THE UNIVERSITY OF MANITOBA

THE ROLE OF FIELD DEPENDENCE-FIELD INDEPENDENCE IN THE CONSERVATION OF MASS, WEIGHT, AND VOLUME

by

Lois A. Forsberg

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY

WINNIPEG, MANITOBA

October, 1973

THE ROLE OF FIELD DEPENDENCE-FIELD INDEPENDENCE IN THE CONSERVATION OF MASS, WEIGHT, AND VOLUME

By: Lois A. Forsberg

A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

ABSTRACT

Thi search was designed to investigate the role of the fie pendence-field independence cognitive style dimensi in the attainment of conservation of mass, weight, and vo . Eighteen boys and eighteen girls from each of grade , three, and five comprised the sample. Subjects were sified as field dependent or field independent on the s of their performance on the Children's Embedded Fig Test. The majority of subjects were of middle socio-ec c background, and IQs ranged from 90-129.

esults showed that field independence facilitated per-f ice on all three conservation tasks, and that this effect reatest at the lower grade levels. However, field de-ence was not related to the order in which the concepts attained, nor to the frequency of the mass-weight-volume alage. In both cognitive style groups, less than half of e subjects who conserved on one or more concepts showed Piagetian décalage pattern. The mass-weight décalage was ound only at grade five, the weight-volume décalage at grade three, and the mass-volume décalage at grades three and five. At the grade-one level, the proportions of subjects conserving mass, weight, and volume did not differ significantly.

The only improvement in conservation performance with age was between grades one and three on the conservation of

mass. At grade five there was a regression in conservation of weight for the field dependent subjects, and in both weight and volume for the field independent subjects. There were no sex differences on the conservation of mass and weight, but boys scored higher than girls on the volume task.

Possible reasons for the failure to replicate the mass-weight-volume décalage were discussed. It was suggested that whether or not the décalage exists may depend on the experiential background of the subjects, the methods of assessment, and the materials used in the study.

An inspection of the conservation protocols and discussions with classroom teachers led to the conclusion that the regressions found at the grade-five level were probably due to the interference of information acquired through classroom instruction.

Theoretical and practical implications of the results were discussed, and suggestions for future research were offered.

ACKNOWLEDGEMENTS

The author is deeply grateful for the generous assistance and helpful comments of Dr. Y. S. Lee under whose supervision this research was carried out. Sincere thanks are also extended to Dr. J. S. McIntyre, Dr. M. P. Janisse, and Dr. A. Bowd for their comments and suggestions, and to Dr. B. Bain for his role as external examiner.

In addition, the author wishes to thank the staffs and students at Hastings, Lincoln, Robert Browning, and St. George Schools where this research was carried out.

To my husband, Don; son, Neil; daughter, Lisa--my deepest appreciation for their continued support and understanding.

This research was supported by Grant Numbers W713031 and W725391 from the Canada Council.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Despite the large number of studies related to Piaget's theory which have been conducted during recent years, little is known about how performance on Piagetian tasks is related to subject characteristics other than chronological age. A number of investigators (e.g., Flavell, 1963, 1970a; Flavell & Wohlwill, 1969; Hooper, Goldman, Storck, & Burke, 1971; Sigel, 1968; Skager & Broadbent, 1967) have commented on our lack of knowledge in this area and have stressed the importance of exploring the role of a variety of traits and skills which, up to the present time, have received little attention. A consideration of such variables might well help to account for the wide individual differences frequently reported in the Piagetian literature.

The failure of investigators to examine the role of subject variables is perhaps not surprising when one considers that Piaget is not himself interested in variables which might accelerate or delay the onset of stages, and that his theory is not designed to deal with them (Flavell, 1963). Piaget's chief concern is with the normative aspects of cognitive growth, and not with individual differences in rate of development. In answer to criticisms of his neglect in this area, Piaget (in Inhelder & Piaget, 1969) states:

> Now, we are no longer dealing with a problem of general psychology, but of differential psychology, psychology of the individual--of each individual. This, I must confess, is a problem I have unfortunately never studied, because I have no interest whatsoever in the individual. I am very interested in general mechanisms, intelligence and cognitive functions, but what makes one individual different from another seems to me--and I am speaking personally and to my great regret--far less instructive as regards the study of the human mind in general (p. 211).

In recent years, there has been an increasing concern (cf. Flavell, 1963; Hooper et al., 1971; Sigel, 1968) that Piaget's exclusive preoccupation with mental structures per se and his failure to deal with what Flavell (1963, p. 441) refers to as the "warm-blooded" aspects of cognition have provided a very limited picture of the child. This view has been aptly stated by Hooper et al., (1971):

> assessment of intellectual functioning should also include explicit consideration of the many noncognitive aspects of human development such as personality factors, socialization influences, peer group interactions, etc. The literature on cognitive development . . . has, unfortunately ignored the affective dimensions of intellectual development and has thus revealed a distinctly sterile and unrealistic overall picture. Children do not demonstrate cognitive growth in an affective vacuum ! (p.75).

Not only have the social-emotional aspects of development been overlooked but, even within the realm of cognitive development, individual differences in performance have generally been ignored. Flavell (1970a) feels that, in order to account for these variations, we need to consider not only the noncognitive, affective dimensions but also a number of "perceptual-attentional, mnemonic, linguistic, and other 'infraconceptual' cognitive skills (p. 45)" which have been found to play impor-

tant roles in adaptive behavior. Similar views have been expressed by others (e.g., Goodnow, 1962; Sigel, 1968).

One class of variables which is thought to integrate a number of noncognitive components and infraconceptual skills such as those listed above is the concept of "cognitive style," a term that refers to "stable individual preferences in mode of perceptual organization and conceptual categorization of the external environment (Kagan, Moss, & Sigel, 1970, p. 204)." Although the relevance of cognitive style to performance on Piagetian tasks has been suggested (Sigel, 1968; Skager & Broadbent, 1967; Vernon, 1969), this topic has not been the subject of extensive empirical enquiry.

Of a number of cognitive styles identified in the past two decades (cf. Kagan & Kogan, 1970), the field dependence-field independence dimension isolated by Witkin and his colleagues (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962) seems particularly relevant within the present context. Witkin has described this dimension in terms of the ability to overcome the influence of an embedding context, and extensive investigations have shown that field dependence is related to performance in a broad range of perceptual and intellectual tasks (cf. Witkin et al., 1962). In the present study, the role of the field dependence-field independence dimension in the attainment of conservation of mass, weight, and volume will be examined. In the present context, "conservation" refers to the recognition that certain proper-

ties (mass, weight, volume, length, etc.) remain invariant in the face of certain transformations of an object (e.g., breaking it in pieces, changing its shape).

The development of conservation of various quantities has been extensively investigated by Piaget[1] and his colleagues at Geneva (e.g., Piaget & Inhelder, 1941; Piaget, Inhelder, & Szeminska, 1960). Their findings and Piaget's claims regarding the role of conservation in cognitive development may be summarized briefly as follows: (a) Piaget conceptualizes cognitive development in terms of qualitative changes in mental structures, and it is his belief that these structures are revealed in the child's performance on the conservation tasks; (b) Although the conservation of various concepts (e.g., mass, weight, volume) are all thought to depend upon the existence of "concrete-operational" structures, they are not all acquired simultaneously. In Piaget's subjects, conservation of mass was attained at about seven years, conservation of weight at age 9-10, and conservation of volume at age 11-12. Although the exact age of acquisition might vary within limits, the sequence of acquisitions is thought to be invariant; (c) In order to account for the delayed acquisition of the conservation of weight and volume, Piaget (cf. 1970) has introduced the concept of "horizontal décalage" (a time lag in development), and he has offered a

---

[1]The name "Piaget" will be used hereafter to represent the Geneva School.

number of explanations for these delays; (d) Conservation of mass is thought by Piaget to mark the emergence of logical thought structures which characterize the concrete-operational stage of development. Conservation of volume is thought to mark the transition from the stage of concrete operations to the stage of formal reasoning.

In the following chapter, the role of conservation in Piaget's stage theory of cognitive development is reviewed in detail, and evidence pertaining to the following questions is presented: How general is the mass-weight-volume sequence which Piaget has proposed to be invariant? How well do Piaget's age norms hold up in diverse cultures and situations? What effect do task variables (e.g., type of material, manner of presentation) have on conserving behavior? How do demographic variables such as amount of schooling or cultural background affect the age of acquisition and the order of attainment of the conservation concepts? Can conservation be accounted for solely in terms of underlying mental structures, or do other variables need to be considered?

Also included in Chapter II is an overview of theory and research pertaining to the field dependence dimension, along with a more detailed rationale for its inclusion in the present study. Following this, specific research hypotheses are set forth. Chapter III contains a description of the experimental design and of the methods employed in

the collection of data, and Chapter IV the results of the investigation. Theoretical and practical implications of the major findings are discussed in Chapter V, and suggestions for future research are set forth.

CHAPTER II

LITERATURE REVIEW

The Basis of Conservation

Piaget (1957a) has proposed that the construction of concepts of conservation implies the existence of a system of mental operations which are described in terms of eight logico-mathematical "groupings" (for details, see Piaget, 1957a). It is this system of "concrete operations" which is said by Piaget to support or explain the acquisition of conservations of all kinds. Thus the transition from the pre-operational to the concrete-operational stage of development is thought to occur at about age seven with the attainment of conservation of mass (substance, amount). Piaget and Inhelder (1947) have stated that "the building up of logical operations . . . may be observed in a singularly clear way through the evolution of notions of conservation peculiar to the child's physics (p. 402)."

According to Piaget (cf. 1957a), the crucial characteristic of mental operations is "reversibility", and he describes two general forms that reversibility may take: (1) negation, which applies only to classes, and (2) reciprocity, which applies to relations. In the case of negation, reversibility generally expresses the notion that every direct operation has an inverse which cancels or negates it (e.g., addition is cancelled by subtraction). In the conservation

problem, it refers to an awareness that all transformations can be annulled by the inverse transformation. Inhelder (1953) describes this form of reversibility as follows:

> when a child transforms a ball of plasticine into a sausage or cake . . . he can from seven years onwards mentally cancel this transformation and thus arrive at the conservation of matter. At about ten years he shows himself capable of carrying out the same reversible reasoning in connexion with conservation of weight and at about eleven years with conservation of volume. In each of these reasonings an actual transformation is cancelled by an inverse mental operation, thus leading to conservation (p. 30).

The second form of reversibility is generally interpreted in terms of "compensatory relations" or a process of logical multiplication. In the conservation of liquid quantity, for example, when the child recognizes that all height changes are compensated for by all width changes, he will assert the equivalence of quantity as necessary and obvious. Piaget states:

> However, the striking thing here is that the child reaches this feeling of necessity as soon as he has understood the phenomenon in question. One can sometimes witness the precise moment when he discovers this necessity. . . . I believe that the feeling of necessity is neither a subjective illusion [as in Hume's analysis of the cause-effect relationship] nor an innate or a priori idea. It is an idea which is constructed at the same time as the overall structures (1969, p. 5).

Prior to the onset of the concrete-operational stage, the child's thinking is thought by Piaget (cf. 1957a) to be largely dependent upon the immediate perceptual appearance of things. When confronted with the conservation task, for example, the pre-operational child centers his attention on a single salient aspect (e.g., height) and asserts that the

transformed object now contains more "because it is higher." From the age of seven to eight years, the child is able to break away from the influence of perception and is increasingly able to apply logical thought processes to the solution of practical problems.

Although developments in perception (e.g., perceptual exploration) and in cognition (attainment of concrete mental operations) are both thought to play important roles in the attainment of conservation, it is not possible to account for conservation in terms of perceptual factors alone (Piaget, 1967). The reason for this is that "conservation . . . involves quantities that are not perceptive but have to be constructed by compensation between different dimensions (Piaget, 1967, p. 533)." Neither can failure to conserve be attributed solely to perceptual factors: Piaget (1957a) explicitly states that "When the most elementary forms of conservation are absent, it is a consequence of the absence of operational reversibility (p. 12)."

Although a detailed discussion of this issue is beyond the scope of this thesis, it should be noted that there has been considerable controversy with regard to the role of reversibility in the attainment of conservation. With regard to reversibility by reciprocity, Wallach (1969) concludes that "indeed, recognition of the necessity of compensation seems likelier to derive from the belief in conservation than to provide the basis for this belief (p. 197)" and that there is "neither any understanding of how reversibility should lead

to conservation nor any experimental evidence that it does do so (1969, p. 203)." Murray and Johnson (1969) have presented similar arguments and conclude that "reversibility is both logically and psychologically irrelevant to conservation (p. 285)."

Flavell (1963) finds the concept of reversibility vague and difficult to define, and Berlyne (1965, p. 209) feels that Piaget has interpreted reversibility "with a great deal of flexibility." Bruner and his colleagues (Bruner, Olver, Greenfield, et al., 1966) have argued that reversibility is not at the heart of the conservation problem, and Piaget's reply (1968b) is that Bruner has failed to understand what is meant by the term. Murray and Johnson (1969) have stated that it is up to the Geneva group to provide clear behavioral criteria with which to distinguish "true" reversibility from what Piaget calls "empirical reversibility" (cf. Piaget, 1957b, in Berlyne, 1965, pp. 222-223).

The Mass-Weight-Volume Decalage

In order to explain the failure of the concrete operations, already available at age seven, to generalize simultaneously to all possible fields of application, Piaget has invoked the concept of "horizontal décalage" (cf. Piaget, 1970; Pinard & Laurendeau, 1969).

The term "décalage" may be defined as a "time lag" or "temporal displacement" and refers to "aspects of cognitive

development which appear at a stage subsequent to the one at which they are normally expected (Inhelder, 1968, p. 31)." Piaget (1954) has distinguished two forms of décalage both of which are related to his concept of stages in mental development. These are (1) horizontal décalage, and (2) vertical décalage.

In the case of "horizontal" décalage, the time lag takes place within a single stage of development so that "several distinct concepts can acquire structure at different ages even though the same operational groupings are involved in each (Pinard & Laurendeau, 1969, p. 133)." The time lag found between the conservations of mass, weight, and volume is the classical example of this type of décalage. According to Flavell (1963), the existence of horizontal décalages represents the notion that "whereas it may be useful to think of an individual as being generally characterized by a given cognitive structure, he will not necessarily be able to perform within that structure for all tasks (p. 23)."

The mass-weight-volume conservation décalage has been verified by Inhelder (1968) in a study of mentally retarded subjects, and Piaget (1957a) has noted the same décalage in a transitivity study. He states:

> But curiously enough, with respect to all the operations, one finds exactly the same lack of correspondence . . . From seven to eight, children become aware of the transitive character of equalities in the case of lengths, etc., but only towards 9 to 10 in the case of weight and towards 11 to 12 for volume (p. 17).

Because of the persistence of this décalage, Piaget (1957a) has concluded that "concrete operations fail to constitute a formal logic; they are incompletely formalized since form has not yet been completely divorced from subject matter (p. 17)."

While "horizontal décalage" refers to asynchronous developments within a particular stage, "vertical décalage" refers to acquisitions which appear at different stages of development. Pinard and Laurendeau (1969) have described the vertical décalage as follows:

> the development of a given conceptual content (e.g., causality, space) is accomplished on several successive levels (sensorimotor, concrete-operational, and formal-operational) according to an analogical process in which this content, already structured at a level established by earlier kinds of actions or operations, is restructured at a higher level by a new kind of operation (pp. 127-128).

The construction of concepts of conservation may be used to illustrate what is meant by "vertical" décalage. The most fundamental notion of invariance appears during the sensorimotor stage when the infant comes to recognize that objects have a permanence beyond his immediate action upon them (sucking, grasping, seeing, etc.). During the pre-operational stage, there is a further advance in the child's understanding of invariance when the concept of "qualitative identity" is constructed. With this attainment, the child recognizes that a transformed object is still the same object, but he fails to recognize that the amount remains the same. It is not until the stage of concrete operations that the child

constructs the notion that certain quantitative properties (mass, weight, volume, etc.) also remain invariant across certain transformations. Although the concept of invariance is common to all of these attainments, it has been constructed and reconstructed at increasingly higher planes of action.

Since "horizontal" décalage refers to the gradual extension of the same operations to several distinct concepts, and "vertical" décalage refers to the application of successively more advanced forms of reasoning to the same conceptual content, it follows that "the horizontal décalages express the differences of speed between the vertical décalages of distinct concepts (Piaget, 1941, p. 270, in Pinard & Laurendeau, 1969, p. 132)." Because of these delays in acquisition, the concrete-operational stage is said to extend over a period of about five years (ages 7-12).

Piaget's Explanation of the Conservation Decalage

Piaget (1969) has confessed that "a fairly important problem for the theory of stages is that of time lags (p. 10)," and Inhelder has stated:

> This impossibility of generalizing the operatory structure a priori to any intuitive content is often disconcerting when an effort is being made to establish general stages of reasoning (1968, p. 302).

Piaget has offered a number of explanations for the conservation sequence. First, he has stated (Piaget & Inhelder, 1947) that the mass-weight-volume sequence comes under the law of "logical implication". Here Piaget seems to

argue that there is a logical hierarchy that makes the later concepts dependent upon the earlier ones. Inhelder (1968) states:

> To affirm the conservation of weight always implies belief in the constant quantity of substance because the weight presupposes the material substratum which is the substance-quantity (p. 288).

Piaget and Inhelder (1947) also add:

> This . . . succession is strictly the same with all children, and comes under the law of logical implication. Conservation of physical volume always implies conservation of matter. Those three elements, which at first are indistinguishable, slowly differentiate themselves . . . so as to integrate into one another in an order of constant succession (p. 403).

There are a number of reasons why the logical implication explanation of the conservation décalage is unsatisfactory. First, it is clear (cf. Lee, 1972) that no such hierarchy exists in the realm of physical science; e.g., although the concepts of weight and mass are interdependent, volume is independent of both. Second, it appears that conservation of a concept is not dependent on an understanding of the concept as defined in physical science; e.g., children regularly conserve mass without having first attained any understanding of acceleration and energy. Third, the logical priority of a concept need not imply its psychological priority (cf. Lunzer, 1960). In addition, it should be noted that while such a hierarchy (if it did exist) might explain the sequence, it is not able to account for the long delay between the acquisitions of the concepts.

Piaget's second explanation is that there is something in the nature of the concepts themselves which necessitates

their fixed order of appearance. He states that the reason for the décalage is "naturally to be sought in the intuitive character of substance, weight, and volume, which facilitate or hinder operational combinations (Piaget, 1950, p. 147)." In order to understand the décalages, it is necessary to analyze not only the subject's logic but also the object's resistances which pose an obstacle to this logic. Piaget (1972) states:

> In the development of operations the subject follows more or less regular laws of development, but not the objects. They vary greatly in being accessible to logic. I would just like to point out that there is a very similar problem in physics, the problem of understanding friction. There is no general theory of friction and each case is explained in its own terms. And the physicist finds it equally as difficult to explain friction as we do explaining decallage (pp. 22-23).

In concluding his discussion of the mass-weight-volume décalage, Piaget (1970) says that "we cannot provide a theory of these décalages without a complete reorganization of our ideas about the development of causal explanations (p. 7)."

A third explanation for the décalage is based on Piaget's belief that, while a system of logical thought operations is essential to the attainment of conservation, other logical structures or "schemas" may be required as well (e.g., Piaget & Inhelder, 1941; Piaget et al., 1960). According to this argument, the child is more likely to conserve if he possesses the "atomism schema"; i.e., if he can conceive of an object as being composed of tiny particles. For the conservation of volume, adequate notions of compression and decompression, metrical continuity, and proportionality are thought to be

essential (Piaget, 1970; Piaget et al., 1960). These advanced schemas are thought to be attained only relatively late in development, during the stage of formal operations (Inhelder & Piaget, 1958).

There is little evidence with regard to the role of these additional schemas in the attainment of conservation. Piaget and Inhelder (1941, in Flavell, 1970b) found that, when sugar was dissolved in water, conservation of mass was supported by arguments based on an atomistic rationale but that this schema was not immediately extended to the conservation of weight and volume. Lunzer (1960) established that notions of infinity and continuity are not necessary for the conservation of volume, nor for the calculation of volume in terms of linear dimensions. However, Towler and Wheatley (1971) have suggested that failure of college students to conserve volume may be partly due to inadequately formed concepts of atomism and metrical continuity. Brainerd's (1971) results support Piaget's claim that volume and density conservation are indexes of the proportionality schema.

In summary, Piaget has proposed that the sequence of mass, weight, and volume conservation is invariant and that there is a considerable time lag between these acquisitions, but he has been unable to offer a satisfactory explanation for this décalage. The first explanation which is based on a logical implication argument has been shown to be untenable, and probably irrelevant. The second is based on the notion that concepts differ in the extent to which they resist the subject's logic.

This type of explanation can be provided only on a post hoc basis (Piaget, 1970). As for the necessity of acquiring additional schemas, there is a paucity of evidence. The evidence pertaining to the existence of the décalage between the acquisitions of the mass, weight, and volume concepts and to the invariance of the sequence is presented in the following section.

Research Evidence

Despite variations in methodology, many studies (e.g., Elkind, 1961a, 1961b; Goodnow, 1962; Kooistra, 1963; Papalia, 1972; Peluffo, 1967; Sigel, Roeper, & Hooper, 1966; Smedslund, 1961a, 1961b; Towler & Wheatley, 1971) support the existence of the conservation décalage reported by Piaget. Inhelder (1968) found that, out of more than 150 retarded subjects, there was not a single instance where a subject conserved weight but not mass, or volume without both weight and mass (Piaget, 1968a, in Inhelder, 1968). It was found, in addition, that many of the adult subjects had never reached the stage of concrete or formal operations. On the basis of these results, Piaget and Inhelder have proposed that the mass-weight-volume décalage might serve as a criterion with which to distinguish imbeciles, retardates, and slow learners (Inhelder, 1968, pp. 18-19).

Elkind (1961a) studied the conservation of mass, weight, and volume in a group of children from kindergarten through grade six and found that the order of difficulty of the tasks was the same as Piaget had observed. According to Elkind,

Piaget's age norms are based on the age at which 75% of the subjects attain the various conservation concepts. Using this criterion, Elkind found that the number of subjects conserving mass and weight were quite consistent with Piaget's findings. However, only 27% of the 11-12 year old subjects were able to pass the volume test. This discrepancy may be attributed to a slight difference in the techniques used for assessing volume: Elkind asked whether two objects took up the same space, whereas Piaget's question was worded in terms of displacement of water level. Elkind does not report the number of reversals in the predicted sequence but, since more of the 5- and 6-year-olds conserved weight than mass (see Elkind, 1961a, Table 1, p. 16), it can be concluded that there were at least some.

In subsequent studies (Elkind, 1961c, 1962), it was found that only 47% of the junior and senior high-school students aged 12-18, and only 58% of the college students who served as subjects were able to conserve volume. Towler and Wheatley (1971) replicated Elkind's study with college students and found that, of 71 female subjects enrolled in a mathematics course, only 61% were able to pass the volume test. All subjects conserved substance, but three made errors on the weight task.

Papalia (1972) studied conservation of number, substance, weight, and volume in subjects ranging in age from six to over sixty-five years. Procedures were similar to those used

by Piaget. Although the order of difficulty of the mass, weight, and volume tasks was as predicted, Papalia found that the 75% level of conservation for either mass or weight was not attained by the age of 11-13. At this same age, only 12% conserved volume, and at age 18-19 only 50% succeeded on the volume task. The only group to reach the 75% level on volume conservation were those aged 55-64 years. From a total of 575 subjects, Papalia reports that only three showed deviations from the predicted mass-weight-volume sequence.

Lovell and Ogilvie (1961a) have suggested that the assessment of volume conservation is quite complex. While 55% of the first-grade children in their study were able to conserve the amount of water displaced by different arrangements of cubes, only 6% succeeded on all of the volume tests. In grade four, 78% passed the displacement task, and 38% passed all of the volume tests.

Uzgiris (1964) tested subjects from grades one through six with four different kinds of material (plasticine, metal nuts, wire coil, and plastic-coated wire). Results showed that, within any given type of material, the sequence was as predicted. However, this order was not always evident when the variety of materials were considered together. The ages of attainment reported by Uzgiris were consistent with Piaget's findings, except for the volume task. Only 20-30 percent of the grade-six children were able to conserve volume. Again, the volume task seemed more abstract than that described by

Piaget. Lovell and Ogilvie (1960, 1961b) have also found that many children who conserve substance or weight in one situation fail to do so when the material or transformation is changed. Flavell (1970a) has noted that the presence of décalages between different materials makes it extremely difficult to establish the onset of a given stage or to determine whether in fact the sequence does exist.

A number of studies have provided only partial support for the predicted mass-weight-volume décalage. McRoy (1967) found that, although volume was more difficult than the other tasks, there was no evidence of a décalage between the acquisition of mass and weight. Nummedal (1970) tested half of her subjects with a Piagetian format and the other half with a nonverbal procedure and found no evidence for a mass-weight-décalage for either group at any grade from one through five. With the Piagetian method of assessment, there was a décalage between substance and volume, and between weight and volume at all ages except grade one. With the nonverbal method, these décalages were significant only at grades three, four, and five. Ten of the 200 subjects in Nummedal's study showed a sequence other than mass-weight-volume. Lee (1972), using a verbal assessment procedure, found that 91% of the grade-one children who conserved mass also conserved weight, and 82.5% conserved volume.

Cross-cultural studies (see Dasen, 1972a, for a review) do not generally lend strong support for the proposed décalage

nor for the invariance of the sequence. Hyde (1970) studied a group of European, Arab, Indian, and Somali children residing in Aden and found that less than half of the subjects who conserved on one or more concepts followed the predicted sequence. De Lemos (1966, 1969, cited in Dasen, 1972a, 1972b) studied conservation in a group of Australian Aboriginals and found that, although the volume task was the most difficult, conservation of weight was achieved earlier than conservation of mass. In a replication of this study, Dasen (1972b) failed to verify the mass-weight reversal reported by de Lemos, but found instead that weight and volume were conserved almost simultaneously. After a careful consideration of all of the factors involved in these studies, Dasen concluded that failure to replicate Piaget's findings could not be attributed to differences in materials or to other slight procedural variations and he suggests that "the particular horizontal shiftings (décalages) typically found in European children may not apply in the same way to other cultural groups (Dasen, 1972b, p. 82)." In addition, Dasen (1972a) has noted a point of confusion with regard to a number of studies which claim to provide evidence for or against an invariant sequence:

> the results for or against a constant order hypothesis are always reported in broad statistical terms, usually in terms of the frequency of conserving responses over age; it is in the total sample or subsample that one test appears to be or not to be more difficult than another. If the concept of hierarchical development has any qualitative value, however, a constant order of development should be found in each individual (p. 32).

Taken together, these studies do not lend strong support for Piaget's claim with regard to the time lag between the conservation of mass, weight, and volume. Whether the décalage exists seems to depend to some extent on the materials used (e.g., Uzgiris, 1964), the method of assessment (e.g., Nummedal, 1970), the type of volume task used (e.g., Lovell & Ogilvie, 1961a), and the statistical procedures used to assess the presence of the décalage. Although the majority of subjects seem to acquire the conservation concepts in the order predicted by Piaget, the sequence of acquisition is not invariant. At present, little is known about specific experiences or subject characteristics which might be related to the décalage phenomenon.

It should be noted, in addition, that for subjects who have attained all three concepts at the time of testing, there is no way in which the order of acquisition can be determined. In many studies (e.g., Papalia, 1972), these subjects represent a large proportion of the total number tested. However, in the case of those children who conserve all three concepts at an age much younger than predicted, it can be assumed either that the décalage does not exist, or that the time lags between the various acquisitions have been considerably shortened. Although such findings would seem to have important implications for the generality of Piaget's theory, there has been a tendency to ignore individual differences in rate of development. Why is it, for example, that a number of subjects conserve volume in grade one (e.g., Lovell & Ogilvie, 1961a) while

many subjects at age 11-12 fail on this task (e.g., Elkind, 1961a; Papalia, 1972)? Can it be assumed that large numbers of adults and college students have not yet reached the stage of formal operations because they fail to conserve volume (e.g., Elkind, 1962)? Can the stage of concrete operations, marked at one end by the conservation of mass and at the other by the conservation of volume, be passed through rapidly for some children, and extended over long periods of time for others? In short, how applicable are Piaget's findings when applied to the individual child as opposed to the group average? Perhaps other variables need to be taken into account in order to explain the wide individual differences between groups and within subjects of the same age.

Demographic variables. Although Piaget is not himself interested in the influence of variables such as sex, IQ, amount of schooling, and socioeconomic status (Piaget, 1969), these variables have been the focus of a number of studies.

Elkind (1961b) has reported that the combined scores on a number of conservation tasks were significantly related to the majority of subtests of the Wechsler intelligence scale. The highest correlation was with the Picture Arrangement subtest ($r=.55$). For Full Scale IQ and Verbal IQ, the correlations were .43 and .47 respectively. Significant relationships between IQ and performance on Piagetian tasks have also been reported in other studies (e.g., Elkind, 1961a; Feigenbaum, 1963; Gaudia, 1972; Goldschmid, 1967, 1968). However, Sigel,

Roeper, and Hooper (1966) found that children aged 4-5 years with an average IQ of 149.5 did not conserve so it appears that chronological age is an important factor to consider.

Hood (1962) found that children with a mental age of five or under did not conserve, while Gruen and Vore (1972) found that differences in performance on conservation tasks were primarily attributable to MA, but not IQ. A number of other investigators (e.g., Freyberg, 1966; Goldschmid, 1967; Goodnow & Bethon, 1966; Mannix, 1960) have reported similar relationships between MA and performance on Piagetian tasks.

Greenfield (1966) has reported that only half of the unschooled African bush children in her study were able to conserve liquid quantity by age 11-13, whereas 100% of the urban school children and bush school children succeeded on the same tasks at this age. The effect of schooling appears to depend on the specific task (Goodnow & Bethon, 1966) and on the particular culture being studied (Dasen, 1972a). Goodnow (1962) has suggested that additional education may hinder rather than facilitate performance on some tasks.

Goodnow (1962) found that social class had no effect on conservation in a group of Hong Kong subjects. However, Almy, Chittenden, and Miller (1966) found that lower-class children lagged about a year behind their middle-class peers on number conservation and conservation of continuous quantity. Gaudia (1972) reports that age of acquisition of conservation is at least a year retarded in Negro children and in lower

socioeconomic groups, with older children showing the most retardation.

Sex differences on Piagetian tasks have not been widely reported but, where they have (e.g., Elkind, 1962; Goldschmid, 1967; Hooper, 1969), differences tend to favor the males. Papalia (1972) found that males in all groups below the age of 55 years scored higher than females, but that females in the two oldest groups in her study (ages 55-64, and over 65) performed better than the males on the conservation tasks.

Alternate Views

Although Piaget's findings have been broadly confirmed in a number of studies (cf. Hooper et al., 1971, for a review), dissatisfaction with Piaget's account of conservation and the role of reversibility has led investigators to suggest alternate interpretations. Of these, a perceptual interpretation has received the most attention and empirical support.

Perceptual vs. operational interpretations. Most investigators would agree that, in order to succeed in the Piagetian conservation tasks, the child must overcome his tendency to rely on the immediate perceptual appearance of things. However, there is a difference of opinion when it comes to the interpretation of this tendency. One view is that reliance on perception (and failure to conserve) denotes an absence of logical thought operations. This is essentially the view held by Piaget. According to Piaget (1957a), the absence of operational reversibility "becomes immediately apparent as soon as

there is a conflict between the perceptual configuration and logic (p. 12)."

An alternate view (e.g., Bruner, 1966; Bryant, 1972; Gelman, 1969; Mehler & Bever, 1967) is that young children might well be able to conserve and would do so if the Piagetian tasks did not present them with misleading perceptual cues. In this view, failure to conserve need not imply an operational deficit as Piaget insists. Rather, a strong tendency to rely on perception may well mask logical thought processes which the child has already acquired. In effect, it is argued that the typical Piagetian task is not suited to assessing the presence or absence of logical thought structures.

Support for a perceptual interpretation of performance on Piagetian tasks can be found in a number of studies. Frank (in Bruner, 1966) found that children were more likely to conserve when the transformations were shielded from their view. Taponier (cited in Berlyne, 1965) found that a number of children who correctly predicted that the water level would rise when water was poured into a thinner container failed to conserve when the transformation was actually carried out. Gelman (1969) and Beilin, Kagan, and Rabinowitz (1966) found that training designed to eliminate reliance on perceptual cues was effective in inducing better performance on Piagetian tasks. In contrast, Smedslund (1961c) and Wohlwill and Lowe (1962) found that this type of training had little effect on weight or number conservation. Goodnow (1962) has reported that adult subjects from Hong Kong performed poorly on Piagetian tasks and

on the Block Design, and she has suggested that even adults may be hindered by a marked perceptual setting to a problem.

There is also evidence that, when different assessment procedures are employed, children below the age of five do show evidence of logical thinking. Gelman (1972) used a non-verbal "magic" paradigm to assess conservation of number and found that surreptitious addition or subtraction of objects elicited strong surprse reactions and search behavior in children aged 3-6 years, whereas displacements of objects did not. These results led Gelman to suggest that:

> very young children possess an adequate concept of basic cardinal numerosity and a logic that treats number as invariant under irrelevant transformations . . . (and that) children who pass the conservation test are demonstrating many extralogical skills as well as their logical capacity; whereas children who fail are doing so for any of a number of reasons (1969, pp. 87-88).

Mehler and Bever (1967) have reported that 60% of their subjects under the age of five years were able to conserve number. However, there is some doubt (cf. Piaget, 1968c) whether the Mehler and Bever technique actually assessed conservation, and Beilin (1968) was not able to confirm their findings. By eliminating the conflict normally produced by pre- and post-transformation displays, Bryant (1972) was able to demonstrate conservation in children as young as three years. Training that some cues provide a more reliable basis for quantity judgments than others also proved effective. On the basis of these results, Bryant suggests that "young children's performance with some invariance problems lies far behind their competence (1972, p. 95)."

The results of these studies suggest that young children do have a basic understanding of the principle of invariance but are unable to use it effectively in the traditional conservation experiment. It has been shown that, when the conflict between perception and logic is reduced, logical thought processes are revealed.

Verbal factors in conservation. There has been considerable controversy as to whether Piagetian tasks are actually tapping underlying mental structures as Piaget claims, or whether they are merely an exercise in verbal skills. Braine (1959) has stated:

> Vocabulary development may well be a factor in many of Piaget's experiments . . . No theory which postulates levels of conceptual development can be regarded as definitely established when the supporting data are obtained through extensive verbal communication with Ss who differ in their ability to verbalize (p. 7).

There are a number of ways in which verbal factors may influence the outcome of a conservation experiment. For example, the question "Which one is longer?" may be interpreted to mean either "Which one looks longer?" or "Which one is really longer?" (Braine, 1964). Estes (1956) found that, when children were asked such questions as "Does it really have more?" following their reply to the standard conservation question, they often changed their original answer.

Another source of difficulty is that terms such as "more", "less", and "same" are not uniformly understood by children (Griffiths, Shantz, & Sigel, 1967). Donaldson and Balfour (1968) found that children under the age of five years are

more likely to use the word "more" in making comparisons than the word "less." Lumsden and Kling (1969) found that training on the concept "bigger" facilitated performance on a size conservation task. Conservers and nonconservers have also been found to differ in their ability to differentiate stimulus dimensions such as "long," "thick," and "thin" (Farnham-Diggory & Bermon, 1968), and in their ability to discriminate connotative from denotative meaning (Nummedal & Murray, 1969).

In view of these findings, a number of investigators (e.g., Brainerd, 1973a; Brison, 1966; Goldschmid, 1968; Miller, 1973) have attempted to control for some of these factors by pretesting the subjects and eliminating those who showed a lack of understanding of terms commonly used in conservation assessment. However, Piaget's position is that language development is itself dependent upon the level of cognitive organization already attained. He states: "operations direct language acquisitions rather than vice versa (Piaget, 1967, p. 533)."

Competence vs. performance. The findings presented in the previous section suggest that, in assessing behavior in the conservation experiment, it is necessary to make a distinction between what the child is capable of doing under optimal conditions (competence) and what he actually does in any given situation (performance). In the "competence-performance" model proposed by Flavell and Wohlwill (1969), this distinction has been fully elaborated. In this model, performance is seen to vary not only as a function of the

subject's cognitive competence, but also with a multiplicity of "automaton" factors (task variables). Flavell and Wohlwill feel that any tests used to diagnose the competence of a child will necessarily entail a certain amount of automaton "noise" which is difficult to measure. Whether or not the requisite operations are functional will depend on the nature of the stimulus materials, the manner of presentation, the demands for information-processing, the role played by memory and other factors: "To say that someone failed to do A in a given situation need not be equivalent to saying that he was fundamentally incapable of doing A, in that situation or in any other (ibid, p. 69)." Flavell and Wohlwill feel that the incorporation of the competence-performance distinction in the analysis of cognitive development would enable us to take into account differences in performance while staying within the general framework of Piaget's system (ibid, p. 96).

Flavell (1963) has stated that Piaget's theory as it now stands, contains "no obvious conceptual machinery" (p. 441) for dealing with individual differences, and he has proposed that such differences might be more easily incorporated into a two-level model (Flavell, 1963, pp. 438-441). This model takes into account the distinction between competence and performance but also gives explicit recognition to the role of subject variables. Flavell proposes that the lower level of this model might include a group of intellectual tools or devices which correspond to Piaget's "operational schemas" and that the upper level would consist of:

> a general cognitive approach or strategy . . . (which) might comprise the child's general tendency to structure and organize concrete givens, to give more weight to cognitive inference and less weight to perceptual impression, to make use of mobile, reversible operations (ibid, pp. 438-439).

When viewed in this manner, successful performance on Piagetian tasks will depend not only on the intellectual tools available, but also on the cognitive approach of the individual. This approach or strategy will determine to what extent, and in what manner, the individual will make use of the mental tools which he possesses; failure to conserve need not imply a deficit at the lower (operational) level as Piaget insists, but might be at least partly attributed to a failure at the upper (cognitive approach) level.

What Flavell has described as a "cognitive approach" bears a marked similarity to Witkin's description of the characteristics associated with the field dependent-field independent cognitive style dimension (e.g., Witkin et al., 1962) and suggests that the two-level model outlined above might provide a theoretical framework within which the concept of cognitive style might be interpreted.

The Field Dependence Dimension

Recent work in the area of perception and cognition has led to the suggestion that people adopt stable and consistent modes of functioning which are manifested across a broad range of perceptual and intellectual activities and reflected in personality as well. This consistency across areas is what

is generally referred to as "cognitive style". Although the field dependent-field independent cognitive style dimension identified by Witkin and his co-workers (e.g., Witkin et al., 1962) was originally thought of as a perceptual style,it has now come to be regarded as one manifestation of a person's general tendency to articulate and structure experience in a "global" versus an "analytic" fashion--a tendency which "pervades the individual's perceptual, intellectual, emotional, motivational, defensive, and social operations (Witkin et al., 1962, p. 4)."

The tests employed by the Witkin group to assess the individual's mode of functioning in the perceptual area are the Body-Adjustment-Test (BAT), the Rod-and-Frame Test (RFT), and the Embedded Figures Test (EFT). In the BAT, the subject is seated on a tilted chair in a tilted room and is asked to adjust his body to an upright position. In the RFT, the subject sits in a darkened room facing a luminous rod and frame, both of which are tilted. His task is to adjust the rod to the true vertical. In the EFT, the subject is asked to locate simple geometric figures which are embedded in a series of complex geometric designs.

What these tests appear to require in common is the ability to keep an item (body, rod, or simple figure) isolated from compelling background forces (Witkin et al., 1962). Persons who perform well on these tests are said to be "field independent" while those who have difficulty in separating items from the embedding field are said to be "field dependent."

Although people become more field independent with age (up to about fifteen years), their mode of field approach remains quite stable (in relation to their age group) over long periods of time (Witkin, Goodenough, & Karp, 1967). Witkin (Witkin et al., 1962) reports that males are generally more field independent than females.

People who perceive in a relatively field dependent manner in the battery of perceptual tests devised by the Witkin group show the same tendency in many other perceptual situations as well. This has been demonstrated, for example, in studies using perceptual illusions, constancies, and reversible perspective (Witkin et al., 1962). Consistency in psychological functioning is not limited to perception but extends also to intellectual behavior. Witkin et al., (1962) found that scores on their perceptual battery were significantly related to the Block Design, Picture Completion, and Object Assembly subtests of the Wechsler scales, but not to the verbal scales. Goodenough and Karp (1961) found that the three Wechsler subtests mentioned above and the field dependence measures all showed high loadings on a factor described as "closure", "adaptive flexibility", or "analytical field approach." Significant relationships between field independence and a variety of intelligence tests have been reported in numerous studies with adults (e.g., Dubois & Cohen, 1970; Elliott, 1961; Wachtel, 1971), and with children (Campbell & Douglas, 1972; Corah, 1965; Pedersen & Wender, 1968). In view of these findings, it has been suggested (e.g., Zigler,

1963a, 1963b) that general intelligence should serve as a control variable when investigating relationships between field dependence and other variables.

There is some evidence that field dependence is an important variable in concept attainment. Dickstein (1968) found that field independence was related to concept attainment in a task containing a number of irrelevant perceptual attributes. He suggests that field independent persons are better able to analyze the stimulus complex and ignore irrelevant dimensions than are field dependent subjects. Elkind, Koegler, and Go (1963) found that field independent subjects performed better than field dependent subjects on a test of perceptual concept formation, but not on verbal concept formation.

Witkin has noted that field independence is closely related to a number of dimensions or factors which seem to involve the ability to "shift set" or to overcome established ways of dealing with the environment (Witkin et al., 1962). These include: (a) the "flexibility of closure" factor identified by Thurstone (1944) and described as "the ability to shake off one set in order to take a new one (p. 111)," (b) Guilford's "adaptive flexibility" factor which Witkin defines in terms of the ability to overcome a predominant organization or context, (c) Podell and Phillips' "spatial decontextualization" factor. In addition, Gardner and his associates (Gardner, Holtzman, Klein, Linton, & Spence, 1959) have identified a similar "field articulation" factor which they inter-

pret in terms of the ability to attend selectively to relevant vs. irrelevant cues.

Evidence suggests that field independent persons perform better in problem-solving situations, even when there is no obvious perceptual component involved. These include the insight problems devised by Duncker (1945) in his studies of "functional fixedness", and the "Einstellung" water-jar problems, both of which are thought to involve the ability to overcome an induced set (Witkin et al., 1962). Witkin has conceptualized this set-breaking process in terms of an ability to overcome embeddedness: "For the set to be broken, the elements must be considered apart from this previously adopted organization and arranged into a new organization (Witkin et al., 1962, p. 77)." Linton (1952) has reported that field independent subjects are more able to overcome a "personal set" (a set which the subject brings to the experiment with him) in order to correctly solve a series of syllogistic reasoning problems.

Because of the relationship found between performance on perceptual and intellectual tests, Witkin has concluded that the trait which he has labelled "field independence" is not limited to perception but might be interpreted as a manifestation of a more general capacity to structure experience in an articulated fashion. He states:

> We have adopted the term "analytical field approach for the style of functioning represented in both the perceptual and intellectual behavior of an individual

> which involves the ready ability to overcome an embedding context and to experience items as discrete from the field in which they are contained (Witkin et al., 1962, p. 80).

In contrast, persons who lack this capacity are said to experience their surroundings in a relatively "global" and diffuse manner.

According to Witkin, field dependent and field independent persons differ not only in their performance on perceptual and intellectual tasks, but in personality as well. In his reports (e.g., Witkin, Lewis, Hertzman, Machover, Meissner, & Wapner, 1954; Witkin et al., 1962), field dependent persons are described as dependent in their interpersonal relations, conforming, suggestible, and lacking in self-confidence and self-acceptance. Field independent persons are said to be characterized by the opposites of these traits. The relationship between field dependence and conformity has been confirmed in several studies (e.g., Linton, 1955; Marlowe, 1958; Rosner, 1957), and there is evidence that field dependent adults and children are more socially dependent than their field independent peers (Bell, 1955; Beller, 1958; Crandall & Sinkeldam, 1964; Gordon, 1953; Pedersen & Wender, 1968). Field independent persons have been found to be higher in achievement motivation than are field dependent persons (Crandall & Sinkeldam, 1964; Honigfeld & Spigel, 1960; Wertheim & Mednick, 1958). Fitzgibbons and Goldberger (1971) conceptualize the field dependent-field independent dimension in terms of task vs. social motivation.

Witkin et al. (1962) have observed that field dependent children are tense, anxious, and lacking confidence in their own judgments in the testing situation. Field dependent and field independent children have also been shown to differ in their response to social disapproval (Konstadt & Forman, 1965) and to frustration (Campbell & Douglas, 1972). Physiological measures indicate that field dependent subjects are prone to anxiety and behavioral disruption in stress situations (e.g., Block, 1957; Cohen, Silverman, Shmavonian, & Bognodoff, 1965), but none of these studies has used children as subjects.

In order to link all of these diverse variables (personality, intellectual, perceptual, motivational) together, Witkin (Witkin et al., 1962, Ch. 2) has introduced the concept of "differentiation," a concept which has its origins in Werner's theory of development (cf. Werner, 1948). According to the differentiation hypothesis, the general capacity to "keep things apart" in experience is a reflection of the underlying extent of differentiation and represents a stable, self-consistent characteristic which is manifested in diverse areas of psychological functioning. Performance on the battery of perceptual tests devised by Witkin is thought to reflect this general capacity (Witkin et al., 1962).

Cognitive Style and Conservation

Vernon (1969) has noted that "one of the few kinds of tests Witkin has not explored is the Piaget-type task of operational thinking (p. 58)"; yet it seems likely that the

characteristics associated with a field independent cognitive style are important factors to consider in relation to performance on the conservation tasks.

On the perceptual level, the ability to attend selectively to relevant stimulus dimensions, to separate items from an embedding context, and to resist distractions all seem clearly relevant to the view that one prerequisite to the attainment of conservation is the ability to resist the influence of misleading perceptual cues. In a number of studies discussed earlier (e.g., Bryant, 1972; Frank, in Bruner, 1966), conservation performance was improved by reducing the conflict between perception and logic. It seems likely that field independent subjects have the ability to resist these perceptual irrelevancies without the aid of training or special screening devices.

On the intellectual level, the field independent person's demonstrated ability to adopt an analytical vs. a global approach, his ability to "shift set" and to restructure the field, his more flexible approach to problem-solving would all be likely to facilitate performance on the conservation tasks. Such persons would be more likely to take note of more than a single dimension than persons less analytically inclined. Many of the problem-solving situations in which field independent persons have been shown to excel seem to have requirements similar to those in the conservation tasks.

Personality and emotional factors might also play a part. Since field dependent subjects tend to be socially-oriented vs. task-oriented, low in achievement motivation, conforming, suggestible, and reliant upon others for their attitudes and opinions, one would expect them to show less interest in the task and to be more readily influenced by irrelevant social cues (e.g., those provided by the examiner). Since their answers might be based more on what they perceive the examiner expects of them than on any consideration of task requirements, it is likely that their performance would be inferior to that of their more task-oriented, self-reliant (i.e., field independent) peers.

On the basis of Flavell's (1963) two-level model previously discussed, it may be suggested that field independent subjects are more likely than field dependent subjects to make efficient use of the mental operations which they already possess. If this is the case, then the mass-weight-volume décalage might be less likely to occur among the field independent than among the field dependent subjects.

Research evidence. It is only very recently that investigators have shown an interest in exploring the role of specific subject variables in performance on Piagetian tasks. As a result, research evidence directly related to the present discussion is quite limited. Fleck (1972) found that field independent children scored significantly higher than field dependent children on conservation problems. However,

this result is not clear since the majority of the field independent children in this study were in grade two, and the majority of the field dependent children in kindergarten. Fleck has not reported the relative difficulty of the various conservation tasks used in this study.

Pascual-Leone (1972) has reported a significant relationship between field independence and conservation in a group of boys of low middle-class background, and in a group of college males. No mention is made of the décalages between various acquisitions and, unfortunately, complete details of this research are not available at present.[2]

Simpson (1970) has studied the "reflective-impulsive" cognitive style dimension (cf. Kagan, 1966) in relation to conservation of mass, weight, and volume. A significant main effect of cognitive style on all tasks (with the exception of one of the three volume tasks) supported Simpson's prediction that reflective subjects would perform better on conservation tasks than would impulsive subjects. The horizontal décalage between the mass, weight, and volume concepts was supported only for the impulsive subjects. There is some evidence (e.g., Campbell & Douglas, 1972) that the reflective-impulsive dimension is closely related to the field dependence dimension.

Goldschmid (1968) has reported significant relationships between performance on Piagetian tasks and personality characteristics. Although self-ratings on an adjective check-

---

[2] J. Pascual-Leone, personal communication, June 13, 1973.

list did not differentiate among children with high and low conservation scores, ratings from teachers and peers were significantly related to conservation performance. High conservers were generally described more favorably by their teachers, preferred by their peers, more objective in their self-evaluation, and less dominated by their mothers. Field independent subjects have been described in similar ways (e.g., Witkin et al., 1962).

Hypotheses

The present study was designed primarily to investigate the role of the field dependent-field independent cognitive style dimension in the attainment of conservation of mass, weight, and volume. In order that results might be directly compared to those reported by Piaget, a Piagetian format (cf. Elkind, 196la; Inhelder, 1968; Piaget et al., 1960) was used. Children in grades one, three, and five were chosen to participate in the study because these grades correspond quite closely with the ages at which Piaget has reported that the majority of subjects attain conservation of mass (age 7), weight (age 9), and volume (age 11). In order that sex differences might also be examined, both boys and girls were included. The major hypotheses of the study were as follows:

Hypothesis 1: Field independent subjects will score significantly higher than field dependent subjects on the conservation of mass, weight, and volume.

Hypothesis 2: The proportion of subjects showing the Piagetian décalage pattern between the mass, weight, and volume concepts will be significantly greater for the field dependent subjects than for the field independent subjects.

The following hypotheses were derived from Piagetian theory with respect to the role of conservation in the development of logical thinking. If Piaget is correct in asserting that the conservation of mass, weight, and volume can be used to assess developmental progress, then:

Hypothesis 3: Performance on the conservation tasks will show a significant improvement with increasing age (grade level).

Hypothesis 4: Performance on the conservation tasks will vary as a function of the particular quantity type being assessed. The order of difficulty (from easiest to hardest) was predicted to be mass, weight, and volume.

On the basis of previous research evidence with regard to sex differences on Piagetian problems, it was also predicted that:

Hypothesis 5: Males will score significantly higher than females on the conservation tasks.

assisted with the administration. Level 1 was used for grade one, Level 1H for grade three, and Level 2 for grade five. Each level requires about 50 minutes to administer, and testing was carried out over a two-week period.

Since the CTMM was devised originally as a group test to parallel the Stanford-Binet, the type of mental abilities assessed are similar. Although the CTMM provides a number of scale scores as well as an MA score and separate language and non-language IQ's,only the total IQ score was considered in the present study. The mean of the CTMM is 100 with a standard deviation of 16 points.

Evidence for the reliability and validity of the CTMM presented in the Technical Report (California Test Bureau, 1965) is as follows: Coefficients of reliability based on the Kuder-Richardson formula No. 21, and by the split-halves method, range from .92 to .95 for the levels used in the present study. Test-retest reliabilities using the same level after a one-year interval were .62 for Level 1, and .87 for Level 2. Using adjacent levels of the CTMM, the test-retest reliabilities were .70 for grades 1-2, .56 for grades 3-4, and .88 for grades 6-7.

Content validity for all levels is based on correlations with the Stanford-Binet. Correlations (Pearson r) between the two tests range from .66 to .74 and, when corrected for range and attenuation, these figures rise to .85 and .87. There is no information in the report on the correlations between Levels 1 and 1H and other standardized tests of mental

ability. For Level 2, the coefficients range from .78 to .81.

It was found that, despite efforts to obtain a relatively homogeneous "average" group with respect to IQ, the mean score at each grade level was somewhat above average, and the range of scores fairly wide. For this reason, subjects scoring below 90 and above 129 on the CTMM were eliminated. Subjects who had either failed or skipped a grade (or for some other reason were an inappropriate age for their grade) were also eliminated so that the age range within any grade could not exceed 12 months. It should be noted that the majority of subjects excluded on the basis of this criterion had previously been eliminated on the basis of extremes in IQ as outlined above. Two grade-one children judged by their teachers to be emotionally disturbed were also excluded.

In summary, these procedures resulted in limiting the population to a relatively homogeneous middle-class group with IQ scores falling between 90 and 129. Maximum age range within any grade was 12 months.

Phase 2: Selection of cognitive style groups. From the subjects remaining after the above selection procedures, 36 boys and 36 girls from each grade were randomly selected and tested on the Children's Embedded Figures Test (CEFT, Karp & Konstadt, 1963) the criterion measure of field dependence-field independence. Choice of the CEFT in preference to another common measure of field dependence, the Rod-and-Frame Test (RFT), was based on several considerations. A pilot study

was carried out using the CEFT and a portable RFT designed according to Oltman's (1968) specifications. The correlation obtained between the two measures (r=.33) administered to a group of children in grades one and three was not high enough to warrant the use of this RFT as a measure of field dependence. Reliability and validity data on either the standard or portable RFT is lacking for children below the age of 10, except for one study with kindergarten children (Dreyer, Dreyer, & Nebelkopf, 1971). The existing evidence (Dreyer et al., 1971; Dreyer, Nebelkopf, & Dreyer, 1969; Witkin, Oltman, Raskin, & Karp, 1971) suggests that the reliability and validity of the CEFT is adequate.

The CEFT consists of 25 picture cards in which the child is asked to locate a hidden figure. In 11 of the cards, the hidden figure is a "tent" and, in the remaining 14 cards, it is a "house". Scores are obtained by counting the number of figures correctly located. Each subject was tested individually by the experimenter in a private office made available by each school. Standard instructions (Witkin et al., 1971) were followed so that no time limit was imposed. The time required to administer the CEFT varied from 15 minutes to 30 minutes.

The 25th and 75th percentiles were used to establish groups of field dependent (FD) and field independent (FI) subjects in the following manner: for each grade, the 9 boys and 9 girls scoring highest on the CEFT were designated "field independent", and the 9 boys and 9 girls scoring lowest on the CEFT were designated "field dependent."

Understanding of relational terms. During the same session and immediately preceding the CEFT, subjects were tested individually in order to assess their understanding of relational terms "more", "less", "same", and "different" which are typically used in conservation tasks. A description of the stimuli used and the details of the procedure are contained in Appendix A. Because of the relatively large number of children showing uncertainty about the word "less", it was decided to avoid the use of this term in the conservation tasks. Subjects whose responses suggested a failure to understand any of the other terms were eliminated from the study. A total of six children (five from grade one, and one from grade three) were excluded for this reason.

Conservation Tests

All subjects were tested on the conservation of mass, weight, and volume. The methods of assessment were similar to those described by Piaget (cf. Inhelder, 1968; Piaget et al., 1960) and to those used in a number of replication studies (e.g., Elkind, 1961a, 1961b; Goodnow, 1962; Papalia, 1972; Uzgiris, 1964).

In order to avoid a possible response set, and to maintain the interest of the children, different materials were used in testing the conservation of mass, weight, and volume. For each of these quantity concepts, there were three transformations which were presented in a fixed order. The same or similar materials and transformations have been employed in a number of previous studies (e.g., Goldschmid, 1967, 1968;

Inhelder, 1968; Lovell & Ogilvie, 1961a; Piaget et al., 1960).

For the conservation tests, the subject was seated across a table from the experimenter, and the session was introduced in the following manner:

> Today I am going to ask you some questions about whether certain things are the same or whether they are different. Then I will ask you to explain to me, in your own words, why they are the same or different. I have several different materials here which I would like to ask you about. People of different ages often have different reasons for saying that things are the same or different, and I am interested in your reasons. Do you think you could do this for me?

At the beginning of each task, the subject was presented with two identical objects and was asked to judge whether they were the same in terms of the quantity being considered. If he did not agree, the objects were adjusted by the experimenter until the subject agreed they were the same. After the initial identity of the objects had been established, one of them was changed into a different shape and the subject was asked whether the two objects were still the same in terms of the property considered (judgment question). The subject was then asked to give a reason for his judgment (explanation question). Prior to each transformation, the initial equality of the stimulus objects was re-established. All sessions were tape-recorded and scored later.

For the conservation of mass, the stimulus objects were two plastic tumblers (4 inches high X 2 3/4 inches in diameter), each half-filled with flax seed. The transformations were performed by pouring the flax from one tumbler into (1) a tall, thin container measuring 10 inches tall X 1 1/4 inches in

diameter, (2) a low container, 6 inches wide, and (3) five small containers, each measuring 1 1/2 X 1 1/2 inches. The standard question asked after each transformation was, "Is there the same amount of flax in this one as in that one, or does one have more flax in it?"

For the conservation of weight, two identical 3-oz. balls of plasticine were used. A child's toy scale was used to establish the initial equality of the weight of the two balls. After the subject agreed that the two balls weighed the same, the following transformations were made on one of the balls: (1) a hotdog, 6 inches long, (2) a pancake, 4 inches in diameter, and (3) three smaller balls of approximately equal size. A ruler was used to standardize the size of the transformed objects. The standard question asked for the conservation of weight was, "Does this hotdog (pancake, etc.) weigh the same amount as the ball, or does one weigh more?"

The type of volume conservation assessed in the present study was "occupied" (displacement) volume because it was on the basis of this procedure that the mass-weight-volume décalage was reported. Piaget found that the conservation of "interior" volume was attained at approximately the same age as the conservation of weight (age 7-8 years) and occupied volume not until about the age of 11-12 (Piaget et al., 1960).

The procedure used in the volume task was based on that described by Piaget et al. (1960) and by Inhelder (1968). Materials were a 1000 milliliter pyrex beaker, two elastic

bands (one red, one green), water, and two sets of 18 solid plastic cubes (3/4 inch). The beaker was filled with 800 ml. of water, and the water level marked with a red elastic band. The cubes were arranged in two blocks of 3 X 3 X 2 (length X width X height). These were identical except that the cubes in the standard block were glued together so that they could be easily placed in the water. After the subject had noted the identity of the two blocks, the experimenter lowered the standard into the water with a pair of tongs and marked the new level with the green elastic band. After the block was removed from the water, the subject was asked to predict what would happen if the comparison block was placed in the beaker. When the subject agreed that the water would rise the same amount, the following tansformations were carried out: (1) 3 X 2 X 3 block, (2) 3 X 1 X 6 block, and (3) three 2 X 1 X 3 piles, each separated by the width of one cube. The criterion question was worded in terms of the displacement of water: "Would this block make the water go up the same amount as that one, or would one push the water up more?"

Scoring. Judgments and explanations were scored separately and then combined into a total conservation score. Correct judgments ("it is still the same") received a score of 1, and incorrect judgments were scored 0. Explanations were scored adequate or inadequate on the basis of the criteria outlined below. Adequate explanations were scored 1, and inadequate explanations were scored 0. Since there were three

tasks on each quantity type, combined scores on any given quantity could range from 0-6. Across all tasks, the scores could range from 0-18.

Tape-recorded protocols were transcribed verbatim onto data sheets and half of these were scored by an independent judge. Inter-rater agreement in adequate vs. inadequate responses was 98%. Percentage agreement in sorting the explanations into specific categories was 90%.

Before describing the criterion used to classify subjects as conservers or nonconservers, it should be noted that there is considerable disagreement as to what type of verbal response is acceptable. Whereas the Bruner group (Bruner et al., 1966) feel that a correct response to the judgment question is adequate, Piaget and his colleagues (cf. Inhelder, 1968) require, in addition, that subjects provide an adequate explanation for such responses. Brainerd (1973b) has recently argued that the Genevans' insistence on an explanation is actually inconsistent with Piaget's own theoretical position with regard to the primacy of thought over language, and that the only defensible procedure is to regard the initial judgment as adequate. A discussion of the relative merits of these two opposing viewpoints is beyond the scope of this thesis. Since the present study was an attempt to replicate Piaget's findings, the more stringent criterion proposed by the Geneva group was adopted. Subjects who received a score of 5 or 6 (3 correct judgments plus 2 or 3 correct explanations) out of a total

possible score of 6 were classified as conservers of that quantity. Subjects who received scores of 0-4 on a particular quantity concept were classified as nonconservers. Similar methods of classification have been used in a number of previous studies (e.g., Nummedal, 1970; Papalia, 1972; Simpson, 1970; Uzgiris, 1964).

Criteria for scoring explanations. Conservation explanations were considered adequate if they met one or more of the following criteria:

1. Compensatory relations: the subject states that changes in certain dimensions are compensated for by changes in other dimensions.
   e.g., "This one is longer, but thinner."

2. Reversibility: the subject states that the transformation could be cancelled by an inverse transformation.
   e.g., "You could pour it back and it would be the same."

3. Addition/Subtraction: the subject states that nothing has been added or taken away.
   e.g., "You didn't add any on or take any off."

4. Identical action: the subject states that the standard object could be transformed in a similar manner to the comparison object.
   e.g., "You could make that ball into a pancake like that."

5. Initial equality and/or irrelevant transformation: the subject states that the two objects were initially equal and/or that the transformation makes no difference to the property in question (these two explanations generally occurred together).
   e.g., "They were the same before, and you just poured them in here."

6. Logical necessity: the subject states a general rule.
   e.g., "No matter what shape it is, it will still weigh the same."

7. Quantitative equivalence based on another property:
   e.g., "It still has the same amount, so it must weigh the same."

The following conservation explanations were considered inadequate:

8. Irrelevant: included in this category are tautologies, unclear responses, and irrelevant remarks.

9. No answer or "don't know".

The following categories were used for scoring nonconservation responses (all were given a score of 0).

IP. Irrelevant perceptual: the subject focuses on dominant perceptual cues, usually in a single dimension.
e.g., "This would make the water go up more because it is higher."

IC. Irrelevant conceptual: the subject goes beyond his immediate perception in attempting to rationalize his nonconservation response, usually by appealing to technical or pseudo-scientific terminology and information.
e.g., "The pancake would weigh less because the weight is distributed over a much larger area, whereas it is compressed more tightly in the ball."

NA. No answer or "don't know".

CHAPTER IV

RESULTS

A summary description of the groups with respect to IQ, age, and field dependence is contained in Tables 1, 2, and 3 respectively. In order to determine whether there were any within-group differences in these variables which might confound results, preliminary statistical analyses were carried out on these data. Throughout these and subsequent analyses, the .05 level of significance was adopted.

Table 1 shows that in five of the six comparisons, the mean IQ of the field independent group was higher than that of the corresponding field dependent group and, in the remaining comparison, the difference was in the opposite direction. Results of t tests indicated that none of the field dependent and field independent groups within grade levels differed significantly in IQ. The mean ages shown in Table 2 indicate that, at each grade level, the field dependent and field independent subjects, and the boys and girls, were closely matched in age. None of the F values obtained in the one-way analyses of variance attained significance.

Since any sex effect might also be confounded by sex differences in degree of field dependence, the mean CEFT scores of the corresponding groups of boys and girls were also compared. Results of t tests shown in Table 3 indicated that none of the differences was significant. It can be concluded on the basis

TABLE 1

Summary of t Tests on Group Differences in IQ

			Mean IQ	SD	t
Gr. 1	Male	FD	106.77	9.43	1.18
		FI	111.77	7.42	
	Female	FD	111.77	8.78	0.39
		FI	110.00	9.30	
Gr. 3	Male	FD	106.00	7.86	1.16
		FI	111.00	9.37	
	Female	FD	107.33	8.41	1.52
		FI	113.00	6.41	
Gr. 5	Male	FD	108.89	5.51	1.72
		FI	114.11	6.62	
	Female	FD	110.67	7.01	0.64
		FI	112.89	7.46	

t (.05, df=17), two-tailed = 2.11

TABLE 2

Summary of One-Way Analyses of Variance on Group Differences in Age

			Mean Age	F
Gr. 1	Male	FD	6.69	1.02
		FI	6.68	
	Female	FD	6.52	
		FI	6.52	
Gr. 3	Male	FD	8.78	2.02
		FI	8.74	
	Female	FD	8.49	
		FI	8.73	
Gr. 5	Male	FD	10.65	0.21
		FI	10.62	
	Female	FD	10.66	
		FI	10.64	

F .95 (3, 32) = 2.90

TABLE 3

Summary of t Tests on Group Differences in CEFT Scores

		Mean CEFT	SD	t
Gr. 1	FD boys	5.33	0.94	1.78
	FD girls	6.44	1.64	
	FI boys	13.88	0.99	0.45
	FI girls	14.22	1.87	
Gr. 3	FD boys	7.77	1.31	0.29
	FD girls	7.55	1.70	
	FI boys	20.33	1.89	0.96
	FI girls	19.44	1.83	
Gr. 5	FD boys	11.33	2.62	0.60
	FD girls	10.66	1.76	
	FI boys	21.00	1.25	0.63
	FI girls	21.33	0.82	

t (.05, df=17), two-tailed = 2.11

of these tests that any differences found between groups in subsequent analyses are not likely to be due to these factors.

Analysis of Variance

The means and standard deviations of all groups on the mass, weight, and volume tests are shown in Appendix B. Data were analysed with a mixed analysis of variance (Winer, 1962) in which the main variables were grade level, sex, and cognitive style, with repeated measures on the quantity type factor. Post hoc comparisons between means were carried out according to Tukey's HSD procedure (Kirk, 1969). A summary of the Tukey tests for the present analysis is contained in Appendix C.

Results of the analysis of variance (Table 4) showed that the main effect of grade level attained significance ($F=6.63$, $df=2, 96$, $p<.01$). However, a significant interaction between grade level and quantity type ($F=3.25$, $df=4, 192$, $p<.05$) revealed that the predicted improvement with age depended on the particular quantity type being assessed. This interaction is illustrated in Figure 1. Post hoc comparisons (Table C.1) showed that, for the conservation of mass, there was a significant improvement from grade one to grade three ($p<.01$), but not from grade three to grade five. For the weight and volume tasks, none of the means at grades one, three, and five differed significantly. Thus, the improvement with age (grade level) predicted in Hypothesis 3 was only partially supported.

The main effect of sex was not significant ($F=2.60$, $df=1, 96$, $p>.10$), but there was a significant Sex X Quantity

TABLE 4

Analysis of Variance of Conservation Scores

Source of Variation	df	MS	F
Grade Level (A)	2	51.69	6.63**
Sex (B)	1	20.25	2.60
Cognitive Style (C)	1	76.08	9.75**
A X B	2	8.12	1.04
A X C	2	22.19	2.85
B X C	1	2.60	0.33
A X B X C	2	3.37	0.43
Error (a)	96	7.80	
Quantity Type (D)	2	43.84	19.76***
A X D	4	7.21	3.25*
B X D	2	9.53	4.30*
C X D	2	1.00	0.45
A X B X D	4	1.12	0.51
A X C X D	4	1.03	0.47
B X C X D	2	1.78	0.80
A X B X C X D	4	2.75	1.24
Error (b)	192	2.22	
Total	323		

*<.05
**<.01
***<.001

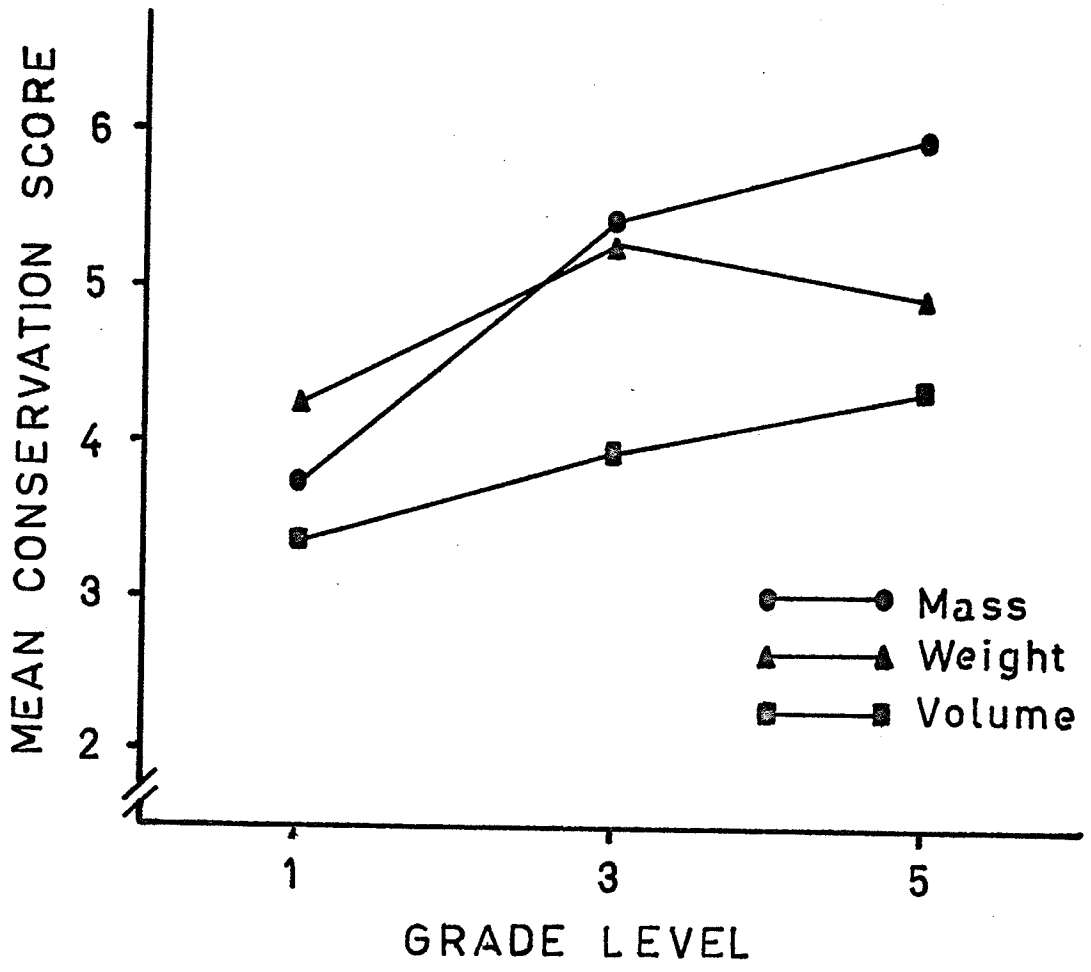

FIG. 1. Grade Level X Quantity Type interaction shown in the analysis of variance.

Type interaction ($F=4.30$, $df=2, 192$, $p<.05$) which is illustrated in Figure 2. Post hoc comparisons (Table C.2) revealed that boys scored significantly higher than girls on the volume test ($p<.01$), but not on mass or weight. Thus, Hypothesis 5 which predicted that boys would score higher than girls gained partial support.

Of major interest is the significant main effect of cognitive style ($F=9.75$, $df=1, 96$, $p<.01$) indicating that field independent subjects scored significantly higher than field dependent subjects on the conservation tasks. None of the interactions involving cognitive style attained significance so that Hypothesis 1 is clearly supported. For purposes of illustration, the performance of field dependent and field independent subjects on the mass, weight, and volume tasks is shown in Figure 3.

The main effect of quantity type was also significant ($F=19.76$, $df=2, 192$, $p<.001$). Post hoc tests (Table C.3) showed that, for groups combined, the mean score on the mass and weight problems were both significantly higher than on the volume test ($p<.01$ in both comparisons), but that the difference between mass and weight was not significant. Post hoc tests of the effect of quantity type within each sex (Table C.4) revealed that females scored significantly higher on conservation of weight and mass than they did on volume ($p<.01$ in both comparisons), but that the difference between their scores on the mass and weight tasks was not significant. For the males, none of the means on the mass, weight, or volume tests differed significantly.

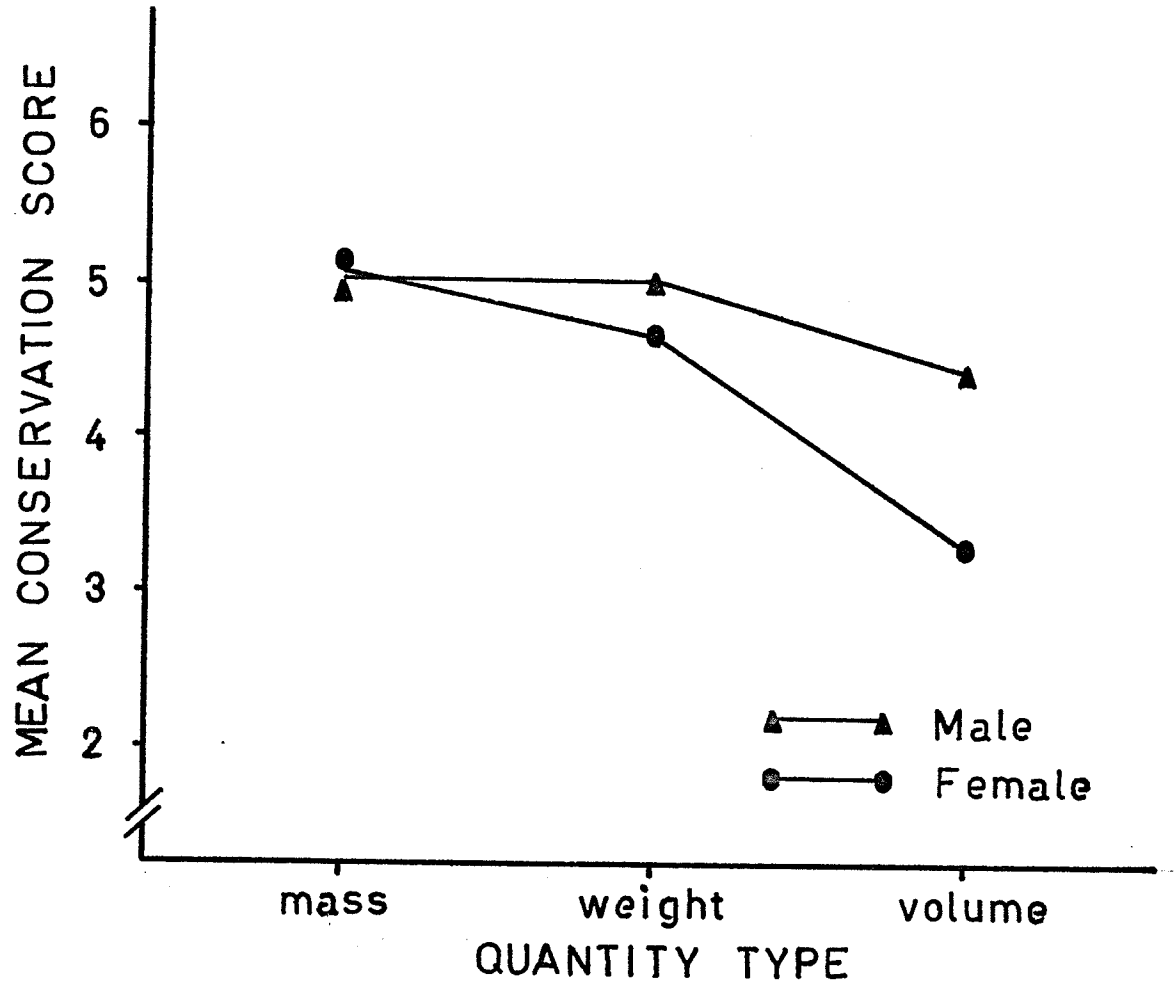

FIG.2. Sex X Quantity Type interaction shown in the analysis of variance.

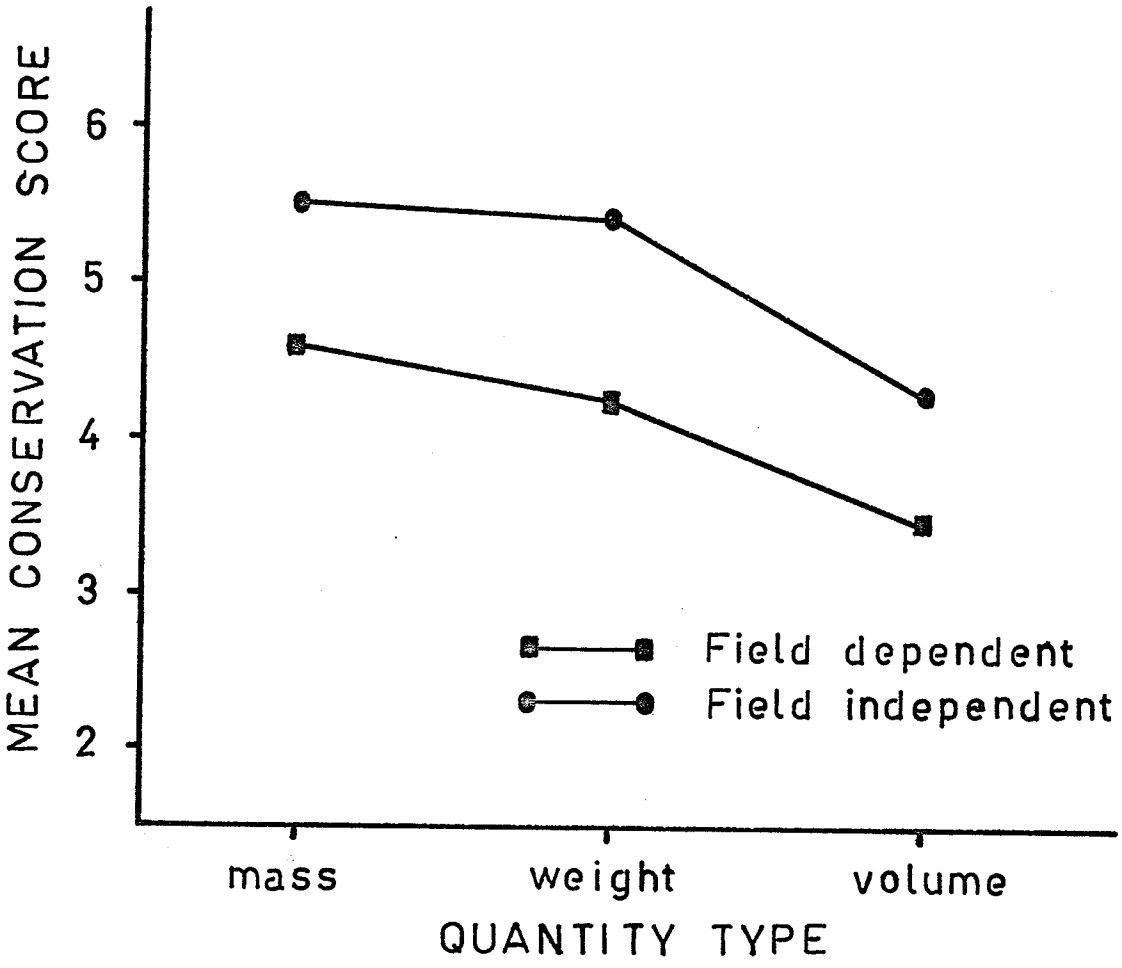

FIG. 3. Conservation of mass, weight, and volume in field dependent and field independent subjects.

The significant Quantity Type X Grade Level interaction noted above also indicates that the relative difficulty of the mass, weight, and volume tasks varied according to the grade level of the subjects (see Figure 4). Post hoc comparisons (Table C.5) showed that the difference between mass and weight was significant only at the grade-five level ($p<.01$), weight and volume differed significantly at grade one ($p<.05$) and at grade three ($p<.01$), and mass and volume differed significantly at grades three ($p<.01$) and five ($p<.01$). It is clear from Figure 4 that the nature of the interaction obtained is not supportive of Piaget's claim with regard to the sequential attainment of the conservation concepts.

In summary, Hypotheses 1 which predicted that field independent subjects would score significantly higher than field dependent subjects on conservation tasks was strongly supported. Hypotheses 3 and 4 which were derived from Piagetian theory and research received very limited support. Results showed that there was a significant improvement with age only on the conservation of mass between grades one and three, and that there was no significant improvement in weight and volume conservation with increasing grade level. Whether there was a significant difference between the mass, weight, and volume tasks depended on the sex of the subjects and on grade level. Post hoc analyses of the interaction between quantity type and grade level did not support the notion of the sequential attainment of the mass, weight, and volume concepts. Since males scored significantly

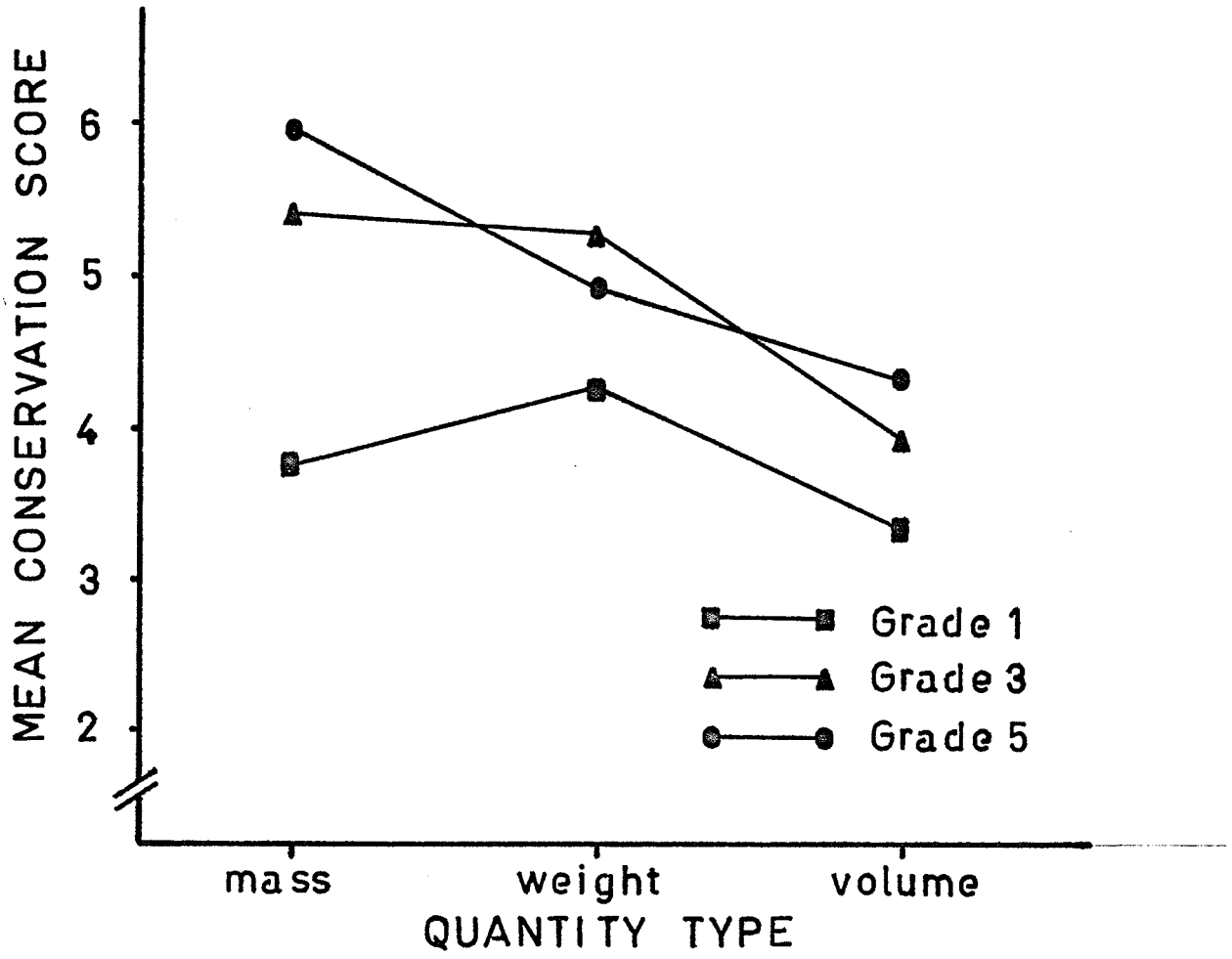

FIG. 4 Grade Level X Quantity Type interaction shown in the analysis of variance.

higher than females on the conservation of volume, Hypothesis 5 was partially supported.

Analysis of Décalages

For the present analysis, subjects were classified as conservers on a particular concept if they scored 5 or 6 on that concept, and as nonconservers if they scored from 0-4. The rationale for this procedure was described in the previous chapter. Since the conservation patterns for the boys and girls were quite similar, data from these two groups were combined.

The frequency of various conservation patterns for the field dependent and field independent subjects is shown in Table 5. In this table, conservation of a concept is designated by a plus (+) sign, and nonconservation with a minus (-) sign. The order of the signs within the patterns represents the conservation or nonconservation of mass, weight, and volume respectively. Thus, conservation of all three concepts is represented by a +++ pattern, failure on all three concepts by a --- pattern, and so forth.

In Hypothesis 2, it was predicted that the frequency of the Piagetian décalage patterns (+--, and ++-) would be greater in the field dependent than in the field independent group. It seems obvious from Table 5 that this is not the case. From a total of 42 field dependent subjects who conserved on one or more concepts, only 16 showed a Piagetian décalage pattern. Nineteen of the 52 field independent subjects who conserved on one or more concepts showed a décalage of this kind. Instead of decreasing with age as might be expected on the basis of

TABLE 5

Frequency of Conservation Patterns in Field Dependent and Field Independent Subjects (n=18)

		NDec	NC	Dec	Rev
Gr. 1	FD	3	7	4	4
	FI	10	2	3	3
Gr. 3	FD	8	5	5	0
	FI	11	0	7	0
Gr. 5	FD	9	0	7	2
	FI	9	0	9	0
Total	FD	20	12	16	6
	FI	30	2	19	3

Note.--N Dec = +++ pattern (no décalage)
NC = --- pattern (fails all three concepts)
Dec = +-- or ++- (décalage patterns)
Rev = --+, -+-, +-+ patterns (reversals)

Piaget's theory, the number of décalages increased from grades one through grade five. The χ^2 test with Yates' correction for continuity (Hays, 1963) was used to test the significance of the proportions of field dependent and field independent subjects showing the Piagetian décalage patterns vs. all other patterns. Results presented in Table 6 showed that the proportions did not differ significantly (χ^2=.0035, df=1, p>.99). Thus Hypothesis 2 is not confirmed, and it can be concluded that whether the décalage exists is not dependent upon the cognitive style of the subjects under investigation.

Although the field dependent and field independent subjects did not differ with regard to the frequency of the Piagetian décalage patterns, the number of field independent and field dependent subjects showing the +++ and --- patterns appear quite different. Table 5 shows that, at grade one, 10 of the 18 field independent subjects conserved all three concepts (+++). This proportion is much higher than would be expected on the basis of Piaget's findings and indicates that a lengthy time lag between acquisitions is not necessary. In contrast, only three of the field dependent subjects succeeded on all three concepts at grade one, and 7 of the 18 subjects failed on all three tasks. At grade three, the differences between the groups are less obvious and, at grade five, the conservation patterns of the field dependent and field independent subjects are quite similar. Thus it appears that, as age increases from about 7 to 11, the importance of cognitive style in the attainment of conservation decreases.

TABLE 6

χ^2 Test of Proportions of Field Dependent and Field Independent Subjects Showing Piagetian Décalage Patterns (Dec) vs. Other Patterns (OP)

	Dec	OP	Total
FD	16	26	42
FI	19	33	52
Total	35	59	94

$\chi^2 = .0035$

χ^2 .95 (1) = 3.84

In order to determine whether there was a significant difference in the proportions of subjects conserving mass, weight, and volume at any grade level, Siegel's (1956) binomial test was used. Contingency tables are presented in Table 7, and results of the binomial tests are summarized in Table 8. If conservation of mass is attained first, followed by the conservation of weight and volume, the mass-weight, and mass-volume décalages should be most apparent at grade one, and the weight-volume décalage at grade three. At grade five, when the majority of subjects should presumably conserve all three concepts, the difference between the mass, weight, and volume tasks should be at a minimum.

It is evident from Tables 7 and 8 that in neither of the cognitive style groups are the décalages as predicted by Piagetian theory. There is no evidence of a mass-weight décalage at either grade one or grade three. From a total of 53 subjects at these grade levels who conserved mass, only five failed to conserve weight. There were five subjects who conserved weight but not mass. At the grade-five level, the décalage between mass and weight conservation is significant ($p<.01$ for the field dependent subjects, and $p<.05$ for field independent). This is the age at which such a difference should be least expected on the basis of Piaget's reports. The existence of the weight-volume décalage is supported at grade three ($p<.05$ for both groups). The mass-volume décalage is significant in the grade-three and grade-five groups, but not at grade one where

TABLE 7

Siegel's Binomial Test of the Conservation Décalages Between Mass, Weight, and Volume for Field Dependent and Field Independent Subjects at Three Grade Levels

Concept		Mass		Weight		Volume	
		+	-	+	-	+	-
Field Dependent: Grade one							
Mass	+	--	--	5	3	4	4
	-	--	--	3	7	1	9
Weight	+					4	4
	-					1	9
Field Dependent: Grade three							
Mass	+	--	--	13	0	8	5*
	-	--	--	0	5	0*	5
Weight	+					8	5*
	-					0*	5
Field Dependent: Grade five							
Mass	+	--	--	11	7**	11	7**
	-	--	--	0**	0	0**	0
Weight	+					9	2
	-					2	5

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

cont'd.

Table 7 (cont'd.)

Concept		Mass		Weight		Volume	
		+	-	+	-	+	-
Field Independent: Grade one							
Mass	+	--	--	13	1	11	3
	-	--	--	2	2	1	3
Weight	+					11	4
	-					1	2
Field Independent: Grade three							
Mass	+	--	--	17	1	11	7**
	-	--	--	0	0	0**	0
Weight	+					11	6*
	-					0*	1
Field Independent: Grade five							
Mass	+	--	--	13	5*	9	9**
	-	--	--	0*	0	0**	0
Weight	+					9	4
	-					0	5

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

TABLE 8

Summary of Binomial Tests of the Mass-Weight, Weight-Volume, and Mass-Volume Décalages shown in Table 7

Grade	Cognitive Style	Mass-Weight	Weight-Vol	Mass-Vol
		p	p	p
1	FD	.656	.188	.188
	FI	.500	.188	.310
3	FD	1.000	.031*	.031*
	FI	.500	.016*	.008**
5	FD	.008**	.685	.008**
	FI	.031*	.060	.002**

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

it should be most evident. Seven of the 22 conservers of mass at the grade-one level failed the volume task, whereas two subjects passed volume but not mass.

Invariant sequence. The figures shown in the lower left-hand corners of the contingency tables in Table 7 represent the number of reversals in the predicted order of acquisition of the concepts. It can be seen that, for groups combined, there were 5 reversals in the mass-weight sequence, 4 reversals in the weight-volume sequence, and 2 in the mass-volume sequence, making a total of 11 deviations from the order predicted by Piaget. Seven of these reversals occurred in the field dependent subjects, and four in the field independent groups. Theoretically, no subject should evidence conservation of weight in the absence of conservation of mass, nor conservation of volume in the absence of mass and/or weight. Although the present findings cast doubt on the invariance of the sequence, given the less than perfect reliability of the measuring instruments, one would hardly be justified in concluding that the sequence is not in fact invariant.

Age of acquisition. According to Elkind (1961a), Piaget's age norms are based on the age at which 75% of the subjects were successful on the various conservation tasks. Comparable data from the present study are shown in Table 9.

Using the 75% criterion suggested by Piaget, it is evident from Table 9 that field independent subjects conserved both mass (78%) and weight (83%) in grade one. For the field dependent

TABLE 9

Number of Field Dependent and Field Independent Subjects Classified as Conservers of Mass, Weight, and Volume (n=18)

		Mass	Weight	Volume
Grade 1	FD	8 (44)	8 (44)	5 (28)
	FI	14 (78)	15 (83)	12 (67)
Grade 3	FD	13 (72)	13 (72)	8 (44)
	FI	18 (100)	17 (94)	11 (61)
Grade 5	FD	18 (100)	11 (61)	11 (61)
	FI	18 (100)	13 (72)	9 (50)

Note.--Percentages indicated in brackets.

subjects, conservation of mass (72%) and of weight (72%) were not achieved until grade three. It appears that these subjects lag about two years behind their field independent peers in the conservation of mass, and even more in the conservation of weight. Since the 75% level on the conservation of volume was not attained at any age, it could be concluded on the basis of this criterion that the conservation of mass and weight are developmentally prior to the conservation of volume. Yet the results from the previous analysis (binomial tests of the décalage patterns) generally failed to support such a claim. This serves to point up the fact that whether the décalages exist may to some extent depend on the type of statistical procedures used to assess them (cf. Dasen, 1972a).

In the present study, any straightforward analysis of the décalage phenomena is complicated by what appears to be a regression at the grade-five level in the conservation of weight and/or volume. This effect is most marked in the field independent group where the percentage conserving weight dropped from 94% at grade three to 72% at grade five. The percentage conserving volume decreased progressively from grade one (67%) to grade three (61%) to grade five (50%). For the field dependent group, the number conserving weight decreased from 72% at grade three to 61% at grade five, and the percentage conserving volume showed an increase from 28% at grade one, 44% at grade three, to 61% at grade five.

Order effects. The number of subjects conserving mass, weight, and volume in Order 1 (m-w-v), Order 2 (v-m-w), and

Order 3 (w-v-m) is shown in Appendix D. The χ^2 test with Yates' correction for continuity (Hays, 1963) was used to test the significance of the proportions of subjects conserving the concepts in the different orders. Tests were carried out for (a) grades separately, (b) grades combined, and (c) field dependent and field independent groups (grades and sexes combined). Of these tests, only the comparison of Orders 2 and 3 for the grade-one subjects yielded a significant result ($\chi^2=4.69$, df=1, $p<.05$). A larger proportion of the subjects conserved weight when it was last in the sequence (Order 2) than when it appeared first in the sequence (Order 3). From these tests, it can be concluded that the practice effects on the conservation tasks are generally not of great importance.

The results reported in the previous sections may be summarized briefly as follows:

(1) The existence of Piagetian décalage patterns is not dependent on the cognitive style of the subjects. In both the field dependent and field independent groups, it was found that less than half of the subjects who conserved on at least one concept showed a décalage between mass and weight, mass and volume, or weight and volume.

(2) For both the field dependent and field independent groups, the décalage between mass and weight was significant only at grade five. The weight-volume décalage was significant at grade three, and the mass-volume décalage at grades three and five. Taken together, these results failed to confirm the notion of the sequential attainment of the conservation concepts.

(3) A total of 11 reversals in the mass-weight-volume sequence were evidenced. This finding casts doubt on the notion of an invariant sequence of acquisition.

(4) Age norms differed for the field dependent and field independent subjects. The 75% level on mass and weight was attained at grade one for the field independent subjects, and at grade three for the field dependent subjects. The 75% level for volume conservation was not attained by any group.

(5) There was a regression in the conservation of weight at grade five for the field dependent subjects, and in both weight and volume for the field independent subjects.

(6) Success or failure on the conservation tasks was generally not dependent on the order of presentation of the concepts.

Subjects' Explanations of Conservation

Table 10 shows the percentages of conservation explanations sorted into the various categories. Since the explanations for mass, weight, and volume were quite similar, these data were combined.

It can be seen from Table 10 that there are no obvious differences in the types of adequate explanation (Categories 1-7) given by field dependent and field independent subjects. For both groups, and at each grade level, the most frequent type of justification for conservation was stated in terms of the initial equality of the two objects and/or the stated irrelevance of the particular transformation (Category 5). Categories 4 (Identical Action) and 6 (Logical Necessity) were rather infrequently used. It appears, however, that field

TABLE 10

Percentages of Various Types of Conservation Explanations Given by Field Dependent and Field Independent Subjects

		Type of Explanation								
		Adequate							Inadequate	
		1	2	3	4	5	6	7	8	9
Gr.1	FD	11	5	6	5	41	10	11	8	2
	FI	7	8	9	3	55	7	7	3	1
Gr.3	FD	10	12	9	5	42	5	11	6	0
	FI	13	15	8	12	35	5	10	2	0
Gr.5	FD	13	14	15	2	30	4	17	5	0
	FI	11	16	9	3	39	5	15	2	0

Note.--1. Compensatory relations
2. Reversibility
3. Addition/Subtraction
4. Identical Action
5. Initial equality and/or irrelevant transformation
6. Logical necessity
7. Quantitative equality
8. Irrelevant
9. No answer

dependent subjects gave more unclear or irrelevant explanations (Category 8) or no answer at all (Category 9) than did the field independent subjects. Thus it is possible that, were a less stringent criterion used (cf. Brainerd, 1973), the difference between the field dependent and field independent subjects would be diminished.

According to Piaget, the attainment of conservation depends upon the logical operations implied by the first three categories (i.e., compensatory relations, reversibility, addition/subtraction). In the present study, these types of explanation do not account for a major portion of the responses. If these were the only explanations considered acceptable, then the number of subjects classified as conservers would be considerably reduced. However, it was apparent during testing that those subjects who provided alternate explanations (i.e., Categories 4-7) seemed as convinced of quantitative invariance as were those who gave reversibility explanations. It is quite possible that further questioning might have elicited the type of explanation discussed by Piaget.

It appears also from Table 10 that there are few marked age differences in the type of explanations for conservation. There is some indication that explanations based on reversibility (Category 2) and on quantitative equality (Category 7) increase with age, and that inadequate explanations decrease with age but, in general, the proportions of explanations in the different categories appear quite stable both across ages

and across cognitive style groups.

The types of explanations used to justify nonconservation responses are shown in Table 11. Since type of explanation varied according to the type of quantity being assessed, the data from the mass, weight, and volume tasks are presented separately. Figures in the table represent the number of children who gave a particular type of explanation.

Explanations for the nonconservation of mass shown in Table 11 tend to support Piaget's claim that children who fail to conserve tend to base their judgment on misleading perceptual features of the display. All subjects who failed to conserve mass supported their judgments with an irrelevant perceptual (IP) response. In the case of the weight and volume tasks, however, the situation is not so straightforward. It is evident that only in the younger age groups does the child give a simple perceptual explanation for nonconservation. With increasing age, there is an increased tendency to go beyond the immediate perceptual appearance of things, and attempt to provide complex rationalizations (IC category) for nonconservation. This developmental change was quite obvious to the experimenter during conservation testing. It can also be seen that, of 19 subjects who gave IC explanations to the weight and/or volume tests, 13 were field independent and 6 were field dependent. Spatial responses to the volume task also increased with age. Three field dependent and twelve field independent subjects based their nonconservation response in the volume task on some sort of reference to the amount of

TABLE 11

Number of Subjects Giving Irrelevant Perceptual (IP), Irrelevant Conceptual (IC), and No Answer (NA) Explanations for Nonconservation of Mass, Weight, and Volume

		Mass			Weight			Volume			
		IP	IC	NA	IP	IC	NA	IP	IC	NA	S*
Gr.1	FD	9	0	1	8	0	1	12	0	2	0
	FI	4	0	1	3	0	0	5	0	0	1
Gr.3	FD	5	0	0	5	0	1	8	0	1	0
	FI	0	0	0	1	0	0	5	3	0	4
Gr.5	FD	0	0	0	3	4	1	3	2	0	3
	FI	0	0	0	2	5	0	2	5	0	7

*Number of subjects who referred to amount of space or room in the volume task is shown in column S.

space or room occupied by the objects.

In the case of weight conservation, younger subjects generally responded in terms of a single dimension: "It weighs more because it is fatter". In contrast, older subjects tended to base their judgments of nonconservation on the perceived density of the object, the distribution of weight over a larger area, or the amount of air pressing down on the object. For example, Jill (grade 5, age 11 years, field independent, IQ=108) replied that the standard ball weighed more than the pancake because:

> "the air is spread out more on that one (points to pancake) and it's closed in on this one (points to ball). If you take newspaper and you put it flat on the scale, it will weigh less, and if you double it up you'll double the weight because the thickness is doubled."

In the next problem she stated that the three plasticine balls weighed the same as the standard ball because:

> "If you put these three balls together, it would make the same shape (as the standard). So they started out the same, so no matter what you do, it would be the same—except make it flat."

The following protocol illustrates the difficulty some subjects had in providing explanations, and the interesting real-life experiences brought into the experimental situation. Bob (grade 5, age 11-12, field dependent, IQ=105) had this to say in defense of his statement that the clay ball weighed more than the hotdog:

> "Well, the....uh....it's like....when it's spread out ....it's less....like you're....distributing your weight....if you're standing on ice, more weight would be in the middle and if you lie out, the weight would be all over."

Similar types of explanations were given by the older field independent subjects in the volume task, whereas the younger and more field dependent subjects who failed to conserve volume tended to base their explanations on some immediate perceptual attribute: "This one would make the water go up more because it is higher."

On the basis of the present qualitative analysis of children's explanations, it is clear that, although there was no marked improvement (and in some cases a deterioration) with age in the ability to conserve volume, qualitative differences in the types of explanations given by subjects at different age levels showed a clear developmental trend.

CHAPTER V

DISCUSSION

The major purpose of the present study was to examine the role of the field dependence-field independence dimension in the attainment of conservation of mass, weight, and volume. On the basis of Witkin's conceptualization of this dimension, it was hypothesized that field independent subjects would perform significantly better than field dependent subjects on the conservation tasks. The results presented above offer strong support for this prediction.

It has been suggested (Flavell, 1963) that performance on Piagetian tasks depends not only on the mental operations available but also on the cognitive approach of the individual. Present findings are consistent with such a view and suggest that, in assessing behavior in the conservation situation, there is a need to make a distinction between the subject's competence and his actual performance. On the basis of the models proposed by Flavell (1963) and by Flavell and Wohlwill (1969), it may be suggested that the relatively poor performance of the field dependent subjects in the present study may be attributed to extralogical factors associated with their approach to the task and not to a deficit at the operational level. It appears that the ability to resist perceptual distraction, to attend selectively to relevant cues, and

to adopt an active-analytic vs. a passive-global approach to problem solving are some of the factors that need to be considered when assessing performance on the conservation tasks.

If field independence is viewed primarily as a skill involving the ability to overcome misleading perceptual cues rather than as a generalized tendency to structure experience in an articulated manner, then results might be taken as support for the perceptual interpretation favored by some investigators (e.g., Bruner, 1966; Mehler & Bever, 1967). It appears that Piaget has underemphasized the importance of perceptual components in the conservation tasks and that individual differences in the ability to overcome perceptual distortions need to be considered. The finding that not all of the field independent subjects succeeded on the conservation tasks further suggests that, while a certain level of field independence is required, it is not sufficient for conservation attainment. Further research will be needed to clarify precisely what traits and skills are crucial to performance on these and other Piagetian problems.

If failure to conserve denotes an absence of logical thought operations, as Piaget claims, then it follows that the relatively poor performance of the field dependent subjects in the present study is attributable to a cognitive deficit, and not to any extralogical (e.g., perceptual) difficulties associated with a field dependent cognitive style. Although there is no direct evidence in the present study to indicate that field dependent subjects are in fact more operationally com-

petent than their performance indicates, there is some indirect evidence which makes an operational interpretation of results difficult to accept. Although it was found that the younger field dependent subjects in the present study lagged about two years behind their field independent peers in their performance on the conservation tasks, by grade five the difference between the two groups had almost entirely disappeared. In order to account for such a finding within the Piagetian framework, it would be necessary to postulate a marked acceleration in the rate of cognitive development somewhere between grades one and five for the field dependent subjects only.

An alternate interpretation is that the two cognitive style groups were equivalent in operational competence throughout the course of their development but that the younger field dependent children were hindered in their performance by a tendency to be influenced by misleading perceptual cues in the tasks. It seems that, by grade five, the majority of subjects had attained a level of field independence sufficient to enable them to resist these particular influences and that failures on the conservation tasks at this age level can be attributed to other factors.

The decrease with age in perceptual explanations for nonconservation, and the corresponding increase in conceptual explanations noted in the present study is consistent with the view that perceptual components become less important with age.

Laurendeau and Pinard (1962) have observed a similar trend in children's explanations of causality and note that the rate of decline in perceptual explanations depends upon the particular problem under investigation. Simpson (1970) has also reported that the influence of cognitive style (reflection-impulsivity) decreases with age from grades one through six.

Results of the present study were generally inconsistent with Piaget's reports and with the results of a number of previous investigations. Most important from a theoretical standpoint is the lack of support for the mass-weight-volume décalage reported by Piaget. Possible reasons for these discrepant findings will now be discussed, along with theoretical and practical implications of the results.

Although the majority of studies reported in a previous section supported the predicted time lag between the acquisitions of mass, weight, and volume conservation, the absence of a developmental lag between mass and weight in the present study is consistent with a number of previous reports (e.g., de Lemos, 1966, 1969; Hyde, 1970; Lee, 1972; McRoy, 1967; Nummedal, 1970). It is difficult to attribute these inconsistent reports to procedural differences since, in the majority of studies, procedures were similar to those used by Piaget. A second possibility is that differences in materials might account for the observed discrepancies. In the present study, flax was used to assess conservation of mass, plasticine for the conservation of weight, and plastic cubes for the

volume task. In the majority of studies reporting the décalage (e.g., Elkind, 1961a; Papalia, 1972), one material was used for all three tasks. There is some evidence (e.g., Elkind, 1961b; Uzgiris, 1964) that conservation of discontinuous quantity (beads, sticks, cubes) is attained earlier than conservation of continuous quantity (water, plasticine, etc.), but Goldschmid (1967) reports the opposite finding. It seems unlikely, therefore, that the use of both continuous and discontinuous quantities in the present study could account for the absence of the predicted décalage. Furthermore, some investigators (e.g., Nummedal, 1970) found no evidence for the mass-weight décalage even when plasticine was used in all of the conservation tasks.

Since the inconsistencies with regard to the existence of the mass-weight décalage do not appear to be due to procedural variations or to differences in materials, it seems likely that they can best be accounted for in terms of the differing life experiences of the subjects under investigation. It has previously been suggested (Dasen, 1972b) that the décalages reported by Piaget may not apply to populations which vary widely in social, cultural, and educational background, and Flavell (1970a) has suggested that some of the so-called invariant sequences may be due to environmental factors rather than to any inherent structural properties of the organism. In this regard, Gobar (1968) has stated:

> What the genetic psychology [e.g., Piaget] neglects is the "environmental history" of the subject . . . there remain the traces of a methodological inconsistency in the researches of genetic psychology: Granting the irrelevance of the historical environment to the study of operations of intelligence, genetic psychology frequently engages in the investigation of the concrete knowledge of the subject . . . As a result of this illicit transition, the concrete knowledge of the subject is sometimes taken as the index of his intelligence (pp. 115-116).

The most likely explanation for the absence of the weight-volume décalage at the grade-one level in the present study is that the particular combination of materials and methods of assessment resulted in a relatively large proportion of the subjects solving the volume task. It has previously been noted that slight procedural variations may have a marked effect on the conservation of volume. When the criterion question is stated in terms of the amount of space occupied by the objects, relatively few subjects pass the volume test (e.g., Elkind, 1961a, 1961c, 1962; Papalia, 1972; Uzgiris, 1964). On the other hand, when the question is worded in terms of the displacement of the water level (as it was in the present study), the volume task appears relatively easy (e.g., Lovell & Ogilvie, 1962; Simpson, 1970).

Few studies have included a variety of materials, but there is some evidence which suggests that conservation of volume may be easier with cubes than with plasticine. Lovell and Ogilvie (1962) found that, when conservation of volume was assessed with cubes and a water displacement procedure, 55% of the grade-one children conserved volume. When the data

of the two cognitive style groups in the present study are combined, the proportion conserving volume (47%) is quite consistent with the Lovell and Ogilvie report. However, both of these results are difficult to reconcile with Piaget's reports that, with either metal cubes or plasticine, volume conservation below the age of 11-12 is quite rare (e.g., Piaget et al., 1960).

Flavell's (1970b) suggestion that the easier forms of volume conservation might actually be a form of conservation of mass is consistent with observations made in the present study. It was noted that a number of children explained their response to the volume question in terms of mass ("you still have the same amount of stuff"), or on the basis of number ("you didn't take any cubes away). Few children at the lower age levels referred to the amount of space occupied by the objects.

It should be noted that, if wide variations in performance occur as a function of the particular materials used in assessment, the generality of Piaget's theory of stages would be seriously limited. Pinard and Laurendeau (1969) state:

> Indeed, if it were true that heterogeneity of objects alone brings about asynchronisms that are both too numerous and too striking, the typical behaviors at the level concerned could entirely lose their identity and the lines of demarcation between levels would be completely blurred (p. 135).

Evidence for or against the existence of the mass-weight-volume décalage has important theoretical and practical implications. First, Piaget has stated that one of the essential criteria of stages is "hierarchization," and the existence of invariant sequences has been used to substantiate this claim (cf. Pinard & Laurendeau, 1969, pp. 125-136). Inhelder (1968) sees the horizontal décalages as proof of the continuity of development. Any evidence that suggests that these décalages do not necessarily exist casts doubt on this aspect of Piaget's interpretation of stages.

Second, a number of investigators (cf. Sigel, 1969) have written extensively on the application of Piaget's theory to pedagogic methods. Recommendations in this area are generally based on the notion that concepts should be introduced into the school curriculum in the order in which they are "naturally" acquired and that instruction should be delayed until the appropriate age level. Given the current lack of agreement (cf. Flavell, 1970a) with regard to (a) the invariance of the sequence, (b) the possibility of establishing sequential invariance, (c) the source of invariance, and (d) the age of acquisition of concepts, it would seem premature at this time to make any firm recommendations with regard to optimal instructional sequences.

Third, Piaget and Inhelder (Inhelder, 1968; Piaget & Inhelder, 1947) have proposed that the invariant mass-weight-volume sequence may be used as a natural ordinal scale of

development. In view of the lack of consistent evidence to support a developmental lag between the attainment of these concepts, and the present uncertainty with regard to the invariance of the sequence, there seems no sound basis for such a recommendation. Results of the present study cast doubt on the appropriateness of the conservation concepts as developmental items.

The preceding comments also have implications for Piaget's epistemological position. It is Piaget's belief (e.g., Piaget, 1929) that the evolution of scientific knowledge in the human race parallels the development of scientific concepts in the child. He has noted, for example, that the explanations of natural phenomena (rain, wind, lightning, etc.) given by the pre-Socratic philosophers are not unlike those he has observed in young children (Piaget, 1929). It has been suggested (Gobar, 1968) that these similarities may reflect the impoverished state of knowledge of both groups rather than any formal similarities in their structures of thought.

According to Piagetian theory, ability to conserve should show a progressive improvement with age. While fluctuations in performance are to be expected in the early stages, concepts in the final stages of development are thought to be marked by permanence and stability (Piaget, 1957b, in Flavell, 1963, pp. 242-244). In the present study, the expected improvement with age was found only on the conservation of mass between grades one and three. At grade five, there was an apparent regression

in the conservation of weight and/or volume. This same phenomenon has also been noted by other investigators, although rather infrequently. Dasen and Christie (1972, cited in Dasen, 1972c) have reported a similar drop in the conservation of weight and volume at ages 10 and 11, and have attributed this to the "interference of quasi-formal concepts such as air pressure and gravity (Dasen, 1972c, p. 25)." Similar findings have been reported by Pinard, Laurendeau, Boisclair, Dagenais, and Morin (1969, cited in Dasen, 1972c). In other cases (e.g., Simpson, 1970, Table 11, p. 116), it is obvious that such regressions have occurred, but these are not commented upon in the text of the report.

Goodnow (1962) has reported a marked drop in the conservation of weight and volume at ages 11 and 12 in two groups of Chinese schoolboys residing in Hong Kong, and has suggested that this regression may have been due to the nature of the science courses encountered by these children. Subjects who had no schooling and those who had no science course showed the expected improvement with age. According to Goodnow, children who had been exposed to science instruction frequently based their nonconservation explanations on notions of density, gravity, and pressure. She has suggested that "there may be a special readiness to give the unobvious answer on an apparently intellectual task and that additional education may produce a poorer rather than a better performance (1962, p. 12)."

It is not clear why the regression in the present study was more marked in the field independent than in the field dependent subjects, but the following evidence suggests that this finding may have been due to a sampling bias rather than to a reliable difference between the two cognitive style groups. A large proportion of the field independent subjects in grade five were from one school (School "A"), whereas the majority of the field dependent subjects were quite equally distributed throughout the three other schools. Although the current science program of the four schools did not appear to differ to any great extent, it was learned that the grade-five children in School A had received their science instruction in the previous year from the Junior High School science teachers. While these teachers reported that they had devoted some time to the discussion and demonstration of principles of density, gravity, buoyancy, and air pressure, in the regular classrooms these concepts were not discussed in depth (if at all). The teachers also thought it likely that these children had picked up notions of pressure and gravity from two guest speakers (one from the City Waterworks, and the other a mining engineer) who had addressed the children in School A during the current year. The explanations provided by these children were very similar to those described by Goodnow (1962) and by Dasen (1972c). On the basis of these findings, it may be suggested that the knowledge yielded by cognitive structures is neither so certain nor so stable as Piaget maintains but, rather, that

it is subject to disruption by irrelevant or incorrect information which is acquired throughout the course of development.

These findings and suggestions might also be considered within the context of the current controversy with regard to the relation between thought and language (cf. Langer, 1969). Briefly stated, Piaget's view is that language is subordinate to intelligence and that the language of the child reflects the underlying mental operations (e.g., Piaget, 1967). Present findings indicate that language may reflect what is being taught in the schools and cannot be considered a reliable indicator of underlying cognitive organization. If language directs thought, as Vygotsky (1962) proposes, it may be suggested that this influence is not always in the right direction. Szeminska (1970) has noted in this regard that "poorly assimilated information can become a mnemonic burden which is not only cumbersome but paralyzes cognitive activity in the areas of perception and manipulation (p. 612)."

Summary

The major points of the above discussion may be summarized briefly as follows:

1. Present results are difficult to interpret within the present Piagetian framework but are consistent with a competence-performance interpretation. The relatively poor performance of the field dependent subjects in the present study has been attributed to extralogical (e.g., perceptual) difficulties and need not imply a deficit at the operational level.

2. Possible reasons for the failure to replicate Piaget's findings with regard to the décalage phenomenon were discussed. It was suggested that the simultaneous acquisition of mass and weight at the lower age levels might best be attributed to environmental factors, and that the failure to replicate the weight-volume decalage was partly due to the particular combination of materials and methods of assessment employed.

3. An inspection of the conservation protocols and discussions with classroom teachers led to the suggestion that the regressions in the conservation of weight and volume at the grade-five level were probably due to the interference of specific information acquired through classroom instruction. Piaget's claims with regard to the relation of language and thought need to be examined in the light of such findings.

4. It was concluded that Piaget has not attached sufficient importance to the role of concrete knowledge in the acquisition of concepts, or to the importance of a variety of traits and skills such as those implied by the concept of field dependence.

5. Results have important implications for Piaget's claims with regard to (a) the basis of conservation, (b) the criteria of stages, and (c) the stability of concepts. The use of the conservation concepts as developmental items has been questioned.

6. There is at present no firm basis for recommending that concepts of mass, weight, and volume be introduced in any

particular sequence or at any given age. Poorly assimilated knowledge may hinder rather than facilitate performance on the conservation tasks.

Suggestions for Future Research

It has been suggested that the differences in performance between the field dependent and field independent subjects in the present study can be attributed to extralogical (e.g., perceptual) difficulties and not to any differences in operational competence. This issue might best be resolved in future studies by presenting field dependent and field independent subjects with two sets of problems which are equivalent from an operational viewpoint, but which differ in the degree to which irrelevant perceptual cues are present. If the competence-performance distinction is valid, then one would predict that field dependent subjects would perform as well as field independent subjects on those tasks in which the conflict between logic and perception was absent, but less well in situations where such a conflict was present. If the operational interpretation is correct, then one would expect that field dependent subjects would do equally poorly on both types of problem.

One might, for example, compare the two cognitive style groups using the screening procedures described by Frank (in Bruner, 1966), or merely compare their performance on the prediction question (i.e., before the transformation is actually

carried out) vs. the judgment question in the conservation situation. The inclusion of children below the age of six in studies such as this might also provide useful information. On the basis of present results, one might expect to find field independent children at this age quite competent in their performance on the conservation tasks. Another approach might be to consider the role of field dependence in studies designed to train the understanding of invariance.

It has been suggested that the presence or absence of the décalages might depend on the specific materials used in the study. Future studies should include a wider variety of materials than have typically been used to assess conservation. Investigation of groups known to differ in terms of experience that might be relevant to a specific conservation concept (e.g., weighing produce at a store) might also be a useful approach. The influence of different science and mathematics programs might also be examined.

Previous studies have tended to focus on the reasons why the child conserves rather than on the reasons for his failure. Present results suggest that children's explanations deserve close attention and that an examination of the non-conservation explanations may be particularly informative.

The present study is limited in several respects. Only children from grades one, three, and five were included, and these were of predominantly middle-class background and within the range of normal intelligence. Future studies should include a much wider age range and populations that are more

heterogeneous with respect to social-cultural background and intelligence. Longitudinal studies are needed in order to assess the invariance of the mass-weight-volume sequence.

Although Witkin has defined field independence in terms of the ability to overcome the influence of an embedding context, it has generally come to be interpreted in terms of a constellation of interrelated skills and dispositions. The relative importance of these various aspects (perceptual, intellectual, personality, etc.) in relation to performance in Piagetian and other tasks needs to be clarified.

Concluding Comments

Much of the current dissatisfaction with Piaget's account of development stems from his neglect of variables which may play important roles in cognitive adaptation. Flavell (1963, p. 82) has suggested that the reason Piaget has tended to ignore developments in other areas (language, perception, etc.) is that he feels that "extracognitive adaptation" is very much a function of the level of cognitive organization already attained. The results of the present study suggest that the relation between perception, cognition, and language might better be regarded as one of mutual support and interaction, and that an adequate account of cognitive development cannot be provided without a consideration of development in these and other areas. A unified theory relating perception, language, and cognition might clarify the problem of décalage in Piaget's theory.

REFERENCES

Almy, M., Chittenden, E., & Miller, P. Young children's thinking: Studies of some aspects of Piaget's theory. New York: Teacher's College Press, Columbia University, 1966.

Beilin, H. Cognitive capacities of young children: A replication. Science, 1968, 162, 920-921.

Beilin, H., Kagan, J., & Rabinowitz, R. Effects of verbal and perceptual training on water level representation. Child Development, 1966, 37, 317-328.

Bell, E. G. Inner-directed and other-directed studies. Unpublished doctoral dissertation, Yale University, 1955.

Beller, E. K. A study of dependency and perceptual orientation. American Psychologist, 1958, 13, 347. (Abstract)

Berlyne, D. E. Structure and direction in thinking. New York: John Wiley & Sons, 1965.

Block, J. A study of affective responsiveness in a lie-detector situation. Journal of Abnormal and Social Psychology, 1957, 55, 11-15.

Braine, M. D. S. The ontogeny of certain logical operations: Piaget's formulation examined by nonverbal methods. Psychological Monographs, 1959, 73, No. 5 (Whole No. 475)

Braine, M. D. S. Development of a grasp of transitivity of length: A reply to Smedslund. Child Development, 1964, 35, 799-810.

Brainerd, C. J. The development of the proportionality scheme in children and adolescents. Developmental Psychology, 1971, 5, 469-476.

Brainerd, C. J. Order of acquisition of transitivity, conservation, and class inclusion of length and weight. Developmental Psychology, 1973, 8, 105-116. (a)

Brainerd, C. J. Judgments and explanations as criteria for the presence of cognitive structures. Psychological Bulletin, 1973, 79, 172-179. (b)

Brison, D. W. Acceleration of conservation of substance. Journal of Genetic Psychology, 1966, 109, 311-322.

Bruner, J. S. On the conservation of liquids. In J. S. Bruner, R. R. Olver, P. M. Greenfield, et al. (Eds.), Studies in cognitive growth. New York: John Wiley & Sons, 1966.

Bruner, J. S., Olver, R. R., Greenfield, P. M., et al. Studies in cognitive growth. New York: Wiley, 1966.

Bryant, P. E. The understanding of invariance by very young children. Canadian Journal of Psychology/Review of Canadian Psychology, 1972, 26, 78-96.

California Test Bureau. Technical Report on the California Test of Mental Maturity Series, 1963 Revision. McGraw-Hill: Monterey, California, 1965.

Campbell, S. B., & Douglas, V. I. Cognitive styles and responses to the threat of frustration. Canadian Journal of Behavioural Science, 1972, 4, 30-42.

Cohen, S. I., Silverman, A. J., & Shmavonian, B. M. Psychophysiological studies in altered sensory environments. Journal of Psychosomatic Research, 1963, 6, 259-281.

Corah, N. L. Differentiation in children and their parents. Journal of Personality, 1965, 33, 300-308.

Crandall, V. J., & Sinkeldam, C. Children's dependent and achievement behaviors in social situations and their perceptual field dependence. Journal of Personality, 1964, 32, 1-22.

Dasen, P. R. Cross-cultural Piagetian research: A summary. Journal of Cross-Cultural Psychology, 1972, 3, 23-39. (a)

Dasen, P. R. The development of conservation in Aboriginal children: A replication study. International Journal of Psychology, 1972, 7, 75-85. (b)

Dasen, P. R. The influence of ecology, culture and European contact on cognitive development in Australian Aborigines. In J. W. Berry, & P. R. Dasen (Eds.), Culture and cognition: Readings in cross-cultural psychology. London: Methuen, 1972. (c).

Dasen, P. R., & Christie, R. D. A regression phenomenon in the conservation of weight. Archives de Psychologie (Genève), 1972.

De Lemos, M. M. The development of the concept of conservation in Australian Aboriginal children. Unpublished Ph.D. thesis, Australian National University, Canberra, 1966.

De Lemos, M. H. The development of conservation in Aboriginal children. International Journal of Psychology, 1969, 4, 255-269.

Dickstein, L. S. Field independence in concept attainment. Perceptual and Motor Skills, 1968, 27, 635-642.

Donaldson, M., & Balfour, G. Less is more: A study of language comprehension in children. British Journal of Psychology, 1968, 59, 461-471.

Dreyer, A. S., Dreyer, C. A., & Nebelkopf, E. B. Portable rod-and-frame test as a measure of cognitive style in kindergarten children. Perceptual and Motor Skills, 1971, 33, 775-781.

Dreyer, A. S., Nebelkopf, E., & Dreyer, C. A. Note concerning stability of cognitive style measures in young children. Perceptual and Motor Skills, 1969, 28, 933-934.

Dubois, T. E., & Cohen, W. Relationship between measures of psychological differentiation and intellectual ability. Perceptual and Motor Skills, 1970, 31, 411-416.

Duncker, K. On problem-solving. Psychological Monographs, 1945, 58 (5, Whole No. 270).

Elkind, D. Children's discovery of the conservation of mass, weight, and volume: Piaget replication study II. Journal of Genetic Psychology, 1961, 98, 219-227. (a)

Elkind, D. The development of quantitative thinking: A systematic replication of Piaget's studies. Journal of Genetic Psychology, 1961, 98, 37-46. (b)

Elkind, D. Quantity conceptions in junior and senior high school students. Child Development, 1961, 32, 551-560. (c)

Elkind, D. Quantity conceptions in college students. Journal of Social Psychology, 1962, 57, 459-465.

Elkind, D., Koegler, R. R., & Go, E. Field independence and concept formation. Perceptual and Motor Skills, 1963. 17, 383-386.

Elliott, R. Interrelationships among measures of field dependence, ability, and personality traits. Journal of Abnormal and Social Psychology, 1961, 63, 27-36.

Estes, B. W. Some mathematical and logical concepts in children. Journal of Genetic Psychology, 1956, 88, 219-222.

Farnham-Diggory, S., & Bermon, M. Verbal compensation, cognitive synthesis, and conservation. Merrill-Palmer Quarterly, 1968, 14, 215-228.

Feigenbaum, K. D. Task complexity and IQ as variables in Piaget's problem of conservation. Child Development, 1963, 34, 423-432.

Fitzgibbons, D. J., & Goldberger, L. Task and social orientation: A study of field dependence, "arousal", and memory for incidental material. Perceptual and Motor Skills, 1971, 32, 167-174.

Flavell, J. H. The developmental psychology of Jean Piaget. Princeton: Van Nostrand, 1963.

Flavell, J. H. An analysis of cognitive-developmental sequences. Presidential Address to Division 7, at the meeting of the American Psychological Association, Miami Beach, 1970. (a)

Flavell, J. H. Concept development. In P. H. Mussen (Ed.), Carmichael's manual of child psychology, Vol. 1, (3rd ed.) New York: John Wiley & Sons, 1970. (b)

Flavell, J. H., & Wohlwill, J. F. Formal and functional aspects of cognitive development. In D. Elkind and J. H. Flavell (Eds.), Studies in cognitive development: Essays in honor of Jean Piaget. New York: Oxford, 1969.

Fleck, J. R. Cognitive styles in children and performance on Piagetian conservation tasks. Perceptual and Motor Skills, 1972, 35, 747-756.

Frank, F. Perceptual screening. In J. S. Bruner, R. R. Olver, and P. M. Greenfield (Eds.), Studies in cognitive growth. New York: John Wiley & Sons, 1966, 192-202.

Freyberg, P. S. Concept development in Piagetian terms in relation to school attainment. Journal of Educational Psychology, 1966, 57, 164-168.

Gardner, R. W., Holtzman, R. S., Klein, G. S., Linton, H. B., & Spence, D. Cognitive control: A study of individual consistencies in cognitive behavior. Psychological Issues, 1959, 1, No. 4.

Gaudia, G. Race, social class, and age of achievement of conservation on Piaget's tasks. Developmental Psychology, 1972, 6, 158-165.

Gelman, R. Conservation acquisition: A problem of learning to attend to relevant attributes. Journal of Experimental Child Psychology, 1969, 7, 167-187.

Gelman, R. Logical capacity of very young children: Number invariance rules. Child Development, 1972, 43, 75-90.

Gobar, A. Philosophic foundations of genetic psychology and gestalt psychology. Martinus Nijhoff: The Hague, 1968.

Goldschmid, M. L. Different types of conservation and non-conservation and their relation to age, sex, IQ, MA, and vocabulary. Child Development, 1967, 38, 1229-1246.

Goldschmid, M. L. The relation of conservation to emotional and environmental aspects of development. Child Development, 1968, 39, 579-589.

Goodenough, D. R., & Karp, S. A. Field-dependence and intellectual functioning. Journal of Abnormal and Social Psychology, 1961, 63, 241-246.

Goodnow, J. J. A test of milieu effects with some of Piaget's tasks. Psychological Monographs, 1962, 76, (36, Whole No. 555).

Goodnow, J. J., & Bethon, G. Piaget's tasks: The effect of schooling and intelligence. Child Development, 1966, 37, 573-582.

Gordon, B. An experimental study of dependence-independence in a social and laboratory setting. Unpublished doctoral dissertation, University of Southern California, 1953.

Greenfield, P. M. On culture and conservation. In J. S. Bruner, R. R. Olver, P. M. Greenfield et al., Studies in cognitive growth. New York: Wiley, 1966.

Griffiths, J. A., Shantz, C. U., & Sigel, I. E. A methodological problem in conservation studies: The use of relational terms. Child Development, 1967, 38, 841-848.

Gruen, G. E. & Vore, D. A. Development of conservation in normal and retarded children. Developmental Psychology, 1972, 6, 146-157.

Hays, W. L. Statistics. New York: Holt, Rinehart, & Winston, 1963.

Honigfeld, G., & Spigel, I. M. Achievement motivation and field independence. Journal of Consulting Psychology, 1960, 24, 550-551.

Hood, H. B. An experimental study of Piaget's theory of the development of number in children. British Journal of Psychology, 1962, 53, 273-286.

Hooper, F. H. Piaget's conservation tasks: The logical and developmental priority of identity conservation. Journal of Experimental Child Psychology, 1969, 8, 234-249.

Hooper, F. H., Goldman, J. A., Storck, P. A., & Burke, A. M. Stage sequence and correspondence in Piagetian theory: A review of the middle-childhood period. Research Relating to Children, Bulletin 28, Urbana, 1971.

Hyde, D. M. G. Piaget and conceptual development. New York: Holt, Rinehart, & Winston, 1970.

Inhelder, B. Criteria of the stages of mental development. In J. M. Tanner & B. Inhelder (Eds.), Discussions on child development, London: Tavestock, 1953. (Republished in R. G. Kuhlen & G. G. Thompson (Eds.), Psychological studies of human development. New York: Appleton-Century-Crofts, 1963, 28-48).

Inhelder, B. The diagnosis of reasoning in the mentally retarded. New York: John Day, 1968.

Inhelder, B., & Piaget, J. The growth of logical thinking from childhood to adolescence. New York: Basic Books, 1958.

Inhelder, B., & Piaget, J. Closing remarks. In D. R. Green, M. P. Ford, & G. B. Flamer (Eds.), Measurement and Piaget. New York: McGraw-Hill, 1969.

Kagan, J. Reflection-impulsivity: the generality and dynamics of conceptual tempo. Journal of Abnormal Psychology, 1966, 71, 17-24.

Kagan, J., & Kogan, N. Individuality and cognitive performance. In P. H. Mussen (Ed.), Carmichael's manual of child psychology, Vol. 1, (3rd ed.). New York: John Wiley & Sons, 1970.

Kagan, J., Moss, H. A. & Sigel, I. E. Psychological significance of styles of conceptualization. In Cognitive development in children. Chicago: University of Chicago Press, 1970.

Karp, S. A., & Konstadt, N. L. Manual for Children's Embedded Figures Test. Brooklyn: Cognitive Tests, 1963.

Kirk, R. E. Experimental design procedures for the behavioral sciences. Belmont: Brooks/Cole, 1969.

Konstadt, N., & Forman, E. Field dependence and external directedness. Journal of Personality and Social Psychology, 1965, 1, 490-493.

Kooistra, W. Developmental trends in the attainment of conservation, transitivity, and relativism in the thinking of children: A replication and extension of Piaget's ontogenetic formulations. Unpublished doctoral dissertation, Wayne State University, 1963.

Langer, J. Theories of development. New York: Holt, Rinehart, & Winston, 1969.

Laurendeau, M., & Pinard, A. Causal thinking in the child. New York: International University Press, 1962.

Lee, Y. S. Conservation décalage in Piaget's theory. Unpublished doctoral dissertation, University of Alberta, 1972.

Linton, H. B. Relations between mode of perception and tendency to conform. Unpublished doctoral dissertation, Yale University, 1952.

Linton, H. B. Dependence on external influence correlates in perception, attitudes, and judgment. Journal of Abnormal and Social Psychology, 1955, 51, 502-507.

Lovell, K., & Ogilvie, E. A study of the conservation of substance in the junior school child. The British Journal of Educational Psychology, 1960, 30, 109-118.

Lovell, K., & Ogilvie, E. The growth of the concept of volume in junior school children. Journal of Child Psychology and Psychiatry, 1961, 2, 118-126. (a)

Lovell, K., & Ogilvie, E. A study of the conservation of weight in the junior school child. British Journal of Educational Psychology, 1961, 31, 138-144. (b)

Lumsden, E. A., & Kling, J. K. The relevance of an adequate concept of "bigger" for investigations of size conservation: A methodological critique. Journal of Experimental Child Psychology, 1969, 8, 82-91.

Lunzer, E. A. Some points of Piagetian theory in the light of experimental criticism. Journal of Child Psychology and Psychiatry, 1960, 1, 191-202.

Mannix, J. The number concepts of a group of E. S. N. children. British Journal of Educational Psychology, 1960, 30, 180-181.

Marlowe, D. Some psychological correlates of field independence. Journal of Consulting Psychology, 1958, 22, 33-34.

McGough, W. E., Silverman, A. J., & Bogdonoff, M. D. Patterns of fat mobilization in field dependent and field independent subjects. Psychosomatic Medicine, 1965, 27, 245-256.

McRoy, J. A study of the development of the concept of quantity by scalogram analysis. Unpublished doctoral dissertation, University of Texas, 1967.

Mehler, J., & Bever, T. G. Cognitive capacity of very young children, Science, 1967, 158, 141-142.

Miller, P. H. Attention to stimulus dimensions in the conservation of liquid quantity. Child Development, 1973, 44, 129-136.

Murray, F. B., & Johnson, P. E. Reversibility in nonconservation of weight. Psychonomic Science, 1969, 16, 285-287.

Nummedal, S. G. The existence of the substance-weight-volume décalage. Unpublished doctoral dissertation, University of Minnesota, 1970.

Nummedal, S. G., & Murray, F. B. Semantic factors in conservation of weight. Psychonomic Science, 1969, 16, 323-324.

Oltman, P. K. A portable rod-and-frame apparatus. Perceptual and Motor Skills, 1968, 26, 503-506.

Papalia, D. E. The status of several conservation abilities across the life-span. Human Development, 1972, 15, 229-243.

Pascual-Leone, J. Piaget's period of concrete operations and Witkin's field dependence: A study on college students and children. Paper presented at the meeting of the Canadian Psychological Association, Montreal, 1972.

Pedersen, F. A., & Wender, P. H. Early social correlates of cognitive functioning in six-year-old boys. Child Development, 1968, 39, 185-193.

Peluffo, N. Culture and cognitive problems. International Journal of Psychology, 1967, 2, 187-198.

Piaget, J. The child's conception of the world. London: Routledge & Kegan Paul, 1929.

Piaget, J. Le mécanisme du développement mental et les lois du groupement des opérations. Archives de psychologie, Genève, 1941, 28, 215-285.

Piaget, J. The psychology of intelligence. London: Routledge, 1950.

Piaget, J. The child's conception of number. New York: Humanities Press, 1952.

Piaget, J. The construction of reality in the child. New York: Basic Books, 1954.

Piaget, J. Logic and psychology. New York: Basic Books, 1957. (a)

Piaget, J. Logique et équilibre dans les comportements du sujet. In L. Apostel, B. Mandelbrot, & J. Piaget, Logique et équilibre. Etudes d'épistémologie génétique. Vol. 2. Paris: Presses Université de France, 1957. (b)

Piaget, J. Review of Bruner et al. Studies in cognitive growth. Contemporary Psychology, 1967, 12, 532-533.

Piaget, J. Preface to the first edition. In B. Inhelder, The diagnosis of reasoning in the mentally retarded. New York: John Day, 1968. (a)

Piaget, J. On the development of memory and identity. Worcester, Massachusetts: Clark University Press, 1968. (b)

Piaget, J. Quantification, conservation, and nativism. Science, 1968, 162, 976-979. (c)

Piaget, J. The theory of stages in cognitive development. In D. R. Green, M. P. Ford, and G. B. Flamer, (Eds.), Measurement and Piaget. New York: McGraw-Hill, 1969.

Piaget, J. Introduction. In M. Laurendeau & A. Pinard. The development of the concept of space in the child. New York: International University Press, 1970.

Piaget, J. Some aspects of operations. In M. W. Piers (Ed.), Play and development. New York: Norton, 1972.

Piaget, J., & Inhelder, B. Le développement des quantités chez l'enfant. Neuchâtel: Delachaux et Niestlé, 1941.

Piaget, J., & Inhelder, B. Diagnosis of mental operations and theory of the intelligence. American Journal of Mental Deficiency, 1947, 51, 401-406.

Piaget, J., Inhelder, B., & Szeminska, A. The child's conception of geometry. New York: Basic Books, 1960.

Pinard, A. & Laurendeau, M. "Stage" in Piaget's cognitive-developmental theory. In D. Elkind and J. H. Flavell (Eds.), Studies in cognitive development: Essays in honor of Jean Piaget. New York: Oxford University Press, 1969.

Pinard, A., Laurendeau, M., Boisclair, C., Dagenais, Y., & Morin, C. Compte rendu d'une étude préliminaire sur le développement intellectuel de l'enfant rwandais. Laboratoire de Psychologie génétique, Institut de Psychologie, Université du Montréal, 1969.

Rosner, S. Consistency in response to group pressure. Journal of Abnormal and Social Psychology, 1957, 55, 145-146.

Siegel, S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1956.

Sigel, I. E. Reflections. In I. E. Sigel & F. H. Hooper (Eds.), Logical thinking in children: Research based on Piaget's theory. New York: Holt, Rinehart, & Winston, 1968.

Sigel, I. E. The Piagetian system and the world of education. In D. Elkind & J. Flavell (Eds.), Studies in Cognitive Development. New York: Oxford University Press, 1969.

Sigel, I. E., Roeper, A., & Hooper, F. H. A training procedure for acquisition of Piaget's conservation of quantity: A pilot study and its replication. British Journal of Educational Psychology, 1966, 36, 301-311.

Simpson, R. E. The effects of cognitive style and chronological age in achieving conservation concepts of substance, weight, and volume. Unpublished doctoral dissertation, University of Alabama, 1970.

Skager, R. W., & Broadbent, L. A. Cognitive structures and educational evaluation. CSEIP Occasional Report No. 5, April, 1967, University of California, Los Angeles, Report No. BR-6-1646, U. S. Department of Health.

Smedslund, J. The acquisition of conservation of substance and weight in children: I. Introduction. Scandinavian Journal of Psychology, 1961, 2, 11-20. (a)

Smedslund, J. The acquisition of conservation of substance and weight in children. V. Practice in conflict situations without external reinforcement. Scandinavian Journal of Psychology, 1961, 2, 156-160. (b)

Smedslund, J. The acquisition of conservation of substance and weight in children. IV. An attempt at extinction of the visual components of the weight concept. Scandinavian Journal of Psychology, 1961, 2, 153-155. (c)

Sullivan, E., Clark, W., & Tiegs, E. California Short-Form Test of Mental Maturity. New York: McGraw-Hill, 1963.

Szeminska, A. The evolution of thought: Some applications of research findings to educational practice. In Cognitive development in children. Chicago: University of Chicago Press, 1970.

Thurstone, L. L. A factorial study of perception. Chicago: University of Chicago Press, 1944.

Towler, J. O. & Wheatley, G. Conservation concepts in college students: A replication and critique. Journal of Genetic Psychology, 1971, 118, 265-270.

Uzgiris, I. Situational generality in conservation. Child Development, 1964, 35, 831-842.

Vernon, P. E. Intelligence and cultural environment. London: Methuen, 1969.

Vygotsky, L. S. Thought and language. Cambridge: Massachusetts Institute of Technology Press, 1962.

Wachtel, P. L. Cognitive style, attention, and learning. Perceptual and Motor Skills, 1971, 32, 315-318.

Wallach, L. On the bases of conservation. In D. Elkind & J. H. Flavell (Eds.), Studies in cognitive development. New York: Oxford University Press, 1969.

Werner, H. Comparative psychology of mental development. New York: International Universities Press, 1948.

Wertheim, J. & Mednick, S. A. The achievement motive and field independence. Journal of Consulting Psychology, 1958, 22, 38.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.

Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. R., & Karp, S. A. Psychological differentiation. New York: Wiley, 1962.

Witkin, H. A., Goodenough, D. R., & Karp, S. A. Stability of cognitive style from childhood to young adulthood. Journal of Personality and Social Psychology, 1967, 7, 291-300.

Witkin, H. A., Lewis, H. B., Hertzman, M., Machover, K., Meissner, P. B., & Wapner, S. Personality through perception. New York: Harper, 1954.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. A. Manual. Palo Alto: Consulting Psychologists Press, 1971.

Wohlwill, J. F., & Lowe, R. Experimental analysis of the conservation of number. Child Development, 1962, 33, 153-167.

Zigler, E. A measure in search of a theory? Contemporary Psychology, 1963, 8, 133-135. (a)

Zigler, E. Zigler stands firm. Contemporary Psychology, 1963, 8, 459-461. (b)

APPENDIX A

Procedure for Assessing Understanding of Relational Terms

Materials: Stimuli used for this assessment were four blocks of wood, all of the same color and thickness, but differing in length and width. The comparison blocks measured 16 X 4 X 1 inches, 8 X 2 X 1, and 2 X 1 X 1, so that they were obviously different in mass, weight, and volume. The standard block was identical to the middle-sized comparison block (8 X 2 X 1).

Procedure: Pairs of blocks were presented to the subject and he was asked to judge whether the two were the same or different in amount and whether there was more or less wood in one or the other. Questions asked were:

(1) Does this block have the same amount of wood as that one, or do they have different amounts?

(2) Which one has more?

(3) Which one has less?

Subjects were also asked to pick out blocks that had the same amount, more, and less wood than the standard block. This procedure was repeated, with appropriate modifications, to assess the subject's understanding of the terms in relation to weight and volume.

APPENDIX B

TABLE B

Group Means and Standard Deviations on Conservation of Mass, Weight, and Volume

			Mass		Weight		Volume		Total	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
Grade 1	M	FD	2.67	2.96	3.78	2.49	2.67	2.60	9.11	6.86
		FI	3.89	2.93	5.33	2.00	4.78	2.44	13.56	6.33
	F	FD	3.22	2.91	3.00	2.35	2.00	2.65	8.22	5.85
		FI	5.22	1.99	5.44	1.67	3.89	2.57	14.56	5.10
Grade 3	M	FD	5.78	0.67	5.33	2.00	4.11	2.57	15.22	4.68
		FI	6.00	0.00	6.00	0.00	5.22	1.72	17.22	1.72
	F	FD	3.89	2.57	4.00	2.65	2.78	2.82	10.67	7.53
		FI	6.00	0.00	5.78	0.67	3.56	2.35	15.33	2.60
Grade 5	M	FD	6.00	0.00	4.33	2.55	5.22	1.64	15.56	3.84
		FI	5.89	0.33	5.78	0.67	4.56	1.81	16.22	1.92
	F	FD	6.00	0.00	5.00	1.22	3.89	2.03	14.89	2.89
		FI	6.00	0.00	4.67	2.00	3.56	2.65	14.22	4.27

APPENDIX C

TABLE C.1

Tukey Post Hoc Comparisons between Means:
Grade Level (within quantity types)

FORMULA: $HSD = q_{\alpha,\nu} \sqrt{\frac{MS\ error}{n}}$ (Kirk, 1969, p. 88)

Difference among Means

mass	1	3	5
$\bar{X}_1 = 3.750$	-	1.667**	2.222**
$\bar{X}_2 = 5.417$		-	0.555
$\bar{X}_3 = 5.972$			-

weight	1	5	3
$\bar{X}_1 = 4.278$	-	1.000	0.666
$\bar{X}_2 = 5.278$		-	0.334
$\bar{X}_3 = 4.944$			-

volume	1	3	5
$\bar{X}_1 = 3.333$	-	0.584	0.973
$\bar{X}_2 = 3.917$		-	0.389
$\bar{X}_3 = 4.306$			-

**$p < .01$

HSD ($p < .05$) = 1.137

HSD ($p < .01$) = 1.420

TABLE C.2

Tukey Post Hoc Comparisons Between Means:
Sex (within quantity types)

Difference among Means

Mass	M	F
$\bar{X}_1$ = 5.037	-	0.019
$\bar{X}_2$ = 5.056		-

Weight	M	F
$\bar{X}_1$ = 5.019	-	0.371
$\bar{X}_2$ = 4.648		-

Volume	M	F
$\bar{X}_1$ = 4.426	-	1.148**
$\bar{X}_2$ = 3.278		-

**$p < .01$

HSD ($p < .05$) = 0.831

HSD ($p < .01$) = 1.076

TABLE C.3

Tukey Post Hoc Comparisons between Means:
Quantity Type (groups combined)

Difference among Means

	V	W	M
$\bar{X}_1$ = 3.852	-	0.981**	1.194**
$\bar{X}_2$ = 4.833		-	0.213
$\bar{X}_3$ = 5.046			-

**$p < .01$

HSD ($p < .05$) = .473

HSD ($p < .01$) = .589

TABLE C.4

Tukey Post Hoc Comparisons between Means: Quantity Type (within sexes)

Difference among Means

male	V	W	M
$\bar{X}_1$ = 4.426	-	0.593	0.611
$\bar{X}_2$ = 5.019		-	0.018
$\bar{X}_3$ = 5.037			-
female	**V**	**W**	**M**
$\bar{X}_1$ = 3.278	-	1.370**	1.778**
$\bar{X}_2$ = 4.648		-	0.408
$\bar{X}_3$ = 5.056			-

**$p < .01$

HSD ($p < .05$) = 0.669

HSD ($p < .01$) = 0.832

TABLE C.5

Tukey Post Hoc Comparisons Between Means:
Quantity Type (within grade levels)

Difference among Means

Grade 1	V	M	W
$\bar{X}_1 = 3.333$	-	0.417	0.945*
$\bar{X}_2 = 3.750$		-	0.528
$\bar{X}_3 = 4.278$			-

Grade 3	V	W	M
$\bar{X}_1 = 3.917$	-	1.361**	1.500**
$\bar{X}_2 = 5.278$		-	0.139
$\bar{X}_3 = 5.417$			-

Grade 5	V	W	M
$\bar{X}_1 = 4.306$	-	0.638	1.666**
$\bar{X}_2 = 4.944$		-	1.028**
$\bar{X}_3 = 5.972$			-

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

HSD ($p < .05$) = 0.821

HSD ($p < .01$) = 1.022

APPENDIX D

TABLE D

Number of Subjects Conserving Mass, Weight, and Volume in Order 1 (m-w-v), Order 2 (v-m-w), and Order 3 (w-v-m)

			Mass			Weight			Volume		
			1 (1)	2 (2)	3 (3)	1 (2)	2 (3)	3 (1)	1 (3)	2 (1)	3 (2)
Gr.1	M	FD	0	3	1	1	3	1	1	1	1
		FI	2	1	3	2	3	2	2	2	3
	F	FD	1	1	2	1	2	0	1	1	0
		FI	3	3	2	3	3	2	2	1	2
	Total		6	8	8	7	11*	5*	6	5	6
Gr.3	M	FD	3	3	2	3	3	2	2	1	2
		FI	3	3	3	3	3	3	3	2	2
	F	FD	2	2	1	2	2	1	1	1	1
		FI	3	3	3	3	3	2	1	1	2
	Total		11	11	9	11	11	8	7	5	7
Gr. 5	M	FD	3	3	3	3	1	2	3	2	3
		FI	3	3	3	3	2	3	2	1	2
	F	FD	3	3	3	2	2	1	2	0	1
		FI	3	3	3	1	2	2	1	1	2
	Total		12	12	12	9	7	8	8	4	8

Note.--Figures in brackets represent the position in the sequence of the concept located at the top of the respective column.

*$p < .05$