for configurational clues, then the narrow range of solution times in the LC group may reflect lack of dependence on perceptual data of any kind. Aside from remaining sufficiently attentive to detect addition or subtraction of objects, the true conserver should be convinced of the equivalence of sets immediately upon completion of the transformation. LC Ss did not display a shorter solution time than other groups, however it is distinctly possible that for a brief period after completion of the transformation LC Ss merely watched to insure that no additions or deletions occurred.

Comparisons Within Verbal Response Groups

A run was defined as two or more successive fixations on the same set. It was postulated that Ss who gave NC responses would demonstrate longer runs on one set than on the other and that this set would be the one judged to be greater in number. No difference between mean length of run on transformed and non-transformed sets was predicted for the LC and IC groups. Table 21 shows results of t tests for differences in mean length of run between sets.

Hypothesis 10a was supported for Task One where the NC group displayed greater mean length of run on the transformed set both in the first three seconds of exposure time and in total exposure time. Mean length of run was significantly greater on the transformed set in total exposure time for Task Two and in the first three seconds for Task Three. Results were thus consistent with previous research (O'Bryan and Boersma, 1971; Wilton and Boersma, 1973) in showing a marked tendency toward visual centration on the part of non-conservers.

Hypothesis 10b, namely that NC Ss would demonstrate

TABLE 21

CORRELATED t TESTS ON DIFFERENCES BETWEEN MEAN LENGTH OF RUN ON TRANSFORMED AND NON-TRANSFORMED SETS IN THE FIRST THREE SECONDS AND IN TOTAL EXPOSURE TIME

Response Group	Del. Gen. Task	Exposure Time	M Length Run Trans. Set	M Length Run Non-Trans. Set	df	t
NC	1	1st 3 sec.	2.57	0	8	7.63***
		Total	5.30	.44	8	5.69***
	2	1st 3 sec.	2.02	.89	10	1.40
		Total	3.40	.87	10	2.83*
	3	1st 3 sec.	1.83	.45	10	2.34*
		Total	3.32	.73	10	2.08
IC	1	1st 3 sec.	.98	.27	8	1.49
		Total	2.76	1.47	8	.92
	2	1st 3 sec.	.81	.42	8	.74
		Total	2.97	2.27	8	.47
	3	1st 3 sec.	1.66	.78	6	.87
		Total	2.55	4.07	6	.58
LC	1	1st 3 sec.	1.55	.20	9	3.19*
		Total	3.19	.39	9	4.14**
	2	1st 3 sec.	1.38	.71	8	.77
		Total	2.25	1.22	8	1.77
	3	1st 3 sec.	1.27	.55	8	1.09
		Total	1.84	1.93	8	.08

* $p < .05$
** $p < .01$
*** $p < .001$

greater mean length of run on the set they subsequently judged to contain the most objects, was not supported. Contrary to expectation, Table 22 shows that in Task One NC Ss had significantly longer runs on the set judged to be smaller in number. As Table 21 indicates, this was the transformed set, and it is pertinent to observe that in Task One objects in the transformed set formed a circle which, in configurational terms, was clearly "smaller" than the row comprising the non-transformed set. No differences were observed in Tasks Two and Three. For Task Two, the diagonal formed by the transformed set could be perceived either as longer or as shorter than the non-transformed set depending upon which extremity S attended to. If S examined the upper extremities she could well have concluded that the non-transformed set was longer and thus greater numerically. If the lower extremities were compared S might have reached the opposite conclusion (see Figure 16, p. 85). Apparently, in Task Two, NC Ss centred their attention on the transformed set which some judged to be greater and others judged to be lesser in number.

In Task Three the transformed set changed from a horizontal row to two vertical columns which, if perceived globally, could have appeared "smaller". Alternatively, if Ss were influenced by the division of this set into two parts they might have concluded that it was greater in number. Again, NC Ss centred their visual activity on the transformed set, but displayed lack of unanimity concerning its relative numerical status.

TABLE 22

CORRELATED t TESTS ON DIFFERENCES BETWEEN MEAN LENGTH OF RUN ON THE SETS JUDGED GREATER AND LESSER IN NUMBER BY THE NC RESPONSE GROUP

Del. Gen. Task	Exposure Time	M Length Run Greater Set	M Length Run Lesser Set	df	t
1	1st 3 sec.	.33	2.33	8	-2.72*
	Total	1.12	4.62	8	-2.41*
2	1st 3 sec.	1.44	1.47	10	- .04
	Total	2.32	2.92	10	- .36
3	1st 3 sec.	1.00	1.28	10	- .38
	Total	1.36	2.70	10	- .94

* $p < .05$

Findings respecting centrative activity on the greater set were at distinct variance with those reported by O'Bryan and Boersma (1970) and Wilton and Boersma (1970). These authors attributed centration on the greater of two elements to primary illusory effects, namely the error of the standard which Piaget (1969a) believes to arise from compensations basic to attainment of perceptual constancies. The centrative activity of NC Ss in the present study was clearly not attributable to illusion of the standard in Task One where the transformed set appeared and was judged by the majority of Ss to be smaller than the standard. Perceptual field effects created by the arrangement of transformed objects in a circle may well have influenced the distribution of fixations and if so, could account for the degree of centration observed in LC Ss in Task One. Eight out of nine NC Ss showed greater mean length of run on the transformed set, and of these, seven judged the non-transformed set to be greater in number. If field effects were responsible for visual centration there is no assurance that they were sufficient to affect the cognitive processing of perceived configurational disparities.

Hypothesis 10c predicting no difference between mean length of run on transformed and non-transformed sets for the IC group was supported for all tasks. Hypothesis 10d was supported for Tasks Two and Three only. During the first three seconds and in total exposure time, the LC group displayed greater mean length of run on the transformed set. As previously suggested, field effects could be responsible for this finding which is otherwise difficult to interpret.

Table 23 summarizes results of tests on Hypotheses 6 to 10d inclusive.

TABLE 23

RESULTS OF TESTS OF HYPOTHESES RELATING TO EYE MOVEMENT PATTERNS

Hypotheses		Description	Findings
6:	Exclusive Centration	1st 3 sec.	S[a] Tasks 1 and 2 NS[b] Task 3
7:	Rate of Coupling	Tot. exp. time	S Tasks 1 IC > NC NS Tasks 2 and 3
8:	No. of Fixations	Tot. exp. time	NS Tasks 1, 2 and 3
9:	Total Solution Time		S Task 2 NS Tasks 1 and 3
10:	Mean Length of Run	a) NC 1st 3 sec.	S Tasks 1 and 3 NS Task 2
		Tot. exp. time	S Tasks 1 and 2 NS Task 3
		b) NC Greater Set 1st 3 sec. Tot. exp. time	 NS Tasks 1, 2 and 3 NS Tasks 1, 2 and 3
		c) IC 1st 3 sec. Tot. exp. time	S Tasks 1, 2 and 3 S Tasks 1, 2 and 3
		d) LC 1st 3 sec.	S Tasks 2 and 3 NS Task 1
		Tot. exp. time	S Tasks 2 and 3 NS Task 1

[a] Supported.

[b] Not supported.

CHAPTER VI

CONCLUSIONS AND IMPLICATIONS

Conclusions and Implications for Theory

The present study was undertaken to test Piaget's (1969b) contention that co-ordinating perceptual activity facilitates conservation of numerical rquivalence when relevant mental structures are sufficiently mobile to permit assimilation of information derived from such activity.

Major findings strongly support Piaget's position. Non-conserving girls who demonstrated relatively greater mobility of intuitive correspondence showed convincing evidence of number conservation after one twelve minute practice period involving induced perceptual activity. The same practice condition resulted in little evidence of structural change among non-conserving girls with relatively low mobility of intuitive correspondence. Regardless of their mobility classification, non-conservers who were not exposed to practice displayed no appreciable change in conservation status over the two week period in which data were collected.

Effects of mobility level and practice can be interpreted theoretically by referring to Elkind's (1967) analysis of the conservation problem. Elkind proposes that conservation implies a three stage process. In the paradigm which follows, _S_ refers to the standard or non-transformed set; _V_ signifies the variable or transformed set before transformation, and $\underline{V}^1$ denotes the transformed set in its post-transformed state. The solution process may then be represented as:

$$S = V$$

$$V = V^1$$

$$\therefore S = V^1$$

Both the initial judgment S = V and the terminal inference S = V^1 are manifested in the child's verbal statements. The intermediate judgment V = V^1 is implicit as a logical condition of the inference S = V^1 and involves identity or constancy of the transformed set.

In debate with Bruner, Piaget (1967) has insisted that in the context of the conservation problem, identity does not refer to simple object permanence, but rather to a reversible operation abstracted from particular stimulus content. As evidence, Piaget cites the fact that simple identity, that is, knowledge that V = V^1 in a particular concrete instance, does not automatically produce conservation. Present findings tend to substantiate this conclusion. Despite the fact that transformations were sequential and slow enough to permit visual tracking of individual objects in practice tasks, some Ss who correctly matched corresponding object pairs and declared that there was "a ball for every girl" at the conclusion of each transformation, nevertheless concluded that sets were unequal in number. Presumably these

Ss were able to represent the transformations they had witnessed, otherwise, their matching attempts would have proved inaccurate; however, judging from their decisions, identity was not co-ordinated with the prior judgment S = V to yield the logical inference $S = V^1$. In the absence of integrative processing, configurational cues appeared to be the predominating determinant of conservation judgments.

The question of integration seems particularly relevant. As Elkind points out, identity is an insufficient condition of conservation since what the child must conserve is not the transformed set but rather the relationship of numerical equivalence between sets. The critical difference between responses of high and low mobile experimental Ss seemed to involve integration of judgments. Explanatory statements given by the majority of HME Ss in post-tests and tests for generalization correspond with Elkind's paradigm to a surprising degree. The following example is typical: "They had the same number to begin with and those ones just stretched out into a longer line, so they have the same number still." Such statements can be regarded as spontaneous because no verbal model was provided during the practice session or thereafter. In contrast, LME Ss typically made no reference to past events and explained their decisions in terms of what they presently perceived, namely, disparity in the configuration of sets.

Although they were exposed to practice under conditions which provided direct perceptual evidence of the equivalence of sets, HME girls did not persist in attempts to match corresponding objects nor did they report counting or alternative methods for obtaining relevant perceptual information. They were not distracted by irrelevant or intentionally misleading color cues and showed comparatively little variability in the time required to reach solution of delayed generalization tasks. All available evidence thus points to the conclusion that the HME group differed from other groups by virtue of their capacity to arrive at conservation decisions deductively. Because they were non-conservers at the outset, practice clearly contributed to structural change and the nature of that contribution can be clarified by referring to the operational definition of high mobility of intuitive correspondence.

The mobility test situation presented Ss with a problem analogous to the conservation problem except in the matter of transformation. Using Wohlwill's terms, it differed along dimensions of redundancy and contiguity which were both greater than in conservation tasks. Having constructed a set equal in number to a given set, S was faced with conflicting perceptual data in the form of concentric circles of differing diameter. The physical correspondence of analogous objects was not disturbed but global size cues were compelling. In terms of requisite operations, it is clear that the mobility task demanded ability to compensate for configurational discrepancies, and to Piaget, compensation implies multiplication of relations, in this instance, relations between size of the set and distance between objects.

It should be pointed out that Bruner (1966) and Piaget (1967) disagree on the question of whether operatory compensation can exist in the absence of conservation. Bruner believes that it can while Piaget insists that Bruner is really describing non-operative covariance which the child may affirm, on the basis of perceptual data, without comprehending its significance. Because it is difficult to explain correct mobility test responses on the grounds of perceived covariance alone, observations tend to confirm Bruner's view on this point.

As previously reported (p. 128), justifying statements given by HME Ss in post-tests and tests for generalization were most frequently classed as identity responses. Very few could be construed as compensation responses. On the premise that high mobile Ss already possessed operatory compensation, this observation is explicable.

The weight of evidence suggests that what high mobile Ss initially lacked was not the operation of compensation, but rather a fully operational schema of identity. If the perceptual activity induced during practice facilitated development of the dynamic images Piaget claims are necessary for representing transformations, and if adequate representation of transformational events aided elaboration of the identity schema, then a rationale exists for observed practice effects. Furthermore, it must be concluded that the attainment of number conservation is dependent on coordination of operative, that is, reversible schemes of compensation and identity.

Conservation is commonly regarded as the sine qua non of mental operations. Present findings confirm Piaget's (1967) view that it is not so much the problem of representing transformations, but more the absence of compensation which accounts for the child's inability to conserve. If children who possess operatory compensation can acquire identity and consequently conservation through comparatively brief periods of guided perceptual activity, future research might profitably explore the bases of compensation in a range of concrete problems not confined to the classic conservation task. With respect to number conservation, mobility of correspondence appears to be a useful construct which could be elaborated and possibly scaled along Wohlwill's dimensions of redundancy, selectivity and contiguity.

The Bruner-Piaget debate concerning the role of language in development of mental operations suggests that it may be pertinent to refer once again to the salient qualitative difference between LC and NC responses. Explanatory statements of Ss who judged sets to be unequal were phrased, almost exclusively, in the present tense. Genevan theorists would interpret this observation as evidence of centration. Accepting this interpretation, two possibilities remain. Either non-conservers failed to refer to prior events because they could not represent them adequately which, according to present analysis, could have been the case for LMP Ss; or alternatively, they were capable of representing original states and transformations, as it was implied that LME Ss could, but did not co-ordinate information derived from these events in order to solve the conservation problem. Unfortunately, very little EM data was obtained from low mobile Ss for it might have been instructive to compare the degree of visual centration in LME and LMP groups. Nevertheless the prevalence of contradictory judgments among LME Ss in the practice series suggested adequate representation but failure of inferential processing. While these observations contribute nothing toward clarification of the role of language in number conservation attainment, they do emphasize the necessity of comparing the language abilities of children who differ in mobility of intuitive correspondence.

A pronounced weakness of this investigation was the non-random, non-representative composition of the EM subsample. While there was no evidence that EM data loss was attributable to systematic effects of any factor or group of factors, there is no assurance that it was not. Consequently the generality of EM findings must be regarded as limited. Gross imbalance in proportions of HME, HMP, LME, LMP, and MC Ss in the EM subsample precluded valid _a posteriori_ comparisons of mobility-treatment groups on EM criteria. In view of mobility-treatment effects on conservation status, such comparisons might have revealed differences of considerable theoretical importance. With apparatus better adapted for recording the EMs of children under six, differences in visual behavior of high and low mobile Ss might fruitfully be explored as might EMs of logical, intuitive and non-conservers during the course of simultaneous and sequential transformations.

While not regarded as isomorphic with cognitive activity, patterns of visual fixation may be regulated by cognitive processes and thus reflect those processes. In general, visual centration tended to distinguish Ss who gave NC responses from those whose responses were classed IC or LC, though differences were less pronounced than in previous studies. EM patterns indicated a greater degree of perceptual activity among IC than among LC or IC Ss and differences in variability were marked.

According to Piaget (1968a) the prelogical period of intellectual development is characterized by intuitive thought at first directed by perceptual qualities of the whole. Later, through decentrative activity which will ultimately form the basis of operatory structures, parts of the whole are discriminated and equivalence comes to be defined by perceived correspondence of analogous units. Lacking the co-ordinated system of operations which will subsequently permit the child to deduce equivalence in situations involving spatial transformation, the conservation problem leaves the transitional conserver with whatever empirical strategies he happens to possess. At this stage the child comprehends the conservation question and mentally transforms perceptual data to arrive at a solution. As Piaget points out, mental processes may not be represented verbally in which case the child may conclude that sets are equal but may not be able to explain how he arrived at such a conclusion. Alternatively, well articulated intuitive strategies may be reported in detail. Both types of response were observed among IC Ss. Some could not provide a definitive reason for their judgments, but methods reported by others included sequential enumeration of sets; decomposition into subsets whose numerical value was immediately recognized; subgrouping and counting; subgrouping and matching; matching units between whole sets, and imagined empirical return of objects to their original state.

The nature of mental constructions which occur during this transitional stage implies a greater degree of response variability among individuals than is observed during the preceding or subsequent stages. EM data support this implication and are consistent with Piaget's views concerning the increase in perceptual activity among transitional conservers.

In conjunction with Piaget's position, present findings imply that instructional experience may dispose the transitional conserver to adopt particular strategies, for example counting or subgrouping, for comparing sets. It is also implied that physical properties including the spatial arrangement of sets may influence the type of strategy adopted by intuitive conservers, and such features might be expected to interact with strategy preferences.

As supplementary criteria of number conservation, EM patterns rarely contradicted and generally tended to confirm classification decisions reached on the basis of verbal responses. To this extent they served to enhance the degree of confidence placed in those decisions.

Findings point to the inadequacy of EM patterns as sole criteria of number conservation status; moreover, theoretical problems would arise were an attempt made to employ EMs for this purpose. Theoretically, nothing can be predicted about the visual activity of logical conservers except by comparison with intuitive conservers and non-conservers. A rationale exists for predicting that logical conservers will centrate less than non-conservers and will exhibit less perceptual activity than intuitive conservers, but the degree of isomorphism between visual activity and mental processes in the period following completion of a transformation would be predictably minimal among Ss who arrived at solution deductively. By the same rationale, isomorphism should be greatest among intuitive conservers. These implications might be tested by examining the comparative reliability of EM variables in predicting primary verbal responses and explanatory statements. The foregoing implications are of necessity confined to number conservation where, unlike other types of conservation, equivalence can be ascertained intuitively.

A final issue of theoretical relevance concerns the question of reinforcement. Given two assumptions, observed practice effects can be explained in the context of learning theory. First, it would be necessary to assume that HME Ss possessed, in Gagné's (1968) sense, the prerequisite abilities to profit from practice. In Gagné's terms, mobility of intuitive correspondence could be defined as one-to-one physical correspondence independent of configuration. If present conclusions are valid, correspondence independent of configuration, capacity to represent transformations, and reversibility should appear at higher levels of a number conservation learning hierarchy. The second assumption is that practice activities were self-reinforcing which might be the case if HME Ss anticipated the equivalence of sets and their perceptual matching activities served both to confirm these response tendencies and to resolve conflict elicited by configurational cues. Such an interpretation is particularly compatible with Berlyne's (1964) analysis of the acquisition of mental operations.

Perceptual discrimination learning cannot be held to account wholly for a process which culminates in deductive inference, however, the practice series could be construed in part as a discrimination learning situation. Indeed, the systematic reduction of color cues was analogous to methods employed by Terrace (1966) to elicit errorless learning in sub-human species.

Findings do suggest that number conservation attainment is not dependent on external sources of reinforcement though it would be of interest to determine whether reinforcement of practice responses would affect the proportion of Ss attaining a terminal status of logical conserver.

Implications for Research

(1) Acceleration Studies

The core of Piaget's theory is the equilibration process, an integrative process involving not only the effect of environmental contingencies on the development of mental structures, but also the role of existing structures in organizing and interpreting phenomenal input. Conclusions derived from this investigation point to the importance of incorporating structural variables in the design of conservation training experiments. The possibility of relevant structural differences within the non-conserver group has been ignored in many acceleration studies and this may explain the equivocal nature of a substantial body of findings (Sigel and Hooper, 1968).

As previously stated (p. 26) effective procedures for accelerating number conservation have generally been those which manipulated attention and consequently induced perceptual decentration. Present findings regarding the effectiveness of co-ordinating perceptual activity are in accord with such results. Training has usually proved more effective with older as opposed to younger children and here again the mobility of existing structures may be a factor differentiating older from younger Ss.

(2) Operations Underlying Conservation Attainment

Hypothetically, effects of exposure to the practice series could be attributed to increased capacity for representing the dynamics of spatial transformations. This explanation is tenable only if a satisfactory rationale is provided for observed differences in the conservation performance of HME and LME Ss. In this connection, Inhelder (1965) found that capacity to anticipate transformation outcomes did not in itself prepare children to conserve continuous quantity. Ss who were able to anticipate the level that liquid would attain when poured into a container of different dimensions from the standard also tended to predict that transformed and non-transformed quantities would be the same after transformation. However, when the transformation was actually performed, Ss reverted to non-conservation judgments. Inhelder's findings are thus consistent with observed behavior of LME Ss whose equivalence judgments contradicted what they said they had observed, and support the conclusion that compensation is an indispensable condition of conservation.

In an experimental analysis of Elkind's conservation model, Schwartz and Scholnick (1970) showed that among Ss who demonstrated identity, equivalence judgments were dependent on the extent to which the dimensions of the standard differed from those of the transformed element. Lefrancois (1968) concluded that operations of identity and combinativity (multiplication of relations) were co-requisites of substance conservation.

Mounting evidence would seem to imply that analysis of the origins of compensation might provide valuable insights regarding the transition from intuitive to logical thought.

Especially pertinent to present findings and to discussion of the bases of compensation is a study by Peters and Rubin (1970). As reported earlier, (p. 33) these authors found that training involving visual matching of color-cued materials was more effective than verbal training for inducing number conservation in Ss rated high in language comprehension. This observation supplies further evidence of the need to investigate the relationship of language to the development of compensation.

(3) Variations in Conditions of Conservation Testing

It was previously inferred (p. 136) that variations in materials and in spatial arrangement of sets may have influenced the EM patterns and verbal explanations of Ss who gave IC responses. This interpretation is consonant with Uzgiris' (1964) report of significant interaction between type of material and chronological age in acquisition of substance, weight and volume conservation. Uzgiris found that response variation across materials was relatively low for grade I Ss who were nearly all non-conservers, and for grade III Ss, 90 per cent of whom had acquired conservation. Intertask variability proved considerably higher for grade II Ss who were described as being in the process of developing conservation-related schemes. Further investigation of interaction between task variables and number conservation status seems warranted.

The unexpected increase of LC responses among HMP and LME Ss in the addition and subtraction problems does not appear to be an isolated finding. In formulating a hypothetical sequence for development of number concepts, Wohlwill (1960) reasoned that more Ss would respond correctly to conventional conservation problems than to problems involving conservation followed by addition or subtraction. His rationale was that ennunciated earlier (p. 131); namely, that if anything, addition and subtraction tasks would be more difficult because of their greater conceptual complexity. Contrary to expectation, scalegram analysis revealed that significantly more Ss passed addition and subtraction tests than passed the conventional conservation items. Wohlwill attributed this perplexing finding to order effects, but inasmuch as his method provided no check on Ss' interpretation of the conservation question, the explanation proposed earlier (p. 131) could apply equally to Wohlwill's findings. Interestingly, in a subsequent study (Wohlwill and Lowe, 1962), Wohlwill points out the possibility that children's conservation responses may reflect absolute rather than relative judgments.

Unfortunately, weak methodology precludes all but speculation on the reasons for markedly improved HMP and LME performance in addition and subtraction tasks. Should such tasks be incorporated in future investigations it is apparent that some method needs to be found for determining whether the Ss are in fact comparing transformed and non-transformed sets or whether they are merely reporting that the transformed set has increased or decreased in number.

(4) Eye Movements and Conservation

O'Bryan and Boersma (1970) compared EMs of LC, IC and NC Ss during solution of substance, length and area conservation problems. Acceleration training was not a factor in this study nor were structural variables assessed, however, in other respects namely age, intelligence, educational experience and conservation status, the present sample appears to be generally comparable. Wilton and Boersma (1970) compared EMs of natural conservers, Ss exposed to conservation training, and natural non-conservers in number, length and substance problems. The sample included grade I and II children of normal intelligence as well as educable mentally retarded Ss.

Contrary to present findings both previous studies present clear evidence that non-conservers center their visual activity on the element they judged to be greater in quantity after transformation. In Wilton's and Boersma's investigation, data are reported for number and length tasks combined, and inspection of means for each of these tasks separately indicates disparity in the direction of differences. Among non-conservers of normal intelligence, reported mean length of run on transformed and on non-transformed sets in the number task were: $\overline{X}$ TRANS = 16.82; $\overline{X}$ NONTRANS = 5.75. In this instance, attention appears to have been centred on the transformed set. Means for the length problem were: $\overline{X}$ TRANS = 9.40; $\overline{X}$ NONTRANS = 14.07. From reported results, it can be inferred that non-conservers judged the transformed set to be greater in the number task and non-transformed set to be greater in the length item. Though the evidence is equivocal, Wilton's and Boersma's observations do not contradict the centration pattern noted among non-conservers in this study. Possibly, non-conservers tend to centrate on the greater set in length, substance and area problems and on the transformed set in number tasks.

Present findings contrast with those reported by O'Bryan and Boersma in two additional respects. First, these authors noted a greater degree of perceptual activity among logical than among intuitive conservers. Secondly, they did not find significant disparity in variance between groups on any EM variable. Both of these differences are explicable in terms of task characteristics. Conceivably, intuitive conservers utilize such task-relevant information as is available to perception in the transformed display. When little relevant information can be obtained they may exhibit correspondingly less perceptual activity. Furthermore it might be postulated that among randomly selected intuitive conservers, individual differences in information seeking and processing strategies increase in proportion to the amount of task-relevant information available.

With the exceptions noted, EM patterns generally corresponded with those previously reported, but were less pronounced. The predominance of high mobile Ss in the EM subsample could be a factor affecting the magnitude of differences between groups, and it is certain that differences were attenuated by information loss resulting from non-parametric statistical analysis. The problem of high variability in visual behavior of intuitive conservers might well be anticipated when future studies are designed.

Implications for Education

Because the transition from pre-operational to operational thought is normally concurrent with the child's earliest educational experiences, Piaget's theories, including his observations on various types of conservation, have been widely noted by those responsible for the design and management of pre-school and primary learning environments. Number conservation has been of particular interest as a result of Piaget's (1952) contention that constancy of the equivalence relationship is fundamental to conceptualization of cardinal and ordinal number and thus basic to some of the first quantitative concepts children acquire in educational settings.

The fact that conservation of number can be accelerated does not imply that successful experimental training methods should be adapted for use in schools. There may be little advantage in hastening conservation attainment *per se*. On the other hand, if it were shown that operations underlying conservation were relevant to the acquisition of a range of quantitative concepts then conditions which facilitate the development of such operations might be of central interest to educators. In this regard present findings suggest further investigation of the correlates and determinants of compensation and identity.

Until recently problems associated with operationalization of Piagetian constructs have impeded systematic attempts to apply Genevan theory to curriculum planning. Lavatelli's (1972) work represents a comprehensive effort in this direction. For the purposes of this study, Wohlwill's (1966) dimensions of selectivity, redundancy and contiguity provided an approach to assessment of the status of mental structures (mobility of intuitive correspondence) and to the design of an effective instructional sequence (the practice series).

The central task of educators has been described as that of discerning the present capacities of the individual child and of exposing him to such environmental conditions as, in interaction with those capacities, will result in permanent, transferable learning. Accordingly, Glaser (1972) proposes that the most fruitful form of educational research involves investigation of aptitude x treatment interactions. Glaser further suggests that measurement of aptitudes should not be confined to product variables but should include process variables as well. Aptitude x treatment interaction was assessed in this study and although mobility of intuitive correspondence could be regarded as product of semi-operational mental structures, analysis of verbal statements and eye movement patterns suggested differences in the conceptual strategies and information processing techniques of logical, intuitive and non-conservers. Some of these differences, for example disparities in linguistic form, are amenable to classroom observation.

Coordinating perceptual activity induced by means of motion picture film and tape recorded instructions was shown to facilitate number conservation attainment among girls with high mobility of intuitive correspondence. The availability of audio-visual equipment, including 8 mm motion picture projectors, which can be independently operated by young children opens the possibility of individualizing and automating presentation of stimulus sequences designed to promote conceptualization of quantitative relations. Methods employed to produce movement of stimuli suggest that 8 mm films depicting conjunction and disjunction of sets could be produced at reasonable cost by educational personnel who lacked technical expertise.

To summarize, while the present study deals with a problem which is not immediately relevant to educational practice, its design and methodology do illustrate a mode of approach to the synthesis of Piagetian theory and curriculum design. In addition, implications exist for qualitative assessment of the status of intellectual structures, and certain practical aspects of methodology are suggestive of instructional techniques.

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APPENDIX A

TAPESCRIPT FOR POST-TESTS AND THE PRACTICE SERIES

1. In a minute, you're going to see some pictures on this little screen. I'm going to ask you some questions about the pictures and when I ask a question, I want you to say the answer. Ready?
2. See these two rows of yellow flowers? Tell me, do both rows have the same number of flowers, or does one row have more flowers than the other?
3. Watch what happens.
4. Now tell me, do both rows have the same number of flowers or does one row have more flowers than the other?
5. Here are some little girls.
6. And here are some big balls for the girls to play with.
7. Let's see if there are enough balls so that every girl can have one.
8. Does every girl have a ball?
9. Are there more girls or more balls or just the same number of each?
10. Now watch what happens.
11. See the red arrow pointing to the girl at the end of the row? Can you point to the <u>ball</u> that belongs to that girl?
12. Now the arrow is going to point to the next girl and I want you to find her ball and point to it.
13. Every time the arrow moves to a different girl, you point to the ball that belongs to that girl. Ready?

14. Good. Tell me, is there a ball for every girl?

15. Are there more balls than girls?

16. Are there less balls than girls?

17. Are there just the same number of balls as there are girls?

18. Look at this picture. Are there more balls or more girls or just the same number of balls as there are girls?

19. Watch what happens.

20. See the arrow. Point to the ball that belongs to that girl. Every time the arrow moves, look at the girl and point to her ball.

21. That's right.

22. Is there a ball for every girl?

23. Are there less balls than girls?

24. Are there more balls than girls?

25. Are there exactly the same number of balls as there are girls?

26. Now look at this picture. Are there more girls or more balls or just the same number of each?

27. Watch carefully what happens.

28. Now watch the arrow and point to the right ball.

29. Good.

30. Is there a ball for every girl?

31. Are there more balls or more girls or just the same number of balls as there are girls?

32. Try this picture. Are there more balls or more girls or just the same number of each?

33. Watch carefully.

34. Point to the ball that belongs to each different girl.

35. Is there a ball for every girl?

36. Are there more girls or more balls or just the same number of each?

37. This time, are there more girls or more balls or the same number of each?

38. Watch what happens.

39. Follow the arrow and point to the right ball each time.

40. Is there a ball for every girl?

41. Are there the same number of balls as girls or are there more of one than the other?

42. Look at this picture. Are there the same number of balls as girls or are there more of one than the other?

43. Watch.

44. Here's the arrow. Point to the right ball each time it moves.

45. Is there a ball for every girl?

46. Are there more balls than girls or just the same number or less balls than girls?

47. This time, are there the same number of balls as girls or are there more of one than the other?

48. Watch what happens.

49. Is there a ball for every girl?

50. Are there more girls or more balls or just the same number of each?

51. And this time, more balls or more girls or the same

number of each?

52. Watch.

53. Is there a ball for every girl?

54. Are there the same number of balls as girls or are there more of one than the other?

55. See these two rows of yellow flowers? Tell me, do both rows have the same number of flowers or does one row have more flowers than the other?

56. Watch what happens.

57. Now tell me, do both rows have the same number of flowers or does one row have more flowers than the other?

58. How do you know?

EXAMPLES OF STATEMENTS USED TO JUSTIFY CONSERVATION JUDGMENTS

The following is a representative list of statements given to justify judgments concerning the numerical equivalence of transformed and non-transformed sets. Statements, given in answer to the question "How do you know?", are quoted verbatim.

Statements Classed LC

These responses each followed a judgment that the transformed and non-transformed sets contained the same number of objects.

"Because when they moved, you moved the same amount as there was when they were close together."

"Because they're the same flowers and they just spread out."

"They got a little farther apart. Its really the same amount of things."

"Because you just put these over here and you never took any away."

"There was the same number before and then you moved these and there's still the same number."

"Before they was the same and they just moved around."

"Because, well, there was the same number at the top and you moved all the tops down here, so it's the same number."

"'Cause, uh, I could see them come down and they could go back up."

"'Cause when they were like this row up here there were the same number, so if you spreaded them out they would still be the same number."

"Because they're just spreaded out. It's the same number. It's longer though."

"Um, because the top had the same amount as the bottom a minute ago."

"Because you put.... Before there was the same number and now you just put lines out of the little circles."

"They have the same because you moved them and they were the same before and now they're the same now."

"When, well before when you showed me, before it moved like that, there was a ball for every square."

Statements Classed IC

Each of the following explanations followed a correct decision regarding the equivalence of sets.

"Because there's one more big and there's one more little and it's the same. My brother told me."

"Well I counted when they were coming down."

"There is.... I forget how I know."

"There are ten here and ten here."

"Like there's two here and two here and two here and two here, and down here there's two and two and two and two."

"Because this one's big and this one's big."

"'Cause I counted them."

"Y' see I put these two to those and those three to those and those five to those."

"One, two, three, four, five, six, seven, eight, nine, ten. One, two, three, four, five, six, seven, eight, nine ten. Ten and ten! The same! They're the same!"

"I don't know."

"Well, there's four here, and these three here and one here. Wait. Well, there's two and two and two and two here, and there's two and two and two and two, so its the same."

"Because I went like this. Two, four, six, eight, and like this; two, four six, eight."

"'Cause I'm learning. I'm learning."

"Same numbers. Still the same. By counting over and over. If it goes farther, it's a bigger number, but it didn't."

"It looks like it."

<u>Statements Classed NC</u>

The following statements all followed an incorrect judgment concerning the equivalence of sets.

"Because it's longer."

"Because the squares are in a line and the balls are squished in a circle."

"Because I can see this is bigger."

"Because they stick out at the end. Those two at the end look like they're going away."

"Because you don't see any balls spread across like that."

"Because there are a few more things at this end."

"Because one is bending and one is standing straight."

"Because they're in a straight crooked line and they're spreaded apart."

"Because you took these from here and you put them here and that makes them small."

"Because the squares are right and the balls aren't."

"Because, you know, see, this is the smaller group."

"Because there's lots there and not lots there."

"'Cause one row is close together and one line is open wide."

PILOT STUDIES

Guided Practice in Visual Matching and Mobility of Intuitive Correspondence

In the spring of 1969, E administered a practice series identical in principle to the film practice series to eleven 5 year old non-conserving kindergarten girls. Materials were toy cups and saucers in colors of magenta, green, yellow and pink. Tasks were the same and instructions similar to those later used in film presentation. Materials were manipulated by E who delivered instructions directly instead of by tape. In addition to the experimental group (EP), two control groups were included. One (NP group, N = 7) received conservation pre- and post-tests only. A third group (HP group, N = 8) was exposed to the same practice condition as the EP group except that materials were homogeneously colored for all tasks. No material or verbal reinforcement was supplied for any group.

On the conservation post-test, 54.5% of EP, 12.5% of HP and 0% of NP Ss gave conserving responses. Mean practice errors were 3.91 for the EP group and 7.28 for the HP group. No relationship was found between change in conservation status and ability to count or ability to solve class inclusion problems. No attempt was made to assess mobility of intuitive correspondence.

A second pilot study involved a group of 13 non-conserving kindergarten boys who were exposed to the experimental condition described above except that materials were red, green, orange, and blue toy cars. It was observed that five Ss who displayed no pre-test - post-test change in conservation status, all judged sets to be unequal when 12 toy animals were arranged in juxtaposed pairs, six in a smaller circle inside a circular fence and six in a larger circle outside the fence. Seven out of eight Ss who advanced in conservation status following practice judged that there were the same number of animals inside as outside the fence. Neither mobility of correspondence nor practice effects were found to be related to counting ability or class inclusion. Results of both studies suggested that mobility of intuitive correspondence and practice in color-guided visual matching should be investigated in a larger scale study with improved controls.

PROBLEMS IN EYE MOVEMENT RECORDING

As previously reported (see p. 134) EM data loss was more than incidental and this finding is consistent with Boersma's and O'Bryan's (1970) detailed discussion of problems associated with use of a stand-mounted camera for EM recording with six year olds. In the event that data loss can be tolerated, use of a stand camera may be preferable in terms of the greater accuracy of EM records obtained with this instrument as compared to wide angle cameras which do not require use of a bite-bar (Mackworth, 1967,1968). Data loss in the present study was felt to be compensated by the quality of data obtained.

Loss of data was not apparently attributable to fear, discomfort or lack of cooperation on the part of Ss tested in the laboratory situation. As noted (p. 58) two Ss were not willing to accept the bite-bar, however, the remainder readily cooperated in this regard and exhibited no hesitation in using the bite-bar during eye closure training and testing. By the time eye closure training was complete, the majority of Ss returned to the bite-bar, without being instructed to do so, after each verbal response. Ss similarly cooperated in fixating the target spot during calibration though it was noted that some Ss seemed to have better voluntary control of EMs than others.

Voluntary control of head and body movements was effectively exerted when Ss were not attending closely to stimulus material, but the principal difficulty in achieving and sustaining calibration appeared to result from a normal activity level characteristic in situations where Ss attention was directed to stimuli on the viewing screen. While the bite-bar was moderately effective in controlling head movements of local origin and while localized limb movements appeared to have little effect on stability of the head, movement originating in the trunk invariably generalized to neck muscles often resulting in slight shifts of bite sufficient to destroy calibration. It is probable that such shifts occurred more frequently among Ss with loose or missing teeth, a condition characteristic of six year old children. In typical instances of calibration loss the corneal reflection spot did not merely move outside configurational scoring boundaries but disappeared entirely from the area recorded on film, an area somewhat larger than the total viewing surface.

For more active Ss, difficulty was experienced in initial calibration. Because it was estimated that motor activity increased in direct proportion to the time S was on the bite-bar, in cases where successful calibration had not been achieved within 30 seconds, S was asked to come off the bite-bar and rest before a subsequent attempt at calibration was initiated. The probability of achieving calibration after three unsuccessful trials with rests and diversionary activities between, was normally regarded as too low to justify further attempts, and in such instances the test concerned was administered without EM recording. Initial calibration was accomplished for most Ss, and as previously indicated most unscoreable data resulted from loss of calibration at some point between stimulus presentation and eye closure.

APPENDIX B

TABLE Bi

EXACT PROBABILITIES OF ASSOCIATION BETWEEN EDUCATIONAL LEVEL AND PROPORTION OF IC RESPONSES IN HM GROUPS

	Probability	
Task	HME	HMP
Imm. Post-Test	.635	.749
Del. Post-Test	.635	.552
Imm. Gen. 1	.635	.474
Imm. Gen. 2	.750	.749
Imm. Gen. 3	1.00	.437
Imm. Gen. 4	.750	.416
Del. Gen. 1	.401	.474
Del. Gen. 2	.859	.600
Del. Gen. 3	.750	.281

TABLE Bii

SUMMARY OF MULTIPLE CONTINGENCY ANALYSES

ON PROPORTION OF IC RESPONSES

Test	Source	df	χ^2
Imm. Post-Test	Total	3	2.59
Del. Post-Test	Total	3	3.98
Imm. Gen. 1	Total	3	1.29
Imm. Gen. 2	Total	3	2.94
Imm. Gen. 3	Total	3	4.46
Imm. Gen. 4	Total	3	1.10
Del. Gen. 1	Total	3	4.82
Del. Gen. 2	Total	3	5.25
Del. Gen. 3	Total	3	.81

TABLE Biii

CHI-SQUARE TESTS ON DIFFERENCES IN PROPORTION OF IC RESPONSES BETWEEN IMMEDIATE AND DELAYED GENERALIZATION TESTS FOR THE FIVE GROUPS COMBINED

Tests Compared		Values of Chi-Square						
		Imm. Gen.				Del. Gen.		
		1	2	3	4	1	2	3
Imm. Gen.	1		10.71**	9.00**	7.34*	.03	.57	1.81
	2			0.00	.25	8.90**	5.76*	3.55
	3				1.00	8.16**	7.11*	3.55
	4					5.53*	5.40*	2.00
Del. Gen.	1						.60	1.63
	2							.47
	3							

* $p < .01$
** $p < .05$

TABLE Biv

COMPOSITION OF THE EYE MOVEMENT SUBSAMPLE BY MOBILITY-TREATMENT GROUPING FOR EACH TASK

Task	Group	Number	Total
Del. Gen. 1	HME	7	
	HMP	6	
	LME	2	
	LMP	2	
	MC	11	28
Del. Gen. 2	HME	6	
	HMP	8	
	LME	1	
	LMP	3	
	MC	11	29
Del. Gen. 3	HME	6	
	HMP	9	
	LME	0	
	LMP	2	
	MC	10	27