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THE UNIVERSITY OF ALBERTA

EYE MOVEMENTS: THEIR RELATIONSHIP TO THE DEVELOPMENT OF CONSERVATION OF LENGTH, AREA AND CONTINUOUS QUANTITY

by

© KENNETH G. O'BRYAN

A THESIS
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled Eye Movements: Their relationship to the development of conservation of length, area, and continuous quantity, submitted by Kenneth G. O'Bryan in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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Date: Jan. 24, 1969.

Abstract

Current controversy between Piaget and Bruner regarding the nature of conservation, its identification and subsequent potential acceleration indicated the need for examination of conservation development via less traditional methodology. A rationale for the investigation of conservation through observation of eye movement patterns (EMPs) of girls in varying stages of concept acquisition was derived from the theoretical positions of Piaget, Bruner and Wohlwill. It was suggested that EMPs might provide behavioral output less liable to contamination by subject control or experimenter cueing, and that such EMPs might reflect increasing perceptual activity (Piaget), the transition from iconic to symbolic representation (Bruner) and the continuum from perceptual distortion to conceptual certainty (Wohlwill).

Ninety-two girls, 6 years through 10 years, were tested on four Piagetian tasks representing length, area, continuous quantity (solid) and continuous quantity (liquid). Stimuli were presented on 16 mm movie and all instructions were taped. Training and laboratory procedures were developed to acclimatize the subject to the equipment and check comprehension of the experimenters' instructions. EMPs were recorded by Polymetric eye movement recorder from point of stimulus transformation to solution decision. Subjects were classified (according to Piaget's techniques) into groups representing stages in conservation acquisition on each task, and the EMPs of each group were then analyzed.

Results indicated that substantial differences were present between non-conservers and conservers on most variables (fixation position and number; couplings; runs and mean length of run) both shortly after transformation and over total time to solution decision. Differences also existed between groups of non-conservers, but were less substantial and less consistent. Plots drawn from permanent records suggested qualitative differences between all groups.

It was concluded that a relationship existed between EMPs and conservation status. The data supported a theory of perceptual activity leading to decentration and indicated a change of viewing strategy associated with change in conservation level. It was suggested that the heavy centration found in non-conservers supported Wohlwill's notion of perceptual redundancy, while the marked perceptual activity and random scanning patterns of the conservers were consistent with Piaget's view of reversible operations. Several implications for further research were noted.

Short Abstract

Ninety-two girls were tested on four Piagetian conservation tasks (length, area, continuous quantity in solids and liquids) presented on 16 mm movie with pre-recorded instructions. The eye movements (EMs) made by the subjects after stimulus transformation were recorded and later analyzed to investigate a hypothesized relationship between level of conservation attainment and EM patterns (EMPs).

Results indicated that changes in EMPs occurred as conservation was attained. Non-conservers were found to fixate more on the stimulus element chosen as greater, to display a greater number of fixations than conservers and to make fewer shifts (couplings) between stimulus elements. The data also suggested a progressive change in EMPs within non-conserver groups.

Results were discussed in terms of the theoretical positions of Piaget, Bruner and Wohlwill.

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The author's wife, Maureen, will know that this January 24 belongs to her as does another January 24, long miles and short years past.

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CHAPTER 1

Introduction

The Problem

Despite the proliferation of conservation based research, there remains controversy relative to its nature, and the means by which its appearance may be ascertained (cf. Bruner, 1966; Piaget, 1967). In line with this, the situation has arisen in which Piaget has gone so far as to suggest that Bruner has "missed the heart of the conservation problem" (Piaget, 1967, p. 532).

Since a large proportion of the evidence upon which an examiner bases his assessment of the presence of conservation is derived from the verbal report of the subject, it seems likely that herein may lie some of the causes for the present controversy. Two points deserve mentioning here. First, there is a difference between Bruner and Piaget in the type of verbal report they are willing to accept as indicating the presence of conservation (Gruen, 1966). Whereas the Bruner group is satisfied with a *primary* conservation response, the Geneva School requires, in addition, an *adequate* explanation. Thus, the two Schools are actually using different criteria for ascertaining the presence of conservation. One result of this is the differential in ages of supposed conservers for one group when compared to those of the other group. As much as three years difference is reported (cf. Braine and Shanks, 1965; Smedslund, 1961). Another problem with the verbal report method is its susceptibility to confounding social interactional factors. For example, one's desire to be successful in the eyes of the examiner or fear of failure, or the unconscious cueing by the examiner may well contribute to an incorrect assessment of the presence of conservation. In short, it would appear essential either that the present criteria for assessing the status of conservation be clarified, or that other less subjective methods for determining such status be investigated. Several recent eye movement (EM) studies suggest that herein may lie a dependent variable less susceptible to differential criteria interpretation and confounding social interactional factors.

Especially relevant to the present study are the following points. First, EMs (points of fixation), using the principle of corneal reflection, can now be reliably recorded (Mackworth, 1967). Second, "eye movements *reflect* (italics added) the human thought process so that the observer's thought may be followed to some extent from records of eye movements ... " (Yarbus, 1967, p. 190). Third, the organism is largely unaware of EMs made in deriving and processing information upon which subsequent actions are based (Thomas, 1963). And fourth, EMs are an aspect of human behavior not easily analyzed by others, and, consequently, less subject to control by the organism through factors arising out of a desire for social conformity (Webb, Matheny and Larson, 1963).

Piaget (1950, 1961) has carefully delineated his view of the role of perception in the origin and development of intelligence.

And he makes several references to the importance of perceptual activity involving EMs in the development of decentration; a cognitive operation essential to the appearance of conservation (Piaget, 1950; 1957; 1961). More specifically, he suggests that non-conservers center on one element of the conservation task while conservers shift freely from one element to the other (Piaget, 1950). If this is indeed the case, differential perceptual activity of non-conservers and conservers should be reflected by differences in EMs, regardless of the subject's verbal report.

The previous discussion suggests that three major research problems need to be dealt with if EMs are to become a meaningful dependent variable in conservation research. First, it must be determined whether or not non-conservers and conservers, identified by Piagetian techniques, do in fact display distinctly different eye movement patterns (EMPs). Second, a comparison of the EM characteristics of Bruner and Piagetian non-conservers and conservers must be undertaken. And third, a study must be done in which an attempt is made to identify non-conservers and conservers on the basis of EMPs, independent of verbal reports.

The present study attempts to deal with the first problem using Piagetian tasks of conservation of length, area and continuous quantity (solid and liquid). The principal questions to be asked are:

Do non-conservers and conservers of the Piagetian type display differences in EMPs while engaged in conservation tasks?

Should they do so, what is the nature of this difference?

What light would the differences shed on the conservation problem?

CHAPTER 2

Review of Related Literature

Eye Movements

The human eye has long been regarded as a mirror of the soul. And English literature is replete with characters whose eyes and EMs mark them as villains or heroes, as fools or intellectual giants. Yet there does seem to be more than tradition or fiction in the relevance of the eye and its movements to the human personality and intellect, since in recent years it has been the subject of considerable research, not only by scientists interested in its physiology, but also by psychologists interested in investigating its relationship to, among other things, cognitive functioning, aesthetic appreciation and schizophrenia. In line with this, three questions deserve consideration. First, what role do EMs play in vision? Second, what are the basic characteristics of EMs? And third, what implications do they have for psychological cognitive research?

As far as perceiving goes, if one is to fixate on something (look at it) he must move his eyes so that the image falls on the fovea. This area, actually smaller than the head of a pin, is the only region in the retina where receptor cells are sufficiently concentrated to produce detailed vision. More specifically, the fovea subtends an angle of about two degrees, whereas the retina as a whole covers a visual angle of approximately 240 degrees. Thus, not more than a thousandth of the total viewing area can be perceived in sharp focus at once. In spite of this, the eye is capable of rapidly distinguishing details within a stimulus field. This occurs because most of the time our eyes are jumping about in the visual field, with the two foveae receiving first details from one part of the field and then another.

The rapid jump the eye makes as it moves from one fixation to the next is the most common type of EM, and is referred to as a saccade, or saccadic EM. These fixations usually last less than a half of a second, although their duration may depend on the viewing field and/or the psychological task, suggesting, in part, that they are cognitively controlled. The jump between fixations usually takes only a few milliseconds with vision being reduced during the saccade and immediately preceding it. The actual speed of the jump depends upon its length and direction, although it may also vary as a function of the individual. If the fovea is not on "target" at the end of the saccade, it adjusts accordingly by additional EMs more molecular in nature. The path between two fixations may be straight, curved or even hooked, but once started cannot be changed.

Since the eye moves so quickly and frequently, EMPs can only be accurately ascertained (recorded) by precision instruments. Several methods are available for recording EMs. Among them there are contact lenses, suction cups, photo-electric devices, electro-oculography and corneal reflection. The latter technique was used in the present study. Briefly, it involves photographing a bright spot reflected off the convex surface of the cornea of the eye. This spot appears to move because the radius of curvature of the cornea is smaller than the radius of the spherical eyeball and the angle of reflection changes as the eyeball rotates. These movements are then correlated with movements within the line of sight.

Reading Research

Numerous studies suggest that EMs may be an important variable in psychological research, especially in respect to cognitive functioning. By far the most extensive psychological area in which EM research has been reported is in reading. Tinker (1958), in the course of a long review of reading studies, concluded that such EM research had reached a plateau, and pointed to the futility of attempting to train EMs in order to increase reading skills. In general, the reading studies have been most successful in areas of process analysis and interlanguage-interracial research. Tinker cites a number of studies (Tinker, 1947; Lord and Wright, 1949; Waterman, 1954; Gray, 1956) in which relationships between various forms of EM (such as fixation duration, saccadic movement, velocity and amplitude) and reading skills were demonstrated. Gray (1956) and Waterman (1954) reported that EMs of readers from different language areas do not differ, either when compared while reading in their own language or when reading in another, well understood language. Other studies indicated that preference for vertical or horizontal display was largely the result of habit (Tinker, 1946, 1947).

In considering the effects of familiarity during reading, Dixon (1951) found that different EMPs were associated with easy (known) and difficult (unknown) material. Tinker (1958) concluded that variation in EMs occurring with variation in subject matter results from difficulty and purpose differences in the material. Laycock's (1955) research involving flexible and non-flexible readers indicated that flexible readers had fewer fixations and shorter pauses when required to read in excess of their normal speed than did the non-flexibles, and were the more efficient readers at higher speeds.

Efforts to improve reading through EM training have been rather inconclusive. For example, Tillson (1955) attempted to train reading through use of the Harvard films and a reading accelerator. Moreover, he noted a significant reduction in fixation frequency and tendency to return to previously fixated material (regressions) and concluded that training had resulted in improved reading technique. Tinker (1958) criticized this conclusion, however, on the grounds that the data do no more than reflect improved EMs as a result of improved reading, and not vice versa. Tinker's point is relevant to the present study for it will later be suggested that EMs reflect the development of conservation in children. Additional support for this position may be ascertained by examining the developmental EM literature.

Although it is difficult to record accurately EMs of young children, especially those younger than six years of age, a number of studies deserve consideration. One of the few dealing with children three to six years of age is the research published by Zaporozhets and Zinchenko (1966). Using complex stimuli, the authors report that a relationship exists between EMs and the development of perceptual activity, such that the isolation of a specific sensory content becomes increasingly commensurate with the material and task concerned as the child becomes older. Zaporozhets and Zinchenko's premise, however, is difficult to assess (as are most Russian translations) since they fail to present in detail their methodological procedure.

Gilbert (1953) obtained EM measures for frequency of fixation and pause duration for children from Grades 1 to 9, and found a steady growth in ocular motor proficiency. His data is similar to that reported by Morse (1951) who found more efficient patterns of EM for children in upper grades. Dunn (1954), in comparing EMs of retarded and normal boys of similar mental age engaged in reading tasks, reported no significant difference between rate of reading, fixations and regressions between the groups. He does not report comparisons between the retardates and boys of the same chronological age, but it may be assumed that they would display differences similar to those found by Gilbert (1953) and Morse (1951) between normal children of different chronological (and by implication, mental) age. Once again it might be argued that the retarded group's EMs reflect their inability to read at their chronological age level, rather than this being a causative factor in their mental development. Blackhurst and Radke (1966), however, report that mentally retarded children *do* have difficulty in fixating objects and controlling visual search behavior, while Rosenberg (1961) demonstrated that severely retarded patients took longer to detect and select a nonsense shape from a matrix than did moderately retarded patients.

Mackworth and Bruner (1966) have also reported differences in EMs of children and adults, but this time in detection and selection of visual information. They concluded that the differences were developmental in nature and related to informative search strategies of the subjects. More specifically, they found that EMPs of children were less consistent than those of adults, and that children exhibited "piecemeal perception" by dwelling on "unimportant" details. Their eye tracks also tended to trace simple contours and to pinpoint on details, thus, according to Mackworth (1967), contradicting a theory of global perception in children.

A relation between EM output and intellectual behavior in normal children was reported by Lorens and Darrow (1962). Although their sample was very small (10), Lorens and Darrow found significant rate increase in EMs during mental multiplication. The change in rate was not related to changes in heart rate or conduction level.

Luborsky, Blinder and Mackworth (1964) have also studied cognition and EMs. They focussed on inspection time of a visual field in relation to the recall of that part of the stimulus field attended to. In so doing they were able to link the time of inspection of part of the visual field with accuracy of recall of perceptual images; the greater the inspection time the greater the recall. Teichner and Price (1966) suggest that the finding of a visual pattern in an array of stimuli is a problem-solving or concept formation task involving successive data inputs represented by successive eye fixations. And, they hypothesized that EMs resulting in the obtaining of new information would represent a data acquisition process which, in turn, might be divisible into hypothesis testing and non-directed movements. Using Simon and Kotosky's (1963) letter sequence, Teichner and Price tested 10 under-graduate males and found indications that correct solutions to sequence tasks were accompanied by more systematic eye movements and increased attention to detail. Similarly, Ford, White and Lichtenstein (1959) concluded, in their study of EMs during free search, that duration varies with the difficulty of the field and that specific search patterns can be isolated from EM recordings. Their findings are consistent with those reported by Zaporozhets and Zinchenko (1966), Mackworth and Bruner (1966) and Conklin, Muir and Boersma (1968).

In the Conklin et al. study, EMPs of high and low scorers on a test of field dependency-independency were compared. Significant differences were found in track length and in Mackworth and Bruner's informative search score variable. Sex differences and duration of EMs were not significantly different between the groups. The authors concluded that field independent subjects employed "better" search patterns than did field dependent subjects. Their findings are important in relation to the present study, in that they suggest a reflection of cognitive processing EMPs.

In summary, the studies cited in this review present evidence that eyes are providing behavioral output which is linked to human cognition. Accordingly, it is suggested that in the realm of cognition, as in the field of reading, EMs reflect cognitive functioning.

Eye Movements and the Perception of Illusions

In the area of perceptual illusions the relationship between EMs as a reflective indicator of behavior and cognitive activity has not been clarified. Evidence for the involvement of EMs in the perception of illusions is presented by Piaget, Vinh Bang and Matalon (1958), Piaget (1961) and Gardner and Long (1962).

According to Piaget's (1961) view, the apparent size of a stimulus is a function of the duration of centration upon it. Moreover, he suggests that over-fixation on a given element will result in a consistent overestimation of it and bring about error of the standard. In this instance, the EMs appear to play an active role by providing misleading data input to the organism which then must evolve strategies of decentration or commit error of the standard. According to Piaget's theory, such strategies are formed in the course of development and are reflected by shifts of fixation. Thus, as conservation is developed, subjects should demonstrate increased scanning behavior (couplings) per unit of time in order to minimize error of the standard.

Gardner and Long (1962) investigated Piaget's notions of error of the standard in a study of control, defense and centration effect in adult scanning behavior. Scanning behavior was determined on the basis of seven electro-oculographic EM scores in which the principal dependent variables were derived from centrations on the standard. Using a size estimation test in conjunction with an inverted T-test (scores on which were not used, however, because of prior contamination of subjects) Gardner and Long found ten extensive scanners and ten limited scanners from a group of women aged between 17 and 44. The extreme groups were then tested on size estimation and the reversed L test together with other variables not relevant to this review. The authors concluded that their results confirmed Piaget's hypothesis that the apparent size of a stimulus element is the function of the duration of centration upon it. A further finding was that extensive scanners seem preoccupied with the veridicality, exactness and acceptability of their responses while the limited scanners seem to accept their perceptual experience in a more relaxed and less critical way.

In collaboration with Vinh Bang, Piaget (1961) investigated perceptual illusions via EMPs and came to some firmly expressed conclusions. Arguing that an explanation of such illusions might be found in examining the percentage of distribution and duration of eye fixations as well as movements of exploration and transport, Piaget and Vinh Bang stated that their study led to:

> a clear confirmation of the interpretation proposed to explain the fact that the upper of two vertical collinear segments is overestimated: the fixations are, in fact, concentrated at the summit of the two verticals so that the upper of the two segments is favoured. In the case of the two horizontal lines the fixations are concentrated around the centre of the figure and symmetrically distributed so that there is no illusion (pp140-141).

Analyses of durations of fixations in these areas led to analogous results and the authors concluded that

> these distributions explain the overestimation of the vertical and the variability in sizes of the errors reported in research XLIV (p. 141).

In effect, Piaget suggests that a subject who is not aware of equality will tend to overestimate the size of that part of a stimulus upon which he centrates, i.e. concentrates his eye fixations. As the subject progressively decentrates, or shifts his point of fixation, so that the points form a more "symmetrically distributed" (Piaget and Vinh Bang, 1961, p. 141) pattern around the stimulus, so the strength of the overestimation diminishes. In another context, the development of intelligence, Piaget (1950) refers to this increase in decentration as a resultant of increased perceptual activity by the subject as he proceeds from the cognitive state of ego-centricity to a state of formal operations.

It is not completely clear from Piaget's work on EMs in perceptual illusions whether he intends the reader to regard EMs as responsible for the appearance of the illusions, or whether they reflect the perceiver's inability to decentrate from the standard and form a symmetrical patterning incorporating all elements of the stimulus. The concept of standard error does seem to imply, however, that the eye is transmitting misleading data and will continue to do so until the organism develops strategies which produce compensatory EMs and variations in fixation times. The development of strategies implies cognitive control by the organism over the perception of elements of the stimulus. Consequent EMs arising from cognitive control are then likely to be of a reflective rather than causative type. In other words they will be the behavioral output of an organism which has come to distrust the input of undirected eye fixations derived from EMs across a perceptually distorted field.

An examination of changes in EMs as a function of age might be expected to reveal stages in the development of conceptual control over potentially misleading perceptual input. Should this be so, and the literature reviewed above points in that direction, EMs may also reflect the development of such concepts as conservation of length, area and substance, in all of which the transformed elements of the stimulus present the subject with a potential perceptual illusion.

Conservation

Before proceeding to a more detailed theoretical discussion of the possible relationship between EMs and conservation, it is necessary, first, to clarify our understanding of the concept of conservation and its development, and second, to understand the importance of perceptual activity involving EMs in the development of decentration, a cognitive operation essential to the appearance of conservation. The following review of literature attempts to lay the ground work for the postulates discussed in the next chapter.

It must be stated at the outset that conservation arising out of the equilibration of cognitive actions (an internalized process involving the operations of reversibility and identity), is an integral part of Piaget's stage development theory of human cognition, and that it is central to the acquisition and subsequent development of logical thought.

Conservation characterizes the appearance of concrete operations (Inhelder and Piaget 1964) and is, according to Sigel and Hooper (1968)

> the ability of an individual to be aware of the invariant aspects or properties of objects in the face of transformation (p. 3).

Under Piaget's theory, one of the factors involved in cognitive development, equilibration, is regarded as an active compensation operator such that a subject confronting an external disturbance will react in a compensatory fashion as an organism active in the act of knowing (Towler, 1967). Provided that the subject possesses the operators of reversibility and identity, any given state of an object is understood to be the result of some transformation, and is the point of departure for further potential transformations. Such a subject would possess conservation. By contrast Piaget (1964) suggests that conservation is not present when the subject:

> does not understand transformations. He does not have the operations necessary to understand them so he puts all the emphasis on the static quality of the states. It is because of this, for example, that in the conservation experiments he simply compares the initial state and the final state without being concerned with transformation (p. 20).

In short, the identity of the original state prior to transformation must be conserved if the subject is to avoid being misled by his perception of apparently different transformed states.

Elkind (1967) indicates that Piaget's position on conservation has sometimes been misunderstood because of his tendency to write for rather specialized readers "immersed in his system and terminology (p. 17) " and hence capable of filling gaps in his presentation. In discussing Piaget's (1957) view that the central problem of conservation is the difficulty the subject encounters in dealing with objects varying simultaneously in two inverse directions, Elkind (1967) argues that emphasis of the conservation of identity at the expense of conservation of equivalence has contributed to a misunderstanding of Piaget's notion of conservation. Elkind's point is relevant to the present discussion because Piaget's standard conservation tasks, including those used in this dissertation, rely upon the examiner's ability to decide whether conservation of identity may be inferred from the subject's responses to tasks requiring the conservation of equivalence.

To clarify his position, Elkind presents a symbolic representation of conservation of identity and conservation of equivalence (1967 p. 16-17). Where S is a standard stimulus and

V is an identical stimulus subsequently transformed to V^1, conservation and non-conservation of identity may be represented thus:

Conservation of Identity	Non-conservation of Identity
Subject judges $S = V$	Subject judges $S = V$
Subject judges $S = V^1$	Subject judges $S \neq V^1$
Examiner infers $V = V^1$	Examiner infers $V \neq V^1$

No such inferential procedure is required in assessing conservation of equivalence. In this case all is dependent upon the subject's judgments as follows:

Conservation of Equivalence	Non-conservation of Equivalence
Subject judges $S = V$	Subject judges $S = V$
Subject (covertly) judges $V = V^1$	Subject (covertly) judges $V \neq V^1$
Subject judges $S = V^1$	Subject judges $S \neq V^1$

The formulation suggests that conservation of equivalence presupposes conservation of identity, but Piaget tends to treat the two as occurring simultaneously. While Elkind may be correct in suggesting that Piaget errs in this regard and that conservation of identity does occur prior to conservation of equivalence, the critical point is that Piaget regards the conservation of identity as the crucial factor in the conservation problem. He is concerned not with the subject's ability to make an equivalence judgment between S and V^1 but with his ability to conserve the identity of V throughout its transformation to V^1.

Piaget summarizes his view of the basic mechanism of identity conservation in his critique of Bruner's position, and he writes (1967) "Conservation ... involves quantities that are not perceptive but have to be constructed by compensation between different dimensions (p. 533)." In effect he suggests that the child discovers that a change in one dimension of an object is compensated for by a change in a different dimension. According to Elkind's (1967) interpretation, the child:

> comes to employ a calculus of discontinuous equations of differences so as to arrive at the notion of a continuous or reversible transformation (p.19).

Piaget (1967) draws a sharp distinction between covariance of dimensions and compensation, a distinction which, he suggests, has been missed by Bruner, in that covariance may be acquired by "direct perceptive recording of real situations without comprehension (p. 533)." Compensation, on the other hand, is held to require a logico-deductive reasoning process independent of the perceptual qualities of the transformed state of the stimulus. Piaget is also careful to distinguish between the operational concept of reversibility, which he often refers to as the operation of logical necessity, and the physical process of "renversabilité" which involves empirical return of the transformed stimulus to its original dimensions as opposed to the logico-spatial return to identity via reversibility. More specifically, operational reversibility is described by Piaget (1964) as a process in an equilibrated system where a transformation in one direction is compensated for by a transformation in another direction. Thus, Piaget and the Geneva School view conservation as involving the operation of reversibility through compensation arising out of logical necessity.

Bruner (1964) approaches the problem from a somewhat different theoretical viewpoint. Disputing Piaget's emphasis on the logical aspects of conservation, Bruner suggests that the study of cognitive growth calls for an investigation of man's attempts to represent internally his external world through actions, images and symbols.

Bruner (1964) presents a three mode theory of representation: enactive, iconic and symbolic. Enactive representation is seen as a mode of representing past events through various motor responses. The learning of such motor acts as dancing, riding bicycles, typing etc does not involve images or symbolic representation but according to Bruner "get represented in our muscles, so to speak (p. 2)". He describes iconic representation as the summarizing of events through selective organization of images and percepts classified through spatial, temporal and qualitative structures of the perceptual field and their transformed images. Thus images are held to represent "perceptual events in the close but conventionally selective way that a picture stands for the object pictured (p. 2)." In symbolic representation a concept is evoked by design aspects incorporating features such as remoteness and arbitrariness. Thus, the symbol "city" bears no resemblance to a collection of objects that physically comprise a city. Symbolic representation, such as that found in language, is productive in a combinatorial sense to a much greater extent than either of the other modes. Hence it is capable of "not only representing experience but also (of) transforming it (p. 4)."

Non-correspondence between systems of representation are said to result in a conflict which provides the impetus for learning. Conservation becomes involved when the child is presented with a conflicting series of events in which one mode of representation appears to be contradicted by another. Perceptual delusion may occur because the iconic mode induced by an object's transformation may overwhelm the symbolic mode and result in a non-conservation response. It then may provide for a conflict which in turn provides the basis upon which conservation may develop. As the symbolic mode strengthens through the child's increasing awareness of the shortcomings of the perceptual delusions arising from the iconic mode, attempts to resolve the conflict occur and eventually an understanding of the concept results.

Piaget (1967), in reviewing Bruner, Olver, Greenfield et al.'s (1966) work on cognitive growth, suggests that Bruner has failed to distinguish between pseudoconservation and true conservation, a failure which, Piaget says, invalidates many of Bruner's conclusions regarding the nature of conservation. He accuses Bruner of equivocation in claiming that neither reversibility nor compensation are necessary for conservation and, in so doing, Piaget underlines the point of difference between Harvard and Geneva.

Bruner sees conservation to be the result of learning (arising out of manipulation and language) which negates the conflicts induced by misleading perceptual cues and thus allows access to the concept of identity. In more specific terms, a transition from the iconic mode to the symbolic mode results in conservation. Piaget has repeatedly insisted (1950, 1964) that conservation arises out of the totality of the child's experience allied with maturational factors and may not appear until logical operations and structures are present.

In suggesting that Bruner is incorrect in stressing the role of language in conservation concept formation, Piaget (1967) writes, "operations direct language acquisitions rather than vice versa (p. 533)." Earlier he had been equally definite in stating that learning itself is subordinate to development (Piaget, 1964). However, Bruner (1966) argues that Piaget's equilibration theory for the development of conservation is faulty "both for its lack of specificity and its circularity of prediction about growth (p. 4)."

Superficially, the difference between Bruner's representational level theory and Piaget's stage development theory of conservation acquisition may seem more apparent than real. But such is not the case. Inhelder, Smock, Bovet and Sinclair (1966) claim that a qualitative difference does exist in that the Piagetian approach proposes a progressive structurization whereby actions and intellectual operations become organized into coherent systems characterized by laws applying to the system as an entity.

Thus, the appearance of conservation is based upon interiorized *thought* operations which are, essentially, fully coordinated structures in the form of reversible operations. Compensation and logical necessity produce a 'thought-action reversibility' concept of conservation. For Bruner, conservation "comes into being when the symbolic mode is activated and becomes dominant over the iconic (perceptual) mode and not necessarily through logical operations" (Gruen, 1966, p. 981). This process is regarded by Inhelder et al. (1966) as 'action reversibility', as distinct from thought-action or true reversibility.

Even though the differences between Piaget's and Bruner's formulations clearly exist, they might well have remained academic were it not for the effect they have had on the problems associated with identification of the presence of conservation and its induced acquisition. Gruen (1966) has pointed out that a number of studies (Braine, 1959, 1964; Smedslund 1963; Frank 1966) produced marked differences in the ages of children at which 'conservation' was first seen to occur. Those studies which accepted Piaget's insistence upon "exploration" of the child's responses to determine the presence or absence of reversibility, compensation and logical necessity, tend to report the appearance of conservation at 7-8 years of age. By contrast, those studies accepting a criterion of correct initial response to the standard question suggest that conservation occurs at 4-5 years of age. The latter type of classification of conservation has been referred to by Smedslund (1963) as a 'symptom response', but it is basically the approach used by the Harvard group to determine presence or absence of the concept.

Clearly, it is essential for any study dealing with aspects of conservation to clarify the theoretical basis upon which it *is* based. This point is well illustrated by Gruen (1966) who found that the Frank (1966) procedure for assessing conservation status resulted in more, and "probably younger" children being labelled conservers than did the Smedslund (1961) procedure applied to the same group. He concluded that the discrepancy was caused by Smedslund's requirement of a "logical justification" of the response.

Additional support for the need to clarify theoretical differences is given by Mermelstein, Carr, Mills and Schwartz (1967), who replicated conservation training techniques devised and reported by Smedslund (1961), Bruner (1964), Beilin (1965), and Sigel and Roeper (1965). Of these various techniques only one (Smedslund) was purportedly based on Piagetian principles and it, too, fell short of full consistency with Piaget's position. Mermelstein et al, found that in no case was the Piagetian concept of conservation induced by the replicated training techniques. This led the authors to agree with Gruen (1966) that the conservation acquired was a different concept to that described by Piaget and had been formulated from a different theoretical premise. Thus, the results of many conservation training attempts are equivocal in that studies claiming Piaget's concepts as their model have tended to be unsuccessful

(Wohlwill, 1959; Beilin and Franklin, 1962; Wohlwill and Lowe, 1962) while studies showing marked deviation from Piaget's formulation report successes in conservation training (Bruner et al, 1966; Beilin, 1965).

In summary, there remains considerable doubt regarding the nature of conservation. The conflict between 'thought-action reversibility' and 'action reversibility', affecting, as it does, efforts to distinguish, assess and induce conservation, is bound to wax more vigorously in the light of Piaget's (1967) stinging criticism of Bruner's concept of, and his colleagues' methodology in, the conservation problem.

The present study does not attempt to mediate the dispute nor to provide an alternative theoretical explanation for conservation. It does, however, seek to present a different type of evidence for assessing the presence of conservation than Bruner's "symptom" response and Smedslund's "logical justification" response. Further, it attempts to do so by using a conservation concept compatible with both Piaget's and Bruner's approaches for assessing the presence or absence of conservation. It also depends heavily upon Piaget's developmental model of transition, a description of which is discussed below.

Stages in the Formation of Conservation Concepts

The phenomenon of conservation has been directly observed in many areas of human cognition. Most notable among those concern the acquisition of invariants in length, distance, area, mass, weight and volume.

Piaget (1950, 1957), Piaget and Inhelder (1941) and Piaget, Inhelder and Szeminska (1960) have performed the seminal investigations of the concepts and their works still provide the definitive criteria in the area. Perhaps their most fundamental observation has been the discovery of common characteristics in children's responses to conservation problems as they proceed from non-conservation to conservation. Classification of these responses has led Piaget to postulate his developmental model of transition, an invariant sequence of steps through which a child must pass in order to develop the concept of conservation. The model proposes a developmental sequence in which the child first, attends to (fixates on) one element of a two part stimulus; second, alternates between both elements of the stimulus without considering the elements simultaneously in a state of hesitation and conflict; third, considers both elements simultaneously and in so doing employs the operations for logical necessity, thus conserving. Both Lefrancois (1968) and Towler (1967) invoked this model to lay a theoretical basis to their acquisition experiments, and their success in inducing conservation implies indirect support to Piaget's theory.

Bruner's investigations and representational level approach, however, do not support Piaget's formulation on this point. For Bruner, the transition from the perception dominated enactive and iconic levels to the symbolic level might be better (also) explained in terms of availability of language symbols. Thus, the exact nature of transition from non-conservation to conservation is still debatable.

Conservation and Perception

While it may not seem cogent to the present study to discuss the work of Piaget as an investigator of perception and hence delineate the differences between his theories of perception and cognition, it is relevant to present a brief review of his research, and that of others, in which a link is forged between perception and conception.

Wohlwill (1962) writes:

> much of Piaget's work on the development of concepts--particularly that on the conservation of length, weight, volume, number, and so forth, is interpretable in terms of the increasing stability of concepts in the face of (irrelevant) changes in the stimulus field (p. 87).

Côté (1967) suggests that perception, for Piaget, involves those structures which give the most direct and immediate knowledge of an object in a sensorial field.

In regard to perception and intelligence, Piaget maintains that they are minimally related (Piaget and Taponier 1956; Piaget, 1961; Wohlwill, 1962; Côté, 1967). For example, Piaget and Taponier (1956) report that a simple perceptual error explanation of young children's non-conservation is insufficient in itself, and invoke the concept of lack of reversible operations as a plausible explanation. In addition, he draws a contrast between the development of conservation and the development of perceptual constancies (Piaget, 1950), arguing that relatively little development takes place in the latter, since all aspects of the stimulus are included in the perceptual exploration of the field. Thus error arises out of distorting elements in the field so that the exact compensations possible in the intellectual constancies are rarely achieved by perceptual exploration. Hence, in Piaget's view, it is most unlikely that a child could consistently arrive at a conservation response through extensive perceptual exploration of a transformed stimulus.

Wohlwill (1962) is critical of the extent of Piaget's separation of perception and conception, suggesting that he overestimates their functional independence. Citing Piaget and Lambercier's (1946) study of size-at-a-distance judgments he argues that there is clear evidence of a 'perceptual compromise' showing mutual interaction, rather than absolute separation, between perception and thinking. This led Wohlwill to suggest that while the structural differences between the products of perceptual and conceptual processes might occur, there was still possible a continual interplay between the two in the nature of the dependence of an individual's conceptual processes on the aspects of information contained in the stimulus field.

Basically, Wohlwill proposes three dimensions along which perception and conception can be related--redundancy, selectivity and continuity. Proceeding from perception to conception, the individual is considered to require less redundant information, be able to tolerate increased irrelevancy in material and be better able to integrate differential aspects of the field. In effect, Wohlwill suggests a continuum with perception dominant at one end and conception dominant at the other. He cites studies by Bruner, Goodnow and Austin (1956), Vurpillot (1960) and Davidon (1952) in support of his dimension theory. Taken together, Wohlwill believes that his three dimensions yield responses of various specificity ranging from those of perceptual judgment in which error prevails to absolute precision as the product of conceptual processes.

In discussing the dimension of selectivity, Wohlwill (1962) suggests that:

> the differentiation of relevant from irrelevant, but more readily discriminable, attributes ... may also lie at the heart of a problem which Piaget has studied intensively--the development of conservation (p. 91).

He points out that one aspect of the stimulus has to be held invariant in the face of highly visible changes in another part. In support of his own position, Wohlwill (1962) found, in studying the redundancy and specificity dimensions, that changes in the amount of irrelevant information determine the extent to which the subject must formulate and test hypotheses.

Bruner (1964) seems to be suggesting a similar formulation of the conservation problem in terms of perceptual relevance. The transition made by the child from the iconic to symbolic levels appears to involve a shift from a dominant perception process to a dominant symbolic process free from the irrelevancies of the perceptual field. Bruner (1964) writes:

> It is plain that if a child is to succeed in the conservation task, he must have some internalized verbal formula

> that shields him from the overpowering visual displays (p.7).

Bruner cites several studies (Frank, 1966; Nair, 1963; Bruner and Kenney, 1966) to support his belief that children experiencing difficulty in transition from the iconic to the symbolic level were being affected by the perceptual content of the stimuli. Bruner (1964) concluded that the older child "is ordering his perceptual world (p. 9)" more effectively and is hence less likely to be led astray by distortions. A number of studies support his theory by finding that non-conservers tend to give reasons based on the perceptual distortion of the elements for their incorrect responses (Feigenbaum and Sulkin, 1964; Frank, 1966; Towler, 1967). Each of these reported success in conservation training techniques incorporating some form of screening from misleading perceptual distortion, which, by implication, is also consistent with Wohlwill's position.

Piaget (1961) draws a distinction not made by Wohlwill or Bruner between aspects of perception. He sees primary perception, absolutely bound by time and space and offering little scope for development, as a rigid forerunner to perceptual activity, a flexible encountering and coupling of elements in the stimulus field. In Piaget's concept of the conservation problem the role of perceptual activity may be allied with his view of centration and decentration. The rise of perceptual activity coincides with an increasing development of decentration on the part of the individual (Piaget, 1961). Decentration is reflected in the coupling of stimulus elements through perceptual activity. Centration, by contrast, is reflected by the individual's tendency to fixate on a particular aspect of the stimulus field. After stating that perceptual activity begins with decentration, Piaget and Inhelder (1956) write:

> The passage from one centration to another (or *decentration*) thus tends to the correction or regulation of centrations by each other, and the more numerous the decentrations, the more accurate becomes the resulting perception. But such a process correspondingly implies an activity to some extent motor in character (going beyond pure perception) and consequently underlying many other active movements such as the 'transfers' of perceptual data one to another, 'comparisons' (reciprocal transfers), 'transpositions' (temporal transfers), etc. It is this combination which constitutes perceptual activity and which is often referred to under the rather vague term 'analysis' (p. 24).

The exact nature of the interaction between perceptual activity and intellectual development has not been completely clarified by Piaget, but he has written (1961) that perception is essentially ego-centric and is bound to the position of the perceiver with respect to the object. Perception is thus restricted by sense data and is non-reversible in contrast to the reversibility associated with intellectual development. Moreover, he has suggested (1961, pp. 353-365) that while primary perception is absolutely bound by time and space it does permit modification of the elements it connects and, through connecting them, distorts them. Again he contrasts perception with intellectual operations, the latter conserving the unique properties of the elements connected. Basically, then, it seems that Piaget considers perception as at first a rigid representation of an object, replete with error which can only be overcome through the development of perceptual activity arising out of decentration. Additional support for this interpretation is provided by Côté (1967) who writes, in translating Piaget (1961),

> Between the distortion due to perceptual relations and the conservation produced by logical relations exist operational systems such as seriation which are derived from perceptual activity and not primary perception. It is perceptual activity and not perception which allows the subject to consider the object without distorting it (p. 179).

Piaget appears to suggest that perceptual activity is at once the foundation of operational structures and at the same time a servant of the intellect in the sense that "once formed, the superior modes of decentration direct perceptual decentrations" (Côté 1967, p. 177). In other words, the onset of decentration and the development of such operations as transfer, transposition, and anticipation, which lead to the higher levels of reversible operations and hence conservation, should be reflected by perceptual activity through which distortions in the perceptual field are overcome. Subsequently perceptual activity will be directed by the intellect as a result of complete intellectual decentration.

As such, Piaget's position is not basically dissimilar from that of Wohlwill in that perceptual activity permits a selective exploration of the stimulus field so that the redundancy and selectivity criteria are complied with. Inadequate perceptual activity would result in error, while directed perceptual activity arising out of conceptual processes (intellectual decentration) would preclude error from distorted stimuli and result in conservation of invariant properties.

It should be noted, at this point, that Piaget's extensive work on the perception of illusions is not directly related to the conservation problem in that it is not concerned with a subject who knows the pre-transformed stimuli to be equal (Piaget, Vinh Bang and Matalon, 1958; Piaget, 1961; Piaget and Lambercier, 1956). There is, however, an indirect association in that such concepts as "centration", "error of the standard" and "perceptual activity" lead, in Piaget's view (1961), to error and correction of error in subjects attempting to solve questions of equality in non-transformed stimuli. Briefly, Piaget suggests that in such cases error of the standard occurs when one element in an illusion becomes the basis by which the other is judged and thereby suffers systematic distortion through perceptual centration and lack of perceptual activity (Piaget, 1961; Piaget and Lambercier, 1956).

Piaget has attempted to demonstrate (Piaget and Lambercier, 1956) that the eye centers upon the standard and that few shifts are made from the standard to the other element in the illusion. This lack of decentration results in an overestimation in the length of the standard and an illusion is perceived. As decentration occurs, through perceptual activity causing couplings or encounters with both elements of the stimulus, the strength of the illusion is said to decrease. Thus, a subject attempting to judge the equality of previously equal, but presently transformed stimuli on the basis of only the transformed elements, would in fact be confronted by an illusion, in which error of the standard might be presumed significant. Error of the standard can only be significant, however, when conservation is not present, since Piaget (1961), Bruner (1964) and Wohlwill (1962) would all agree that the conserver has overcome the perceptual distortion present in the field. The manner by which the perceptual distortion is overcome, however, remains the key question.

A possible relation between EMs as an aspect of perceptual activity, and the development of intellectual decentration leading to conservation of length, area and continuous quantity is discussed in the next chapter. Postulates and hypotheses are formulated in terms of changing eye-movement patterns reflecting conservation development.

CHAPTER 3

Rationale, Postulates, Definitions and Hypotheses

By far the most systematic and prolonged investigation of the conservation problem is that of Piaget and his collaborators. Consequently, the present study is based primarily upon his notion of the steps leading from non-conservation to conservation. The perception based theories of Bruner and Wohlwill are relevant, however, in that they imply changes in EMPs in individuals proceeding towards conservation. It is here proposed that these changes are related to Piaget's concept of developing decentration concomitant with increased perceptual activity, and, further, that both EMPs and concurrent perceptual activity should undergo recordable changes as the organism proceeds from non-conservation, or perceptual dominance, to conservation or operational/symbolic dominance. To investigate this notion, EMPs of children (girls) at various stages of Piaget's step explanation of conservation development will be recorded and analyzed.

Rationale and Postulates

Piaget proposes a model of progression to a state of conservation via a series of steps. Usually there are three such steps, some of which may be divided into substeps depending upon the type of conservation task involved.

To reiterate, in the first step (in reality a state of non-conservation) Piaget (1950) believes that the child attends to only one particular element of the transformed stimulus field. The child has no operational structure to allow him to conceive that what is gained in one dimension is lost in another, therefore logical multiplication is not possible. In the conservation of length task, for instance, he is likely to almost exclusively centrate on the element he perceives as longer, thus virtually failing to consider the other element at all. Accordingly, in step 1 the child reports that a certain element is longer or greater or heavier according to the task involved. He suffers little cognitive conflict at this point since his perception of the field is dominant; no reversibility operators, which would enable him to conserve the invariant properties of the stimulus have been formed, and perceptual activity is at a minimum.

In Bruner's theory the child would not be able to symbolise the transformation and would thus be the victim of distorting perceptual elements. Wohlwill would see the child in step 1 as beset by redundant and unselected stimuli which would destroy his conceptual/intellectual approach to the problem. Critical to the present study is the proposal of minimal perceptual activity, and centration on the perceptually distorted element. On the basis of this formulation the following postulate is proposed.

Postulate 1

In the first step toward the conservation of length, area and substance:

(a) The perceptual activity of the subject, as reflected by shifts between all the elements of the stimulus field, will be at a minimum;

(b) Centration, as reflected by points of fixation, will be at a maximum on the stimulus element reported by the subject to be longer, greater in area, or more in substance.

Piaget suggests that the second step in the developmental sequence arises out of the subject's dissatisfaction with his original responses, whether they be overtly or covertly expressed. For example, a child engaged in the conservation of substance task may first report that the sausage-shaped plasticine is more, and then change his response to the other stimulus--the ball-shaped plasticine. Often this change is accompanied by verbalization (Piaget, 1950; Piaget and Inhelder, 1941) and marked hesitation and conflict. It is supposed likely to include an increasing tendency to shift attention or decentrate from one point of fixation to another, and to couple the stimulus elements through shifts of fixation between the transformed and non-transformed elements.

Bruner might explain such a step as a partial transition from the iconic level to the symbolic level, and the child's increasing verbalization of the problem at this point seems to offer some support for such a view. Wohlwill's theory is consistent with such a second step occurring as part of a continuum from perceptual distortion to intellectual certainty. The child in the second step would not have sufficiently overcome the redundancy of the stimulus field, nor would he have been able to make an accurate selection of invariant properties. His conflict, however, would be indicative of a growing strength of conception over perception.

Postulate 2

Children in step 2 will provide non-conservation answers characterized by conflict between the two elements of the stimulus. Evidence of dissatisfaction with the primary response will be present and a secondary response will occur. Their perceptual activity will be marked by greater diversity of fixation points and by an increased number of couplings between the stimulus elements. There will remain, however, more fixations upon the secondary response stimulus, i.e. the one chosen after evidence of conflict. The perceptual activity will be reflected in EMPs and numbers of fixations and couplings.

The child in step 3 possesses full conservation. Decentration is supposed to be complete and no part of the stimulus element should be fixated more than the other. Decision making will be on the basis of operational schemata whose logical multiplication properties (according to Piaget) overweigh the distorting effects of the perceptual field. In Bruner's system, the symbolic mode would be of sufficient strength and development to supplant the enactive and iconic modes, thus producing a conservation response. Wohlwill would suggest that specificity had been obtained and that the point on the continuum between perception and concention in which the certainty of a conceptualized answer was present had been reached. The child in step 3 is identifiable on the basis of his conservation response backed by a logico-spatial-justification of the response. Accordingly, postulate 3 is proposed thus.

Postulate 3

Children possessing conservation, as determined by the presentation of a logical justification of a conservation response, will demonstrate EMPs characterized by maximum decentration, maximum couplings and minimum search for perceptual clues. A sharp decrease in total number of fixations will also occur.

Definitions

Since the EMPS, upon which the subsequent hypotheses are formed, are regarded as consisting of duration, number, position and continuity of fixation points on one or the other element in the stimulus display, several dependent variables were nominated and are defined below.

Total exposure time: The period of elapsed time, measured in one-tenth seconds from completion of stimulus transformation to solution decision (eye closure) by the subject.

Scoreable frames: Sixteen mm movie frames, photographed at the rate of 10 per second, which contain no blurred, vanished or undefineable corneal reflections[2].

First twenty scoreable frames: The first 20 scoreable 16 mm one-tenth second movie frames from transformation of the stimulus.

Fixation: One or more successive corneal reflections, recorded at the rate of 10 frames per second, within the same circular area subtended by 15 minutes of arc in the stimulus field. Specifically, the point on which a subject concentrates his gaze for a period of one-tenth second while EMs are being recorded.

Run: Two or more one-tenth second fixations exclusively on one or the other stimulus elements.

Mean length of run: The ratio of the summated number of one-tenth second fixation points in all runs to the summated number of runs made.

Coupling: Shifts of fixation point from one stimulus element to the other.

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[2] Corneal reflections may be blurred as a result of very rapid movement, or, in the case of eye blink, vanish completely from a movie frame.

Coupling per unit of exposure time: The ratio of the summated number of shifts to the summated number of scoreable frames from transformation of the stimuli to decision.

Plot: The positions of continuous series of fixation points plotted as an overlay on the stimulus elements as a representation of specific EMPs.

Element: The transformed or non-transformed parts of the total stimulus after manipulation.

Hypotheses

Hypothesis 1: Girls in step 1 will:

(a) Demonstrate more fixations during total exposure time and first 20 scoreable frames on the stimulus element they select as the greater after transformation;

(b) Demonstrate a greater mean length of run, in total exposure time and first 20 scoreable frames, on the stimulus element they choose as greater after transformation;

(c) Demonstrate fewer couplings per unit of total exposure time and in the first 20 scoreable frames than girls in step 2 or step 3;

(d) Demonstrate a greater mean length of run in total exposure time than girls in step 2.

Hypothesis 2: Girls in step 2 will:

(a) Demonstrate more fixations during total exposure time on the stimulus element chosen after evidence of conflict, i.e. on the final non-conservation response;

(b) Demonstrate a similar number of fixations on the two stimulus elements during the first 20 scoreable frames;

(c) Demonstrate a greater mean length of run, over total exposure time, on the stimulus element finally chosen as greater after transformation;

(d) Demonstrate a similar mean length of run on both stimulus elements in the first 20 scoreable frames;

(e) Demonstrate a greater mean length of run in total exposure time than girls in step 3.

Hypothesis 3: Girls in step 3 will:

(a) Demonstrate a similar number of fixations on both stimulus elements over total exposure time and first 20 scoreable frames;

(b) Demonstrate a similar mean length of run on both stimulus elements over total exposure time and first 20 scoreable frames;

(c) Demonstrate more couplings per unit of exposure time over the total exposure time and first 20 scoreable frames than girls in steps 1 and 2.

(d) Reach solution with fewer fixations over total exposure time than girls in steps 1 and 2.

Hypothesis 4: Plots drawn from EM records of subjects selected as representative of each step will reflect increasing decentration as the subject proceeds from non-conservation to conservation. Such decentration will be represented by EMPs exhibiting decreasing concentrations of fixation points on stimulus elements and increasing coupling of the elements.

CHAPTER 4

Apparatus, Stimuli and Pilot Studies

Apparatus

The Eye-Movement Recorder

In the present study a Polymetrics Products Eye-Movement Recorder (Model V-1164-1), employing the principle of corneal reflection, was used to obtain permanent photographic records of EMPs. Full technical data on the apparatus may be obtained from the designer's article (Mackworth, 1967) or from the manufacturer[3].

In brief, however, the Eye-Movement Recorder records EMPs by means of a Pathé "Professional" 16 mm reflex movie camera on film at a constant exposure rate of 10 frames per second. Foot and hand controls permitted the simultaneous recording of EMs in conjunction with the presentation of stimulus material. The stimuli appear approximately 26.5 inches (variations occur due to different subject skull formation) from the subject's eyes within a useable viewing area of 7.8 inches by 7.8 inches. Recording accuracy is within plus or minus one degree when subjects view a 20 degrees wide and 20 degrees high display. Thus, eye-spot accuracy can be ascertained within an area about the size of a Canadian 25¢ piece.

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[3]Polymetric Company, 1415 Park Avenue, Hoboken, New Jersey, U.S.A. 07030.

In operation the recorder is mounted on a wishbone-shaped base plate supported by a heavy bench. The base plate also houses an adjustable headrest and bite-bar. The subject, seated on an adjustable chair, views the stimulus display with both eyes while biting on a dental impression made from Kerr Impression Compound. Foam rubber supports were used to make the apparatus and chair more comfortable for young children. A metal tube was also added to the focussing device in order to speed the location of the corneal reflection spot. Figure 1 is a photograph of an actual subject taken after completion of the experimental procedure. Figure 2 presents a view of the subject undergoing testing, the experimenters and apparatus.

Additional Experimental Apparatus

(a) Movie Projector. A Bell and Howell Autoload 16 mm movie projector equipped with heat shield and stop action was used to present the stimulus material. This projector, shown in Figure 2, was positioned on a box so that the projected area was perpendicular to the line of vision. The projector was focussed on the ground glass screen at the rear of the EM recorder and was operated concomitantly with taped instructions. Projection distance and light intensity were constant for all subjects. The stimulus material was projected so that the total possible viewing area on the ground glass screen was used.

(b) Tape recorders, head phones and microphones. Two Sony tape recorders were used. One recorder supplied verbal

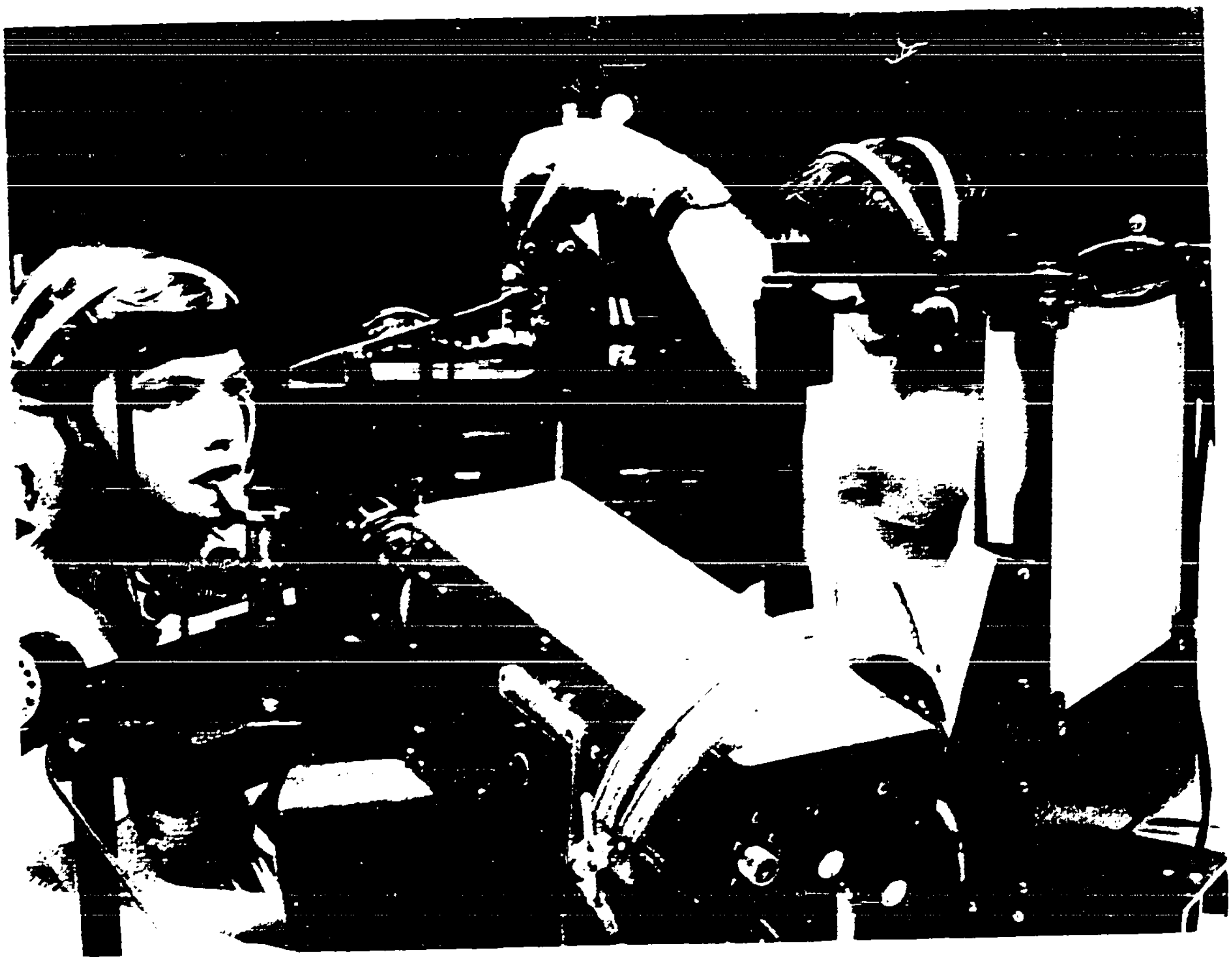

Fig. 1. Subject undergoing eye movement recording.

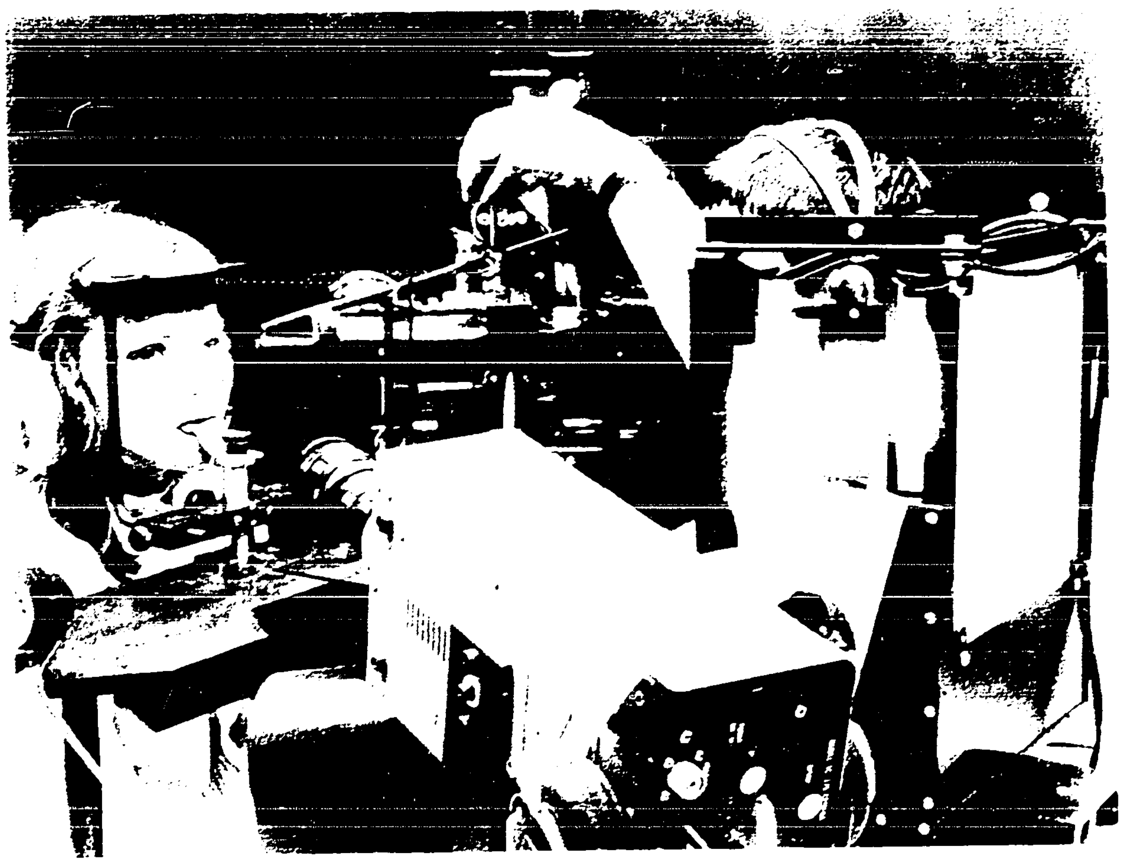

Fig. 1. Subject undergoing eye movement recording.

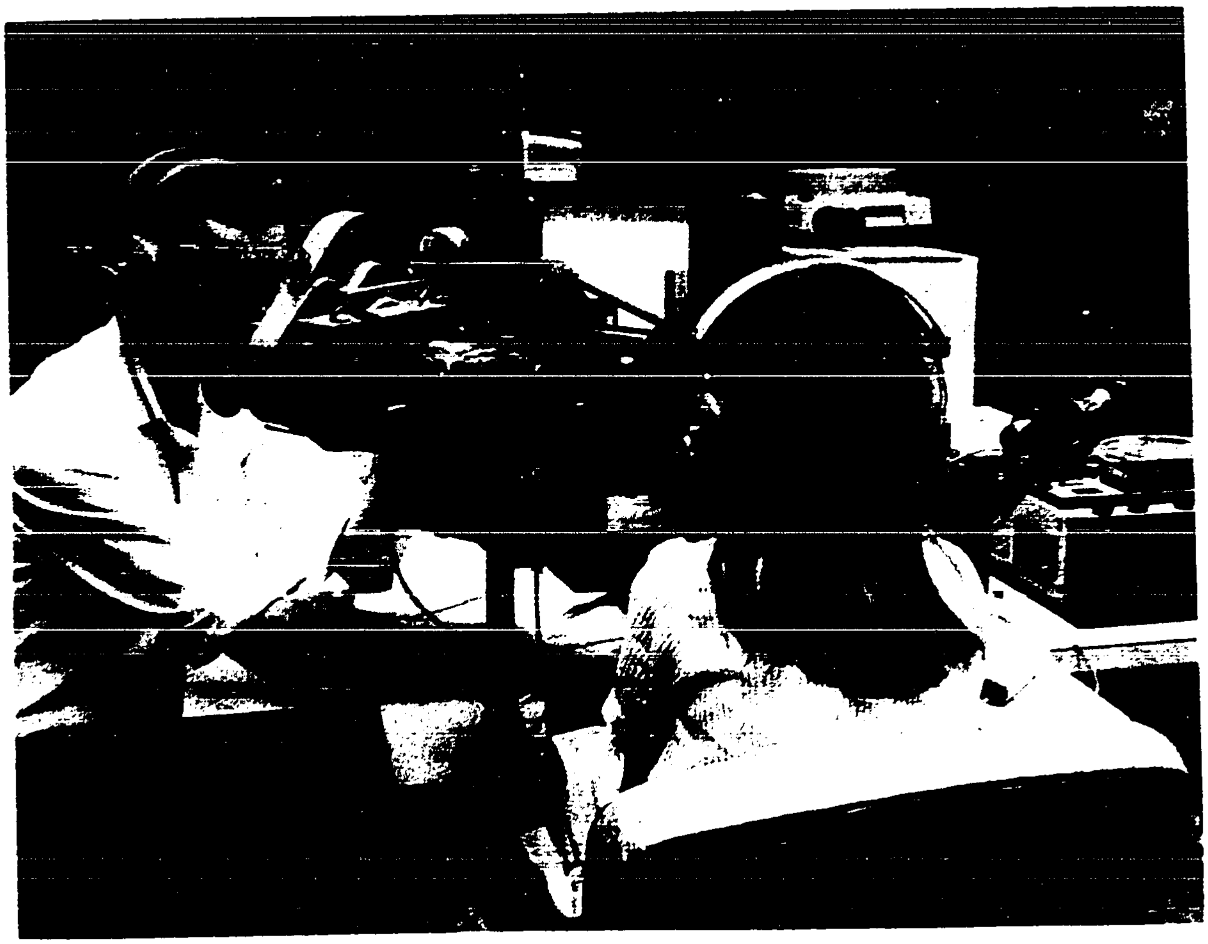

Fig. 2. Subject, experimenters and apparatus during EM recording.

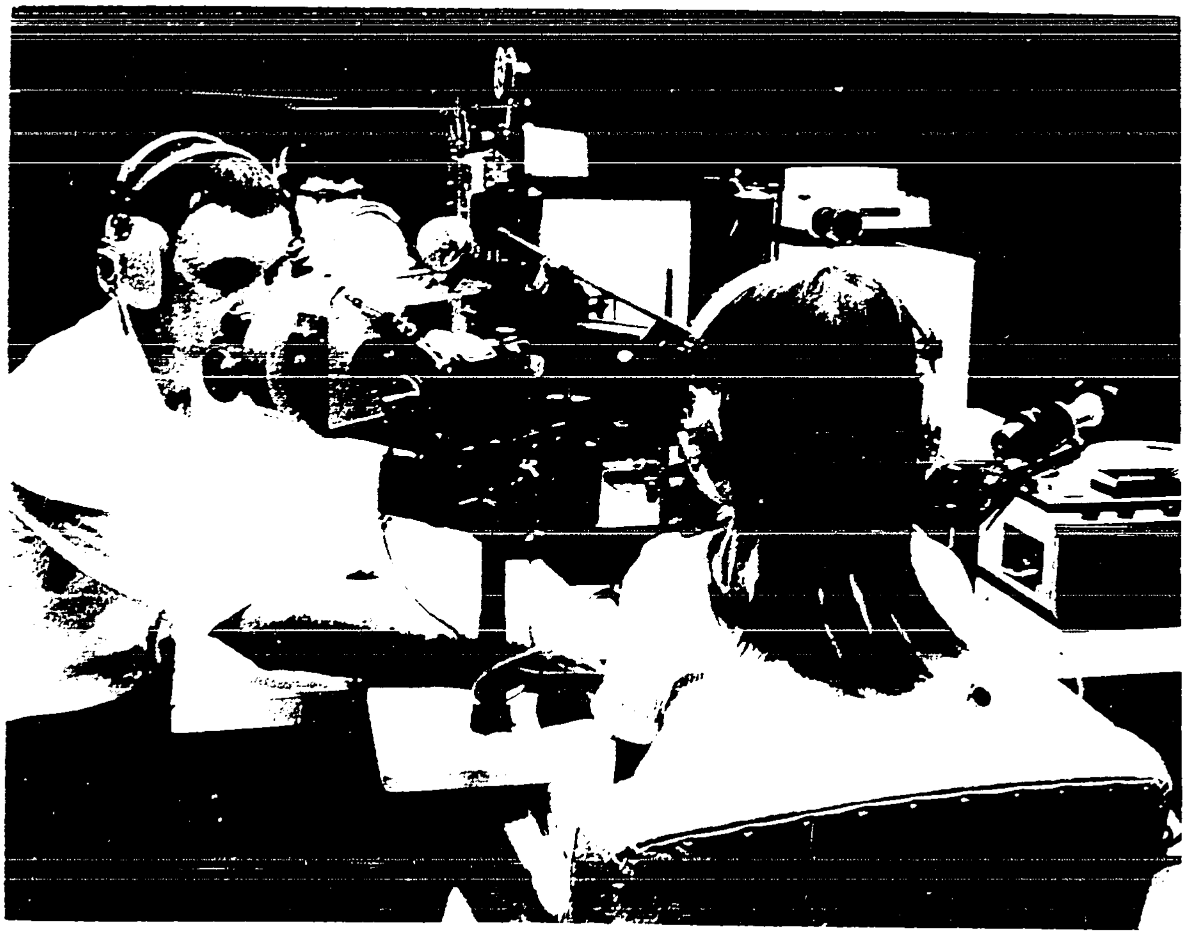

Fig. 2. Subject, experimenters and apparatus during EM recording.

instructions to the subject via dual earphones. The instructions from this recording were monitored through monaural headsets by the experimenter and his assistant while the data were being collected. A microphone link-up enabled communication between both experimenters and subject without removal of the headsets. The second tape recorder was used to monitor the subjects' verbal responses to the stimuli and thus provide a record for subsequent additional analysis of responses.

(c) Dental Equipment. Dental compound for the preparation of bite-bars was maintained at a suitable temperature by a compound heater and all bite-bars were prepared prior to an experimental session. Bite-bars were subsequently sterilized by a pressure autoclave prior to reuse.

Laboratory

All experimentation was conducted in a specially constructed sound attenuated EM laboratory in which illumination control and equipment preparation facilities were provided. This allowed good control over the experimental conditions while testing was in progress.

Analysis Equipment

Eye-movement recordings were analyzed by viewing the 16 mm film through a micro-film reader allowing a three frame exposure. The records so obtained by agreement between two scorers were later spot checked by an independent examiner on a Kodak Analyst projector providing stop action and single frame projection. Of 100 such checks of fixation position, 98 per cent agreement was found with the records of the two scorers.

Pilot Studies

A Polaroid camera was used to record eye fixations in one of the pilot studies aimed at providing an empirical basis for the present investigation. This camera provides an almost instantaneous record of the EMs and allows the experimenter to adjust his apparatus and technique accordingly. It was not used in the actual investigation, however, because it has limited capacity to record minute variation in movement and requires the interruption of the experimental procedure for resetting, developing, etc.

Preparation of Stimuli

The Tasks

The study is based on four Piagetian tasks designed to test for the presence or absence of conservation. A full discussion of them may be found in Piaget's writings (1950, 1957, 1964) or those of his collaborators (Piaget & Inhelder, 1956) and each of them has been subsequently used by other experimenters. Tasks and instructions used in the present investigation are described in detail in Appendix 1. Their basic forms, however, are as follows.

Conservation of length involves presenting to the child two exactly equivalent horizontal strips of black paper, each 30 cms. long by 1 cm. wide. Care is taken to make sure that the child perceives that the two strips are exactly equivalent in length. One of the strips is then moved to an oblique position, in the present study to a 45° angle. Now she is questioned regarding the comparative length of the strips after transformation of position. Typical responses are described by Piaget, Inhelder and Szeminska (1960, p. 105) and on the basis of these responses the child is classified as a non-conserver at a particular step of development, or, if she conserves length and logically justifies her answer, a conserver. Several variations of this length test have been used (Lovell, Healey and Rowland, 1962; Vernon, 1965) and Piaget's interpretation of the results has been supported.

The second task used in this study is that of conservation of area. Here two "plots", represented by similar-intensity black cardboard 10 cm. X 5 cm. rectangles are presented to the subject. Care is taken to make sure that the child perceives them as being equal in size and "amount of black" (or "amount of grass") depending upon the examiner's assessment of the age and language/concept development of his subject[4]. The transformation of one of the shapes into an L shaped plot is accomplished by cutting one of the rectangles in half and rearranging it to form an L (Piaget, <u>et al</u>., 1960). The subject is then classified, according to her response to the

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[4] In the present study "amount of black" was found to provide a good overall reference concept since "amount of grass" was somewhat equivocal, the subjects inquiring whether the grass was long or short! Further, the word "area" proved to be a rather abstract term for many of the children below the age of nine.

transformed shape of the stimulus, as either non-conserver or conserver. Similar studies in area conservation have been carried out by Lovell et al., (1962) and Vernon (1965).

Conservation of substance (continuous quantity) in a solid is one of the best known Piagetian conservation tasks; a method of testing for its presence is described by Piaget and Inhelder (1941). Here the child is presented with two identical balls of plasticine and is assured of their equality. One of the balls is rolled into a sausage and the child is required to conserve the amount of plasticine in face of figural transformation. Many researchers have used this test for both identification (Elkind, 1961; Vernon, 1965; O'Bryan and MacArthur, 1967, 1968) and training purposes (Smedslund, 1961). It seems likely that the transformation produces a strong perceptual distortion in favor of greater quantity in the sausage.

The fourth task used in the present study deals with conservation of substance in a liquid. Here the child is shown two beakers, each equivalent in size and each containing the same amount of water. The water's shape is then transformed by pouring it into a flat container of greater diameter and the child asked to conserve its quantity. The original task is described by Piaget and Inhelder (1941) and various forms of it have been since used by researchers including Vernon (1965), Lefrancois (1968) and Towler (1967).

In the present study, EMs of children engaged in the tasks form the basic variables to be considered. Consequently, some modification was necessary so that EM recordings could be obtained. The rationale underlying the modifications, the modifications themselves, and pilot studies relating to them are discussed next.

Modification of Piagetian Tasks

The presentation by others of Piaget's conservation tasks has often varied widely in technique and experimental control (Peel, 1960). The result of such variation has been seen to lead to equivocal findings (Gruen, 1966). Nevertheless, if Piaget's view of the advent of conservation is adequate, methods which closely approximate his own should provide similar results. In view of the special difficulties associated with EM recording, certain variations in the standard Piagetian procedure were necessary, and in this instance, a study by Singh (1968) is relevant. His research found that film administered tasks produced the same results as experimenter presented tasks.

Singh's findings indicated that a movie presentation of Piagetian stimuli was feasible. Accordingly it was decided to make a 16 mm movie of the tasks to be used in the study and tape record verbal instructions. Such a procedure had two advantages. It provided a presentation (stimulus material) suitable for projection onto the ground glass viewing screen of the EM recorder, thus eliminating unwieldy manipulations of stimulus material for each subject; and it utilized a consistent procedure for all subjects.

Thus, such a movie was produced and edited. Five versions were made and exhibited to researchers who had worked with Piagetian concepts. On the basis of their recommendations, and the findings of the pilot studies reported below, several copies of a final version were produced and synchronized with tape recorded verbal instructions. Three deviations from the Piagetian presentation took place. The children could not touch the actual materials; the initial equality response had to be ascertained by an eye closure (subjects had to remain on the bite-bar in order to maintain calibration); and a movie presentation was used with taped verbal instructions. To counteract possible confounding factors in this procedure, especially with respect to judging equality of initial response, a training technique was devised and tested. This technique will be described in Chapter 5.

In order to determine whether the tasks on film were demonstrably different from the experimenter administered tasks, two pilot studies were performed.

Pilot Studies[5]

Pilot Study 1

Forty Grade 1 children were divided randomly into two groups of 20 each and tested in a private room at an Edmonton elementary school for conservation of length, area and substance. On the basis of their responses to clinical type Piagetian questions, members of each group were classified as non-conservers or conservers in each of the conservation tasks. Responses were

[5] Raw data and subsequent analyses are described in Appendix II.

recorded and were later analyzed to provide a check on the original classification and also to allow comparison with responses in a later retest. A Chi-square test for independent samples revealed no significant differences between the groups although conservation of substance (solid) did reach a higher chi square value. Two weeks after the initial testing, one group (Group A) was transported to the University EM laboratory and retested. The test on this occasion utilized the movie and tape-recorded presentation while the subject was seated at the eye camera undergoing EM recording. The second group (Group B) was retested using the same materials and presentation as those employed previously. Again, although some variation in responses was noted, a Chi-square test revealed no significant differences between the groups. Those changes in conservation level which did take place probably arose out of having learning effects and natural development of the concept. From this experiment, and the results obtained by Singh (1968), it was concluded that a movie presentation would not destroy the essential qualities of the Piagetian tests for conservation.

Pilot Study 2

The second pilot study is perhaps misnamed since it took place *subsequently* to the data collection in the investigation proper; but it is included in this section since its results are relevant to the question of acceptability of the movie presentation of Piagetian tasks.

In order to control for presentation order effects 40 subjects were selected from the sample after they had been through the experimental procedure proper. They were then randomly assigned to two groups and retested. Group A was retested on the movie presentation (but not in the laboratory) while Group B was retested under the normal clinical conditions. Once again, no significant differences were found between the groups, although conservation of substance (solid) approached significance with the film presentation accounting for a higher number of conservers. In this instance the lack of three dimensionality in the movie may be a factor. Nevertheless, it was decided that the results supported a decision that the tasks did not deviate markedly from the Piagetian concept. It is interesting to note also that over all retests and equivalent forms tests the percentage of agreement averaged above 85. Phi coefficients ranged from .52 to .90. All testing in both studies was carried out by the same examiners.

Preliminary Eye-Movement Studies

Prior to any formalized pilot work, considerable research on the feasibility of EM recording with small children (5 years and older) had been carried out. As a result, certain modifications had been made to the EM recorder and an "acclimatization" procedure devised. It was found that a highly relaxed, informal approach worked well to counteract the anxiety experienced by children introduced into the laboratory for the first time. Laboratory coats were dispensed with when it was noted that the subjects regarded the investigators as potential dentists. Further, it was found that the children responded well to direct statements about the pieces of equipment, rather than to cover stories such as "space exploration". Introduction of the compound covered bite-bar was best achieved by an actual demonstration of its use by an investigator and subsequent candy rewards to "take away the 'icky' taste". Only one refusal in over 100 cases testifies to the readiness of the subjects to accept the bite-bar.

Also, in the course of the preliminary research, it was noted that stimulus cards with inbuilt intrinsic interest facilitated calibration of the instrument and minimized subject fatigue. Colored circles of diminishing size and "target areas" proved effective in this regard. A description of the target and calibration technique is included in Appendix III.

It should be stressed at this point that the establishment of a non-threatening, natural and enjoyable atmosphere is critical to EM experimentation with young children. Hence the training procedures described in the next chapter were designed from the preliminary research with a fun, game-like basis. Additionally, it was found that instant playback of a child's answer to questions regarding his name, age, school etc. was most effective in providing an acceptance of the technical equipment in the laboratory.

During all the preparatory work, polaroid EM recordings were made and analyzed. Although statistical analysis at this stage was not possible owing to the uncontrolled nature of the recordings, some indications were present that differences existed between the EMPs of non-conservers and conservers.

While the "movie-proving" pilot studies were progressing, EM movie recordings were made. Many of the early recordings were not of good quality owing to technical difficulties arising out of experimentation in recording procedures. Consequently they were not analyzed rigorously. Nevertheless, they also provided strong indications that there were recordable differences in several aspects of EMs. Further, their collection provided the investigator with valuable experience in operational techniques.

On the basis of the pilot studies it was concluded that the movie presentation of the stimuli and subsequent EM recording was feasible for children over the age of 5 years 6 months. Although recordings could be obtained for younger children, it was felt that the potential refusal level and experimental time would increase, and that the EMPs would be less reliable. Thus, it was decided to employ the experimental procedure described in the next chapter.

CHAPTER 5

Experimental Procedure

The Sample

The population of girls in the first three grades of an Edmonton elementary school was tested. Initially, there were 101 subjects. Five of the girls were from non-white racial origins and, though tested on all tasks, they were excluded from the study. One subject refused to undergo the procedure and two others produced unrecordable EMs, one because of intense watering of the eye resulting in diffusion of the corneal reflection--the other because of gagging on the bite-bar. No subjects were excluded through defective vision although seven wore glasses. All glasses were removed prior to experimentation. Tests made and verbal reports from the subjects indicated no difficulty in viewing the stimuli. Health reports on the school's cumulative records were also checked and, again, no serious defects requiring the subject's exclusion were found. One subject's EM recordings were confounded by technical difficulties and were discarded.

Table 1 presents sample characteristics for the Lorge-Thorndike Intelligence Test, the Blishen Canadian Occupational Scale (1958), and ages in months. Both intelligence and occupational status measures indicate that the sample was perhaps slightly lower than might have been expected for Edmonton. But in any case, the sample was representative of norms associated with the instruments.

TABLE 1

Sample Characteristics of Lorge-Thorndike Intelligence Measures, Blishen Canadian Occupational Scale Ratings, and Ages

Variables	Mean	S.D.	Range
Lorge-Thorndike	102.00	11.4	77-132
Blishen Scale	50.00	11.50	30- 78
Age (months)	94	11.4	75-122

Procedure

Transportation and Pre-Training

The subjects were transported to the University of Alberta laboratory by taxi in groups of 5 per day. On arrival they were met by a playroom attendant who conducted them to the Education Clinic playroom. There they were given toys, drawing materials etc. and, under supervision, were allowed to play. Prior to the commencement of such play, however, the group of children was instructed in a new game--that of closing the eyes on discovery of an answer to questions related to establishing the presence of concepts of length, area and quantity (solid and liquid). The following standard procedure was used.

The playroom attendant prodeced two strips of cardboard and asked whether one was longer, shorter or the same length as the other. No answer was accepted until all subjects closed their eyes. The game was repeated until perfected by the whole group. Next, two large pieces of black cardboard, equal in area were produced and related questions were asked with the same results required. This procedure was then repeated for balls of plasticine and glasses of water. Thus, the children were initially trained to close their eyes upon knowledge of an answer.

Laboratory Training Period

After pre-training in the playroom the children were introduced individually to the laboratory where the purposes of the various pieces of equipment were explained to them. Considerable effort was expended at this stage to ensure that the subject was not frightened by the array of instruments. She was permitted to investigate the equipment and encouraged to ask questions about it. Once comfortable in the room, the subject was asked to remember the game she played earlier and to try it again. The following procedure was used.

The examiner asked the subject to look at the items he held (which were, in order of presentation, two unequal lengths of cardboard, two equal lengths of cardboard, two equal areas of black cardboard, two unequal areas of black cardboard, two equal balls of plasticine, two unequal amounts of plasticine and two unequal amounts of water). First, the subject was then asked to say whether the two lengths were the same and to close her eyes immediately upon "knowing" the answer. A similar procedure was used for all the items listed above and repeated until the examiner was confident that the children were able to understand the concepts of length, area and quantity, and to respond with an eye closure. At no stage was any transformation of the materials made. All subjects had to pass the initial playroom and laboratory training periods before the experimental session proper began.

Introduction to Apparatus

After completion of the laboratory training the subject was asked to sit at the EM recorder and make an impression on dental compound covering a child-size bite-bar. This rather delicate operation was accomplished by the investigator's demonstration of the technique on a detached bite-bar and encouraging the subject to follow suit on the bar attached to the camera base. Each bite-bar was individually adjusted so that a comfortable and firm impression could be made. Once an adequate impression was made the subject was presented a movie to view on the ground glass screen and instructed to listen to directions through a headset. The bite-bar set hard during this period. Little difficulty was experienced in obtaining subject cooperation.

Movie Training Period

Once comfortably seated, the subject then received additional instructions through her headset that the game she had learned was now on a movie and she was going to play it "just like before." Synchronization of movie and recorded directions was performed by the investigator's assistant.

During the training procedure the subject was shown, on movie film, a series of five stimulus figures each containing two elements. These were, in order of presentation, two unequal lengths of cardboard; two equal lengths of cardboard; two equal areas of black cardboard; two unequal areas of black cardboard and two unequal piles of clay. The sequence number and content of the movie pretraining were selected to provide training in eye closure and prevent the development of a set to regard a stimulus presentation as necessarily equal or unequal on the basis of its order of presentation or the position of its elements. Further, the number of stimuli presented varied from the number used in the playroom, the laboratory pre-training and the actual experiment in order to avoid unwanted patterning and fatigue effects. A direct attempt was made to avoid any development of a belief on the part of the subject that a particular property of the stimulus element (eg. blackness, width, shape) necessarily indicated equality.

In each case of the movie pretraining the subject was asked to judge the equality of the top and bottom elements of the stimulus figure. Upon knowing her answer she was instructed to close her eyes, thus indicating to the experimenter the point of decision. Each subject was required to successfully perform all aspects of the movie pretraining prior to undergoing EM recording.

Calibration of the Eye Movement Recorder

The subject was instructed to bite on the dental impression and look steadily at an initial target card inserted in front of the stimulus viewing screen. After location of the corneal reflection on the visual screen the subject was rested and then quickly checked for recall of the "game's rules." She was then asked to fixate upon the center of a calibration card and each of its corners while fine calibration adjustments were made. At this point the recording camera was operated and the movie presentation of the conservation tasks commenced. The subject did not leave the bite-bar until completion of each segment of the movie, then her consequent decision on the conservation question was discussed.

In order to avoid differential cueing and possible learning effects all subjects received the same stimuli and taped instructions in the same order. Girls who indicated undue discomfort or inability to see or comprehend the nature of the task were excluded from the study. This necessitated, as mentioned in the sample section, the removal of three subjects from the sample.

Any bias brought about by handedness toward one or the other stimuli after transformation was controlled for by placing the elements one above the other and in subsequent questioning referring to them as either the top or the bottom. In addition, element transformation was done randomly in order to avoid any top or bottom position preference, while in one task, conservation of substance (liquid), both elements were transformed. Eye movement recordings were made from point of transformation completion to eye closure.

After the presentation of each task and completion of the subject's decision making, the subject was told to open her eyes and leave the bite-bar. Subsequently she was asked to report her answer. The stimuli were not present during the report period.

All instructions used were those suggested by Piaget in his experiments involving these tasks, with the exception that the subject was required to close her eyes to indicate that she recognized the initial equivalence of the pre-transformed elements. No doubt was raised by any subject on this point, either during the initial presentation or subsequent questioning.

Assessment of Conservation Status

The child's initial answer to the conservation question was recorded by the experimenters on checklists and by a tape recorder. The subject was then questioned, according to Piaget's reported clinical technique, for the reasons behind her response. She was classified independently by both experimenters as a non-conserver (of step 1 or step 2) or conserver, and returned to the playroom under instructions to tell no one about the laboratory and the game she played. The playroom attendant ensured that these instructions were followed.

The initial classifications made by the experimenters (both of whom had experience with Piagetian investigation) were later discussed in the light of the taped responses. Five doubtful classifications were agreed upon in the subsequent discussion. In general, subjects appeared in the same classification in each task. However, there was some indication of the presence of the phenomenon of horizontal decalage, hence numbers in groups varied slightly from task to task.

CHAPTER 6

Results

Classification of subjects into two non-conserver groups and one conserver group was made prior to the scoring of the EM records. Table 2 illustrates the composition of each of these groups for the four tasks.

Before statistical treatment of the data each non-conserver's choice of the greater element was noted. Numbers of fixation points and length of run on the elements chosen as greater or lesser were calculated according to the definition of these variables in Chapter 3. Since the conservers made no choice of element the scores on these variables for each subject were calculated on the transformed and non-transformed elements in length, area and continuous quantity-solid. Scores on the variables for continuous quantity-liquid were calculated for first-transformed and second-transformed. Had scores been calculated for top versus bottom elements results would have been the same in terms of number of fixations and runs on stimulus elements, although direction of any differences may have varied. Use of transformed and non-transformed was decided upon only because it was felt that these were more meaningful terms than top stimulus element versus bottom stimulus element.

Within Group Hypotheses

The following hypotheses were tested by t-tests (one-tailed) on correlated samples (Ferguson, 1959, p. 138).

1. (a) Girls in step 1 (NC1) will demonstrate more fixations during total exposure time and first 20 scoreable frames on the stimulus element they select as greater (GE) after transformation.

   (b) Girls in NC1 will demonstrate a greater mean length of run in total exposure time and first 20 scoreable frames on the stimulus element they choose as greater after transformation

2. (a) Girls in step 2 (NC2) will demonstrate more fixations during total exposure time on the stimulus element chosen, after evidence of conflict, as greater after transformation.

   (c) Girls in NC2 will demonstrate a greater mean length of run over total exposure time on the element chosen as greater after transformation.

Correlated t-tests (two-tailed) (Ferguson, 1959, p. 138) were used to test the following hypotheses.

2. (b) Girls in NC2 will demonstrate a similar number of fixations on the two stimulus elements during the first 20 scoreable frames.

   (d) Girls in NC2 will demonstrate a similar mean length of run on both stimulus elements in the first 20 scoreable frames.

3. (a) Girls in step 3 (CONS) will demonstrate a similar number of fixations on both stimulus elements over total exposure time and first 20 scoreable frames.

   (b) Girls in CONS will demonstrate a similar mean length of run on both stimulus elements over total exposure time and first 20 scoreable frames.

Results of these analyses are presented in tables 3, 4, 5, and 6. In these tables it should be noted that each group's scores are analysed separately and bear no relation to the scores of either of the other groups, nor does the score on any given task affect in any way scores on the other tasks. Further, several abbreviations are used and these are here expanded.

Table 2

Composition and characteristics of the sample groups for four Piagetian tasks

Task	Non-Conservers 1				Non-Conservers 2				Conservers			
	N	$\bar{X}$AGE	$\bar{X}$IQ	$\bar{X}$SES	N	$\bar{X}$AGE	$\bar{X}$IQ	$\bar{X}$SES	N	$\bar{X}$AGE	$\bar{X}$IQ	$\bar{X}$SES
Length	34	94	102	48.0	21	91	103	48.0	37	97	101	50.4
Area	33	91	100	47.5	23	91	107	49.2	36	99	101	50.1
C.Q. Solid	30	90	103	51.2	23	94	101	49.3	39	98	102	50.4
C.Q. Liquid	36	91	101	48.1	18	93	105	50.2	38	98	102	50.9

Table 3

Analysis of fixations on stimulus elements over total exposure time for all groups on each task

	Non-Conservers 1				Non-Conservers 2				Conservers			
Task	GE$\bar{X}$	LE$\bar{X}$	t	p	GE$\bar{X}$	LE$\bar{X}$	t	p	GE$\bar{X}$	NTE$\bar{X}$	t	p
Length	39.6	10.9	8.0	**	35.9	20.0	3.8	**	16.4	13.2	1.6	ns
Area	29.1	19.1	2.9	**	35.1	14.6	5.5	**	12.6	15.1	1.3	ns
C.Q. Solid	35.3	12.5	6.5	**	28.1	22.7	1.2	ns	15.7	13.2	1.1	ns
C.Q. Liquid[a]	38.2	17.1	6.3	**	27.4	19.1	1.7	ns	15.4	18.2	1.8	ns

[a] Both elements transformed

* Significant at .05 level ** Significant at .01 level.

Table 4

Analysis of fixations on stimulus elements during the first 20 scoreable frames from transformation for all groups on each task

Task	Non-Conserver 1				Non-Conserver 2				Conserver			
	GE$\bar{X}$	LE$\bar{X}$	t	p	GE$\bar{X}$	LE$\bar{X}$	t	p	TE$\bar{X}$	NTE$\bar{X}$	t	p
Length	16.3	4.6	7.8	**	14.2	5.8	3.2	**	11.4	8.6	1.3	ns
Area	13.9	6.0	4.1	**	16.0	4.0	6.5	**	10.9	9.1	1.9	ns
C.Q. Solid	14.4	5.6	4.3	**	11.9	8.0	1.6	ns	11.7	8.1	2.1	*
C.Q. Liquid[a]	16.8	3.2	9.1	**	11.8	8.2	0.5	ns	8.6	11.3	-1.4	ns

[a] Both elements transformed; conservers TE$\bar{X}$ is first element transformed NTE$\bar{X}$ is second element transformed

* Significant at .05 level ** Significant at .01 level

Table 5

Analysis of mean length of run on stimulus elements over total exposure time for all groups on each task

	Non-Conservers 1				Non-Conservers 2				Conservers			
Task	$GE\bar{X}$	$LE\bar{X}$	t	p	$GE\bar{X}$	$LE\bar{X}$	t	p	$TE\bar{X}$	$NTE\bar{X}$	t	p
Length	22.1	4.7	5.4	**	16.1	8.1	1.9	*	6.9	5.2	1.5	ns
Area	12.3	9.5	1.3	ns	17.2	5.8	3.3	**	7.5	5.6	1.5	ns
C.Q. Solid	18.3	5.8	5.3	**	12.8	10.0	1.0	ns	7.1	6.5	0.4	ns
C.Q. Liquid[a]	20.7	7.6	2.6	**	12.5	8.4	2.0	**	6.9	8.8	1.0	ns

[a] Both elements transformed

* Significant at .05 level ** Significant at .01 level

Table 6

Analysis of mean length of run on stimulus elements over first 20 scoreable frames for all groups on each task

Task	Non-Conservers 1				Non-Conservers 2				Conservers			
	GE$\bar{X}$	LE$\bar{X}$	t	p	GE$\bar{X}$	LE$\bar{X}$	t	p	TE$\bar{X}$	NTE$\bar{X}$	t	p
Length	14.6	2.7	8.3	**	9.5	7.3	0.4	ns	6.4	4.8	1.4	ns
Area	12.2	4.7	4.1	**	9.0	8.6	0.1	ns	6.7	4.8	1.7	ns
C.Q. Solid	11.3	5.0	3.2	**	10.9	5.0	2.9	**	6.2	5.4	0.8	ns
C.Q. Liquid[a]	15.4	2.8	7.8	**	9.2	6.6	0.6	ns	6.1	7.2	-0.9	ns

[a] Both elements transformed

** Significant at .01 level

C. Q. Solid	Continuous quantity in solids
C. Q. Liquid	Continuous quantity in liquids
GE$\bar{X}$	Mean number of fixations (or mean length of run) on stimulus element chosen as greater.
LE$\bar{X}$	Mean number of fixations (or mean length of run) on stimulus element regarded as the lesser.
TE$\bar{X}$	Mean number of fixations (or mean length of run) on transformed element.
NTE$\bar{X}$	Mean number of fixations (or mean length of run) on stimulus element not transformed.

In the case of continuous quantity in liquids, both elements were transformed and here TE refers to the element first transformed while NTE refers to the element transformed second.

Across Group Hypotheses

Hypotheses comparing group performances on the variables were tested by analysis of covariance (Winer, 1962, p. 592) using age in months as a covariate. Newman-Keuls tests on ordered pairs of adjusted means (Winer, 1962, p. 80) were used in all cases in which a significant adjusted F was found by the analysis of covariance. Hypotheses thus treated were

1. (c) Girls in NC1 will demonstrate fewer couplings per unit total exposure time and in the first 20 scoreable frames than girls in CONS.

   (d) Girls in NC1 will demonstrate a greater mean length of run in total exposure time than girls in NC2.

2. (e) Girls in NC2 will demonstrate a greater mean length of run in total exposure time than girls in CONS.

3. (c) Girls in CONS, will demonstrate more couplings per unit of exposure time and in the first 20 scoreable frames than girls in NC1 and NC2.

   (d) Girls in CONS will reach solution with fewer fixations over total exposure time than girls in NC1 and NC2.

The results of the analyses performed on these hypotheses are presented in Tables 7, 8, 9, 10, 11, 12, 13 and 14.

Neither IQ nor SES proved to be significant in any task on any variable and consequently were not used as covariates in the final analyses.

Because non-conservers, by definition, choose one or the other element as greater or lesser, the distribution of their choices also provides relevant information. As a group, non-conservers were fairly consistent over all tasks in terms of numbers. There was a tendency to find the top element of the display chosen less often than the lower element but transformation of the elements did not seem to cause systematic choice upon the one transformed. Table 15 presents a summary of the choice distribution by non-conservers.

Hypothesis 4 was investigated by the drawing of EM patterns representing the tracks made by subjects as they viewed the stimulus elements. Figures 3(a), 3(b), 4(a) and 4(b) illustrate these tracks. The subjects were selected on the basis of their reflecting apparently "typical" EMPs of the groups in which they were classified. Such a procedure is admittedly open to considerable error and the figures should be viewed as illustrative rather than representative.

In Figures 3(a) and 3(b) one subject is drawn from each group to illustrate EMPs felt to be characteristic of the group. Thus,

Table 7

Summary of analysis of covariance for couplings per unit time over total exposure for all groups on each task

Task	Source	DF	MS	ADJF	p
Length	Group	2	8.93	32.77	.0001
	Within	88	0.27		
Area	Group	2	2.68	10.42	.0001
	Within	88	0.26		
COS	Group	2	4.36	16.49	.0001
	Within	88	0.26		
COL	Group	2	26.62	10.31	.0001
	Within	88	0.26		

Table 8

Summary of tests of significance on ordered pairs of means for couplings per unit time

Task	NC1$\bar{X}$	NC2$\bar{X}$	p	NC1$\bar{X}$	C$\bar{X}$	p	NC2$\bar{X}$	C$\bar{X}$	p
Length	.06	.09	*	.06	.16	**	.09	.16	**
Area	.08	.08	ns	.08	.13	**	.08	.13	**
C.Q. Solid	.07	.08	ns	.07	.13	**	.09	.12	**
C.Q. Liquid	.06	.09	*	.06	.12	**	.09	.12	**

* Significant at .05 level ** Significant at .01 level

Table 9

Summary of analysis of covariance for couplings in the first 20 scoreable frames for all groups on each task

Task	Source	DF	MS	ADJF	p
Length	Group	2	27.6	17.7	.0001
	Within	88	1.6		
Area	Group	2	18.9	11.6	.0001
	Within	88	1.6		
C.Q. Solid	Group	2	14.9	9.4	.0001
	Within	88	1.6		
C.Q. Liquid	Group	2	21.1	15.9	.0001
	Within	88	1.3		

Table 10

Summary of tests of significance on ordered pairs of means for couplings in first 20 scoreable frames on all tasks

Task	NC1$\overline{X}$	NC2$\overline{X}$	p	NC1$\overline{X}$	C$\overline{X}$	p	NC2$\overline{X}$	C$\overline{X}$	p
Length	1.9	2.0	ns	1.9	3.5	**	2.0	3.5	**
Area	2.6	1.9	*	2.6	3.6	**	1.9	3.6	**
C.O. Solid	2.4	2.5	ns	2.4	3.6	**	2.5	3.6	**
C.O. Liquid	1.6	2.4	*	1.6	3.2	**	2.4	3.2	**

Table 11

Summary of analysis of covariance for fixations in total exposure time for all groups over each task

Task	Source	DF	MS	ADJF	p
Length	Group	2	5287.0	17.57	.0001
	Within	88	331.5		
Area	Group	2	5859.3	31.42	.0001
	Within	88	186.5		
C.Q. Solid	Group	2	4214.4	18.90	.0001
	Within	88	223.0		
C.Q. Liquid	Group	2	5094.3	18.42	.001
	Within	88	276.5		

Table 12

Summary of tests of significance on ordered pairs of means of fixations for all tasks

Task	NC1$\overline{X}$	NC2$\overline{X}$	p	NC1$\overline{X}$	C$\overline{X}$	p	NC2$\overline{X}$	C$\overline{X}$	p
Length	53.0	55.5	ns	53.0	31.9	**	55.5	31.9	**
Area	55.4	54.8	ns	55.4	30.5	**	54.8	30.5	**
C.Q. Solid	50.6	52.7	ns	50.6	31.6	**	52.7	31.6	**
C.Q. Liquid	59.5	49.5	**	59.5	34.9	**	49.5	34.9	**

** Significant at .01 level

Table 13

Summary of analysis of covariance for mean length of run for all groups on each task

Task	Source	DF	MS	ADJF	p
Length	Group	2	1013.4	8.3	.0001
	Within	88	122.0		
Area	Group	2	572.8	7.3	.0001
	Within	88	78.8		
C.Q. Solid	Group	2	255.0	2.7	.076
	Within	88	96.0		
C.Q. Liquid	Group	2	598.3	8.9	.0001
	Within	88	668.8		

Table 14

Summary of tests of significance on ordered pairs of means for mean length of run by all groups on each task

Task	NC1$\overline{X}$	NC2$\overline{X}$	p	NC1$\overline{X}$	C$\overline{X}$	p	NC2$\overline{X}$	C$\overline{X}$	p
Length	18.8	11.9	*	18.8	7.9	**	11.9	7.9	ns
Area	14.0	16.5	ns	14.0	7.6	**	16.5	7.6	**
C.Q. Solid[a]	15.0	11.7	ns	15.0	9.5	ns	11.7	9.5	ns
C.Q. Liquid	17.2	11.9	*	17.2	8.8	**	11.9	8.8	ns

* Significant at .05 level ** Significant at .01 level

[a] No significant F in analysis of covariance

Table 15

Summary of choices of top or bottom transformed or non-transformed, stimulus element by Non-conservers over all tasks

Task	Choice				
	Top	Bottom	Transformed	Not Transformed	N
Length	20	35	35	20	55
Area	23	33	23	33	56
C.Q. Solid	26	27	27	26	53
C.Q. Liquid[a]	25	29	29[b]	25[c]	54

[a] Both elements transformed - [b] Tall, thin container - [c] flat, wide container

different subjects represent the group on each task since no one subject possessed group characteristics across all tasks. This within subject variation is illustrated in Figures 4(a) and 4(b) in which EMPs of subjects exhibiting horizontal decalage are presented. Here, the EMPs of two girls are drawn for all tasks. Marked differences appear as the subject proceeds from non-conservation to conservation. Similarities are noted between subjects in the same classification but the patterns are sufficiently different to emphasize the difficulty of selecting representational EMPs.

In all Figures the transformed elements are as follows:

Length	--	bottom element transformed
Area	--	top element transformed
C. Q. Solid	--	bottom element transformed
C. Q. Liquid	--	flat container first, tall container second.

All figures are drawn for a total time to solution base since it was felt that all fixation points to solution should be shown. As a result, the speed to solution of the conserver contrasted with centration on the elements by NC1 subjects and extensive coverage of the stimulus by the NC2 subjects could be illustrated.

Tables 16 and 17 present a summary of the tests on the hypotheses. Since hypothesis 4 was interpretational in the sense that no statistical analyses were applied to it this hypothesis is not included in the tables.

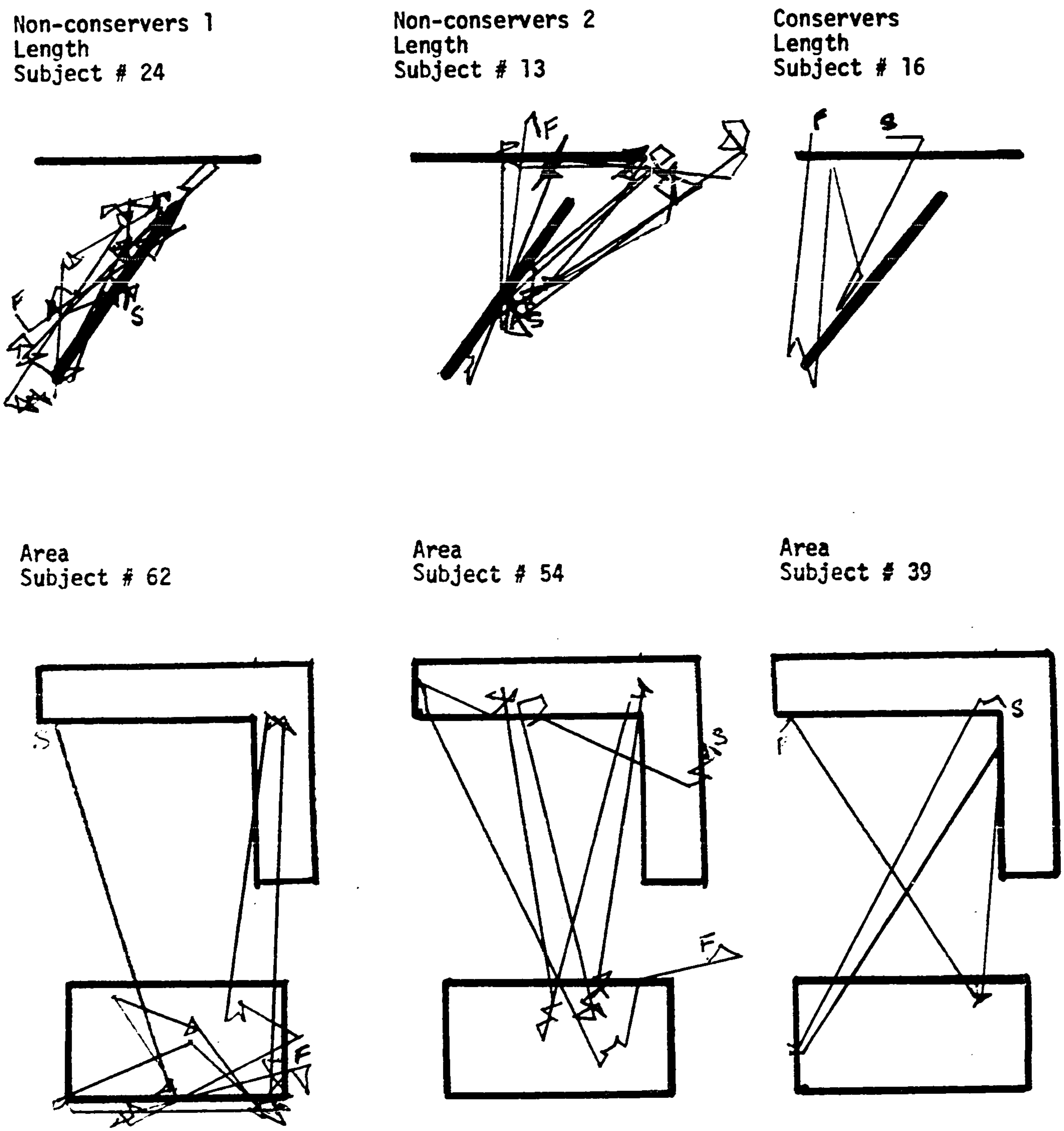
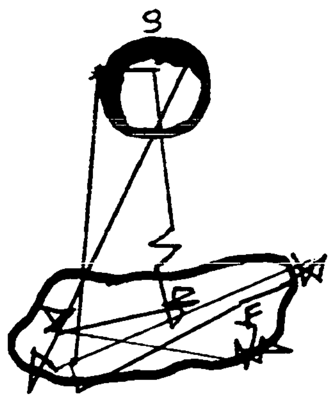


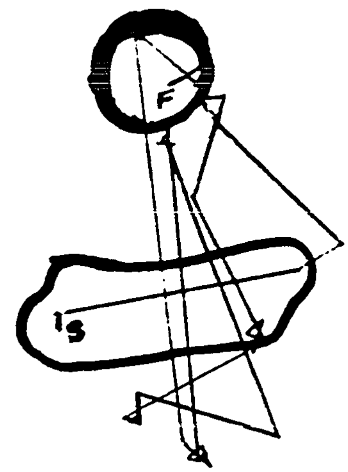
Fig. 3(a) Plots of EMPs of subjects in each group for length and area.

Non-conservers 1
C. Q. Solid
Subject # 48

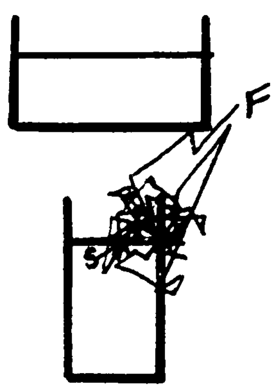


Non-conservers 2
C.Q. Solid
Subject # 50

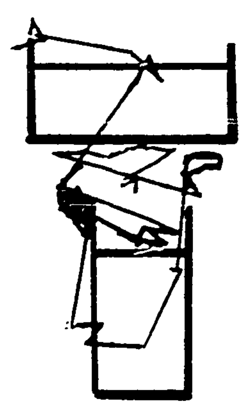
Conservers
C.Q. Solid
Subject # 51



C.Q. Liquid
Subject # 85



C.Q. Liquid
Subject # 6



C.Q. Liquid
Subject # 60

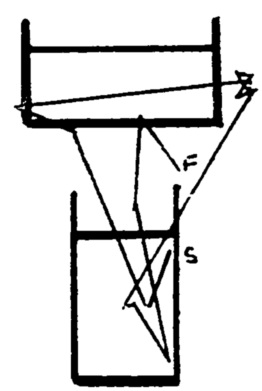
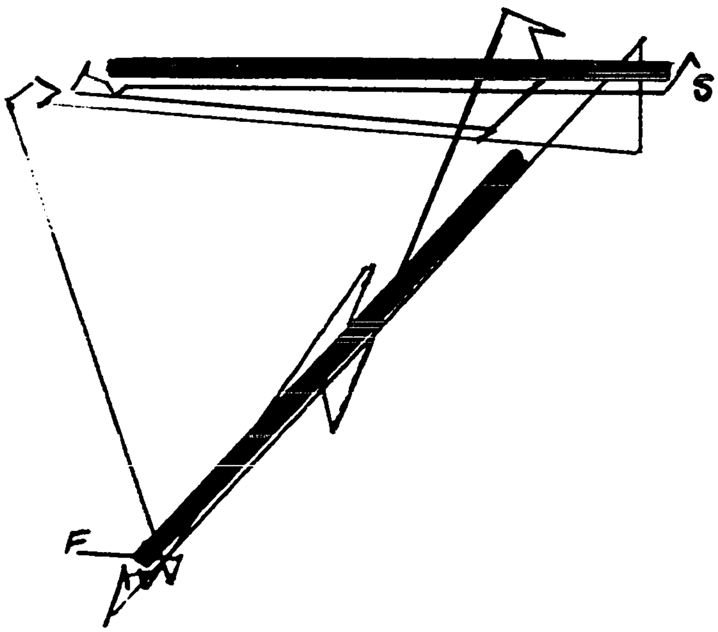
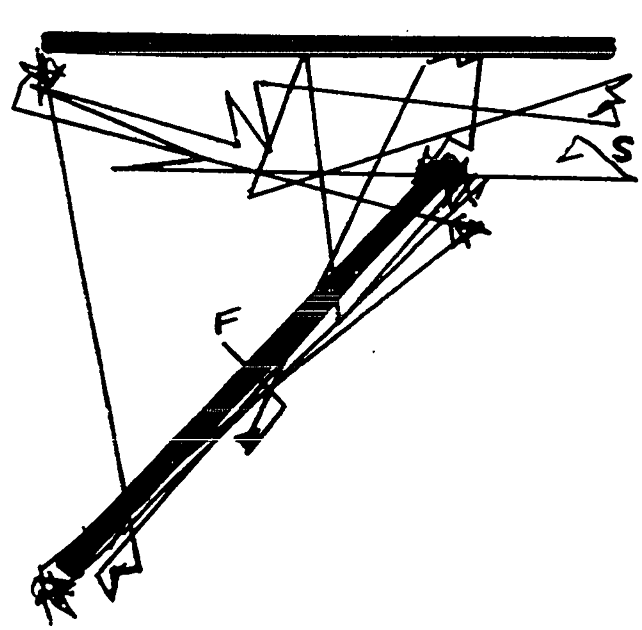


Fig. 3(b) Plots of EMPs of subjects in each group for continuous quantity (Solid and Liquid)

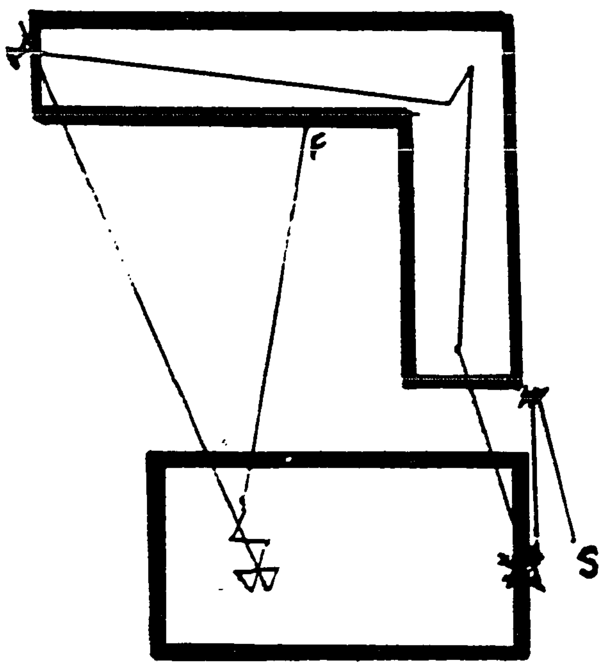
Subject # 41 NC2



Subject # 61 NC2



Subject # 41 NC1



Subject # 61 CONS

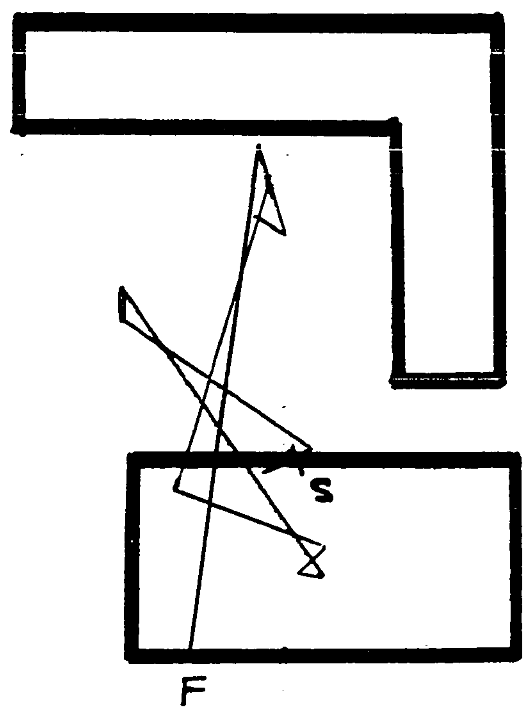


Fig. 4(a) Plots of EMPs of individual subjects exhibiting horizontal decalage (length, area).

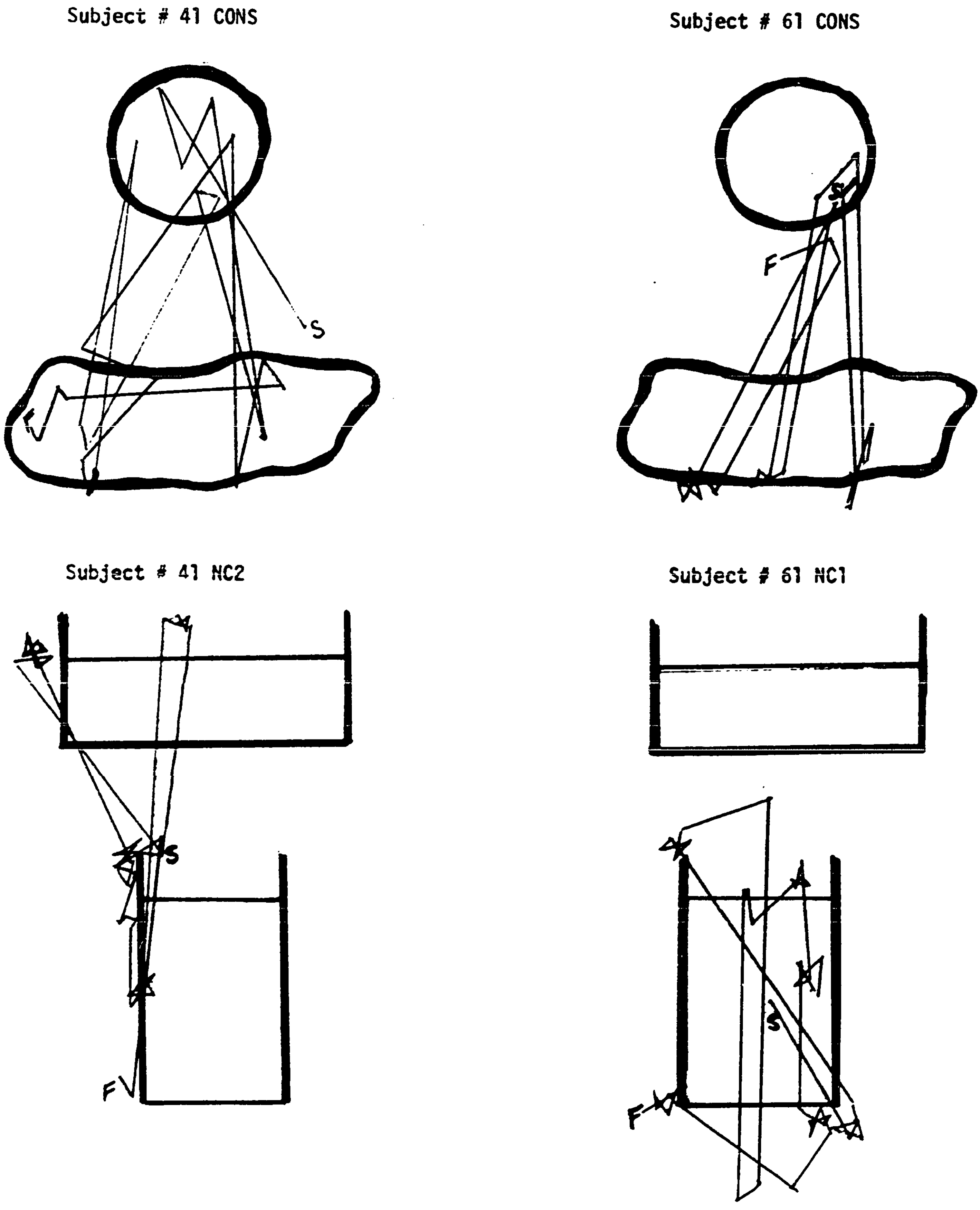


Fig. 4(b) Plots of EMPs of individual subjects exhibiting horizontal decalage (continuous quantity--solid, liquid).

Table 16

Summary of Tests of Hypotheses

on within group comparisons

No.	Hypotheses Description	Variable	Tasks L	A	QS	QL
1 (a)	NC1 will display more fixations on greater element	Total t. 1st 20 f.	S S	S S	S S	S S
1 (b)	NC1 will display greater $\overline{X}$ length run on greater element	Total t. 1st 20 f.	S S	NS S	S S	S S
2 (b)	NC2 will display same number of fixations in 1st 20 frames	1st 20 f.	NS	NS	S	S
2 (a)	NC2 will display more fixations on greater element in total time	Total t.	S	S	NS	NS
2 (d)	NC2 will display same $\overline{X}$ length run on both elements in 1st 20 f.	1st 20 f.	S	NS	S	S
2 (c)	NC2 will display greater $\overline{X}$ length run on greater element in total time	Total t.	S	S	NS	S
3 (a)	Conservers will not display more fixations on either element	Total t. 1st 20 f.	S S	S S	S NS	S S
3 (b)	Conservers will display similar $\overline{X}$ length run on both elements	Total t. 1st 20 f.	S S	S S	S S	S S

S Supported hypothesis at .05 level or greater

NS Not supported hypothesis at .05 level

Table 17

Summary of tests of Hypotheses

on Across Group Comparisons

No.	Hypotheses Description	Variable	Tasks L	A	QS	QL
1 (c)	NC1 will demonstrate fewer couplings than NC2	Per unit t. 1st 20 f.	S NS	NS NS	NS NS	S S
	NC1 will demonstrate fewer couplings than CONS.	Per unit t. 1st 20 f.	S S	S S	S S	S S
1 (d)	NC1 will demonstrate a greater $\bar{X}$ length of run than NC2	Total t.	S	NS	NS	S
2 (e)	NC2 will demonstrate a greater $\bar{X}$ length of run than CONS	Total t.	NS	S	NS	NS
3 (c)	CONS will demonstrate more couplings than NC2	Per unit t. 1st 20 f.	S S	S S	S S	S S
3 (d)	CONS will reach solution with fewer fixations than NC1	Total t.	S	S	S	S
	CONS will reach solution with fewer fixations than NC2	Total t.	S	S	S	S

S supported hypothesis at .05 level or greater

NS not supported hypothesis at .05 level

CHAPTER 7

Discussion

Discussion of the results follows three principal trends. First, a general overview of the findings in terms of the subject's performance on the Piagetian tasks and concomitant EMs is presented. Second, the implications of the results for the theoretical rationale upon which the postulates were based are considered. Finally, an interpretation of conservation development reflected in changing EMPs is offered.

The recording and measurement of EMs did not result in excessive discomfort for the subjects. Follow-up interviews with parents and teachers indicated that no girl reported eye-strain or headaches after the experimental procedure. Forty subjects from the original sample who were asked to take part in a subsequent, independent study in EMs all responded favorably. This suggests that the apparatus and experimental conditions did not represent an unduly threatening situation to the subjects. Accordingly, it is felt that the results obtained were sufficiently free of such factors as subject apprehension, distaste or fear of confinement, (i.e., seated in the apparatus), that they may be considered valid tests of conservation.

The EM recordings obtained demonstrated no marked deviation in type or form from those reported by other researchers

(Mackworth and Bruner, 1966; Mackworth, 1967), who used similar equipment. There seems no reason to suspect that the EMPs recorded for the sample would differ in quality for reasons other than through reflection of the state of conservation attainment reached by the subjects. Calibration of the instruments presented no special difficulty in the experimental sample and subjects displayed ability to remain in a stable position in the equipment throughout each segment of the procedure. It is likely, however, that the extensive training period helped considerably to achieve familiarity with the laboratory and that a similar familiarization process is necessary when EMs of young subjects are recorded.

Classification of the subjects into groups resulted in a distribution approximating that normally obtained with similar samples and tasks. The absence of significant IQ and socio-economic status effects were also generally consistent, but it was felt necessary to investigate them in view of Vinh Bang's (1959) findings. The expected appearance of age as a significant variable indicated the need for either stratification of groups, or a covariate analysis approach for the measurement of possible differences between the groups on the dependent variables. The latter procedure was chosen because it enabled treatment of the subjects in blocks of greater size and allowed a measure of statistical control over the possible confounding effects of age. All analyses across groups were thus adjusted for age variation.

Further, the very similar profiles obtained across the tasks indicate that no appreciable learning effects leading towards conservation, or vice-versa, appeared to be present. Consequently, it is felt that the presentation of the tasks consecutively and on movie has not seriously affected the validity of the study. In any case, scores across tasks were not analyzed.

The results indicate gross differences between FMPs of non-conservers and conservers on every variable in almost every instance (Tables 16 and 17). Clearly a change is reflected in EMPs of girls once a conservation status, based on Piaget's position, is reached. However, the change is not so well delineated between the non-conservers of step 1 and those of step 2. Differences do seem to exist but they appear to be more of a qualitative rather than quantitative type (Figures 3(a), 3(b), 4(a) and 4(b)).

Inspection of Figures 3(a) and 3(b) reveals several clearly defined qualitative trends. Subject 24's centration effect upon the transformed stimulus element is most marked. The number of oblique tracks parallel with the line suggests a movement back and forth along it. The horizontal line appears to have been largely in the peripheral vision since it is foveated on one occasion only.

By contrast subject 13, an NC2 who chose the horizontal line as longer, exhibits more couplings and has several vertical, horizontal and oblique track patterns. There is, again, marked centration illustrated by overlapping lines and bunched fixation points but, as well, there is some suggestion of visual measuring of the two lines. This may be reflecting Wohlwill's proposed phenomenon of cue selection as the subject attempts to perceptually check the "equality" of the lines. Her lack of success in this instance may be consistent with notions of misleading, redundant and irrelevant cues (Wohlwill, 1962; Bruner et al., 1966; Gelman, 1968). Certainly this subject extensively foveated the areas of the lines to the right of center, and it may be significant that her fixation points extended beyond the horizontal line's right limit. However, it is also possible that recording error tolerance may account for some of the extension.

A striking change is noted in the EMPs of the conserver subject 16. This girl exhibited the most marked characteristics of her group. Rapid vertical shifts between elements, few areas of concentration of fixation points and almost equal distribution of fixations occur. This pattern varies very little from task to task and hints at rapid perceptual activity in the form of constantly shifting areas of centration.

While EMPs of the non-conserver subjects on length are probably the most indicative of centration effect and developing perceptual activity, their EMPs on the other three tasks are also of the same general quality. The most interesting single plot, however, is that of NC1 subject 85 who fixated almost exclusively on the conjunction of surface and wall of the chosen element. By comparison NC2 subject 6 had an area of heavy fixation high on the wall of the thin container but also fixated on the surface and walls of both containers, thus suggesting increasing perceptual activity and developing decentration. This activity appears to reach its peak with conserver on this task. Subject 60 has only one small area of centration. Generally she moves her eyes rapidly around the elements, touching directly the height of the thin container and the width of the flat container. In addition she fixates close to four of the six walls and her fixations are evenly distributed. In short, she has not centred on either element nor indicated areas of centration within either element.

Figures 4(a) and 4(b) illustrate the EMPs made by two subjects in horizontal decalage. While both girls exhibit characteristics of group patterns according to their classification for a given task, the most notable feature of the plots is the apparent transitional nature of the EMPs in keeping with the transitional status of the subjects. Both subjects display "typical" NC2 patterns in length. Subject 41 records two concentrations of fixation on the chosen element as an NC1 in area but there are suggestions of perceptual activity in the plot. Subject 61, a conserver in area, nevertheless tends to center somewhat on the non-transformed element. Similar patterns are obtained for both on conservation of continuous quantity in solids, but again there is evidence in the plots of minor centration effects. Only in Subject 61's NC1 response to the liquid task is extensive centration noted. On the same task Subject 41 (NC2) did display areas of heavy fixation but also engaged in couplings which suggest imminent development of more vigorous perceptual activity.

The EMPs in Figures 3(a), 3(b), 4(a), and 4(b) lend some support to Piaget's (1950) views of the nature of the error commited by non-conservers of group 1 in conservation of quantity tasks. In most explicit terms, he writes:

> Moreover, it is clear that the reasons for the error are of a quasi-perceptual order: the rise in the level, or the thinness of the column, etc., deceives the child. However, it is not a question of perceptual illusions; perception of relations is, on the whole correct, but it occasions an incomplete intellectual construction. It is this pre-logical schematization, which is still closely modelled on perceptual data though it recenters them in its own fashion, that may be called intuitive thought (p. 130).

The statistical data clearly indicate that there is extensive centration on one element of the stimulus in strongly non-conservation subjects. This element is the one chosen as greater. Thus, if a subject chooses the transformed element the concentration of fixation points is generally heavier on that element. Should she choose the non-transformed element the greater concentration of fixation points occurs generally there. In the conservation of continuous quantity in liquid task, both elements were transformed, therefore the subject had, in effect, to conserve equivalence. That is, she had to operate on the basis that while A was equivalent to B, A became C (the tall container) B became D (the flat container) and, therefore, C was equivalent to D. Once again it was found that the fixations centred on the stimulus element chosen as greater when equivalence was not conserved.

At this point it should be noted that "element" is often used by Piaget to refer to a property of the transformed stimulus such as height, width, tallness, thinness etc. The present study was not designed to investigate within element (as defined in Chapter 3) differences in centration. Since centration effects upon the total stimulus element have been demonstrated by non-conservers, a study designed primarily to investigate within element centration in conservation of liquid tasks seems a logical next step.

Piaget's point that a child who centers his thought on a single relationship will not conserve is at the heart of his theory, and the present data are not inconsistent with his position. It is at least possible that the centration effect found in the EMPs reflects the concentration of the attention of the subject on a perceptually dominant element of the field and thus, in Piaget's (1950) words, suggests that

> Concentration of attention on one idea is precisely nothing else but the centring of thought (p. 131).

But, on the basis of non-conserver 1 responses, an argument might certainly be made for Wohlwill's position that the subject is confounded by the perceptual dominance of a given element. Wohlwill (1962) suggested that attention to redundant and irrelevant information in the stimulus field leads to non-conservation. The data do indicate considerable redundancy of attention to certain areas of the stimulus field in both groups of non-conservers compared with conservers. Further, little evidence of fixation on the non-chosen element was found in the EM recordings of non-conservers 1.

This indicated that perceptual factors inherent in the post-transformed stimulus might well have *caused* non-conservation. Such a proposition will be discussed in terms of future research later in the chapter.

Bruner's (1966) theory on the nature of conservation development is not seriously challenged by the non-conserver 1 EMPs. His finding that "all non-conservation responses are backed by perceptual reasons (p. 200)" received implicit support from the present data. Further, his suggestions that non-conservers display impeccable "perceptual logic (p. 202)" and that they are "highly dependent upon the perceptual properties of events and upon images that represent these events ikonically (sic) (p. 193)" are not inconsistent with the present results.

Since there is a marked lack of signs of perceptual activity in non-conserver 1 EMPs, there seems little doubt that Piaget's (1950) view of the passivity of the non-conserver confronted with perceptual distortion is tenable. Arguing that perceptual activity constitutes one of "the flexible supports which will be required for the launching of the operational mechanism (p. 85)", Piaget claims that:

> Every decentralization of an intuition thus takes the form of a regulation which is a move towards reversibility, transitive combinativity and associativity, and thus, in short, to conservation through the co-ordination of different viewpoints. Hence we have articulated intuitions which progress towards reversible mobility and pave the way for the operation (pp. 138-139).

The results thus indicate that Postulate 1 is presently tenable. Perceptual activity is minimal and centration on the element reported as greater occurred. It is concluded that girls at a gross non-conservation level are unable to overcome the perceptual distortion of the transformed stimuli, and that this inability is reflected by EMPs in which concentration of fixation is upon one or the other elements while perceptual activity is effectively absent.

Non-conservers 2 also appear to be misled by their centration on the greater element. Interestingly, however, the centration effect is neither as consistent nor as general as that found in non-conservers 1. Although the effect is not so clearly marked as had been hypothesized it does indicate a tendency to increased decentration in terms of inspection of the other element. Surprisingly, however, there was less evidence of increased perceptual activity in terms of couplings. It seems that the data point to a form of "dual centration". Centration first appears on one element then on the other without a great deal of shifting from one to the other. Despite the overall results, however, inspection of individual protocols in this group suggests that a number of individuals appeared to be engaging in some measuring strategies. It is possible that a difference does exist between the non-conserver groups but that attempts at comparison or measurement of the elements are not an easily definable feature in the progression toward conservation.

At this point Piaget's ideas of coordination of view points may be relevant. In discussing decentration in the context of a correction of centering on height by decentering of attention onto width Piaget (1950) writes:

> transition from a single centring to two successive centrings heralds the beginnings of the operation. Once he reasons with respect to both relations at the same time, the child will, in fact, deduce conservation (p. 131).

The present data partially indicate that NC2 subjects display successive areas of centration on the two elements. This perhaps suggests the "beginnings of the operation" in terms of an increased awareness of the properties of the other element. But, in the absence of conservation of identity or equivalence, the subject is still dependent upon his visual analysis of the transformed elements and thus falls victim to the distorting perceptual cues.

Results of hypotheses set for non-conservers 2 are sufficiently equivocal to cause difficulty in interpreting them wholly in terms of any of the theoretical positions reviewed. Nevertheless, some insight can be gained by noting that the appearance of inconsistency suggests that this group is in a form of intermediary stage between non-conservation and conservation. Certainly, the girls demonstrate different EMPs than those in the conserver group. An increased awareness of the other element in the stimulus field was apparent, but perceptual activity in the form of couplings was not consistently greater than the other non-conservation group.

The results of non-conservers 2 indicate that this group is beset by conflict. It demonstrates, generally, a part perceptual--part conceptual approach and thus appears to follow Wohlwill's formulation of a continuum. However, Piaget's theory of decentration does suggest a transition period in which a subject's responses are clouded by conflict. Bruner, too, might be invoked to explain the results in terms of partial displacement of the effects of visual displays by symbolic referents.

Despite the number of possible tempting interpretations of the data in terms of one or all of the theoretical positions, it is felt that the records obtained do not justify an unqualified acceptance of Postulate 2. Accordingly, the conclusions reached propose that girls in a second stage of non-conservation display EMs which often reflect different patterns than those of the other groups, but that they do not provide an acceptable means of reliable classification across all tasks. Further, there does not seem to be an increase in perceptual activity, although there is some evidence of a differential distribution of fixations. Although clearly different from conservers in number of fixations and couplings, non-conservers 2 displayed a mean length of run similar in two instances to non-conservers 1, and in the three cases, similar to conservers. Thus it is concluded that non-conservers 2 display EMPs containing characteristics of both non-conservers 1 and conservers and, therefore, represent a difficult-to-identify transitional stage.

The most striking feature of the results is the strong evidence for hypotheses set for the conservers, and it is in these EMPs that Piaget's formulation of the conservation problem received most support. The conservers exhibited a marked and sudden decrease in number of fixations, a high level of perceptual activity and, in all but one case, no centration effect upon a stimulus element. There seems little doubt that the data present a clear reflection of conservation attainment in the EMPs of conservers and that the quality of the EMPs supports Postulate 3.

Piaget (1950), despite his description of steps towards conservation, has written:

> the crucial turning-point for the beginning of operations shows itself in a kind of equilibration which is always rapid and sometimes sudden, which affects the complex of ideas forming a single system and which needs explaining on its own account (p. 139).

He later clarifies this view by proposing that conservation occurs when transitivity, reversibility, associativity and identity are finally combined into one logical groupment. Thus he contends that:

> the distinguishing characteristic of the mobile equilibrium peculiar to the grouping is that the decentralization, already provided for by the progressive regulations and articulations of intuition, suddenly becomes systematic on reaching its limit (p. 142).

There is evidence in the data that conservers display EMPs reflecting "decentralization", and that conception of the invariant property of the transformed stimulus element precludes distorting perceptual effects. The very strong differences found between conservers and non-conservers at both levels lends some support to Piaget's (1950) suggestion that grouping is sudden and complete (p. 140).

Further evidence for Piaget's position is provided on an individual level by those subjects who manifest horizontal decalage. Here, a considerable change may be noted in the plots (Figure 4) of their EMPs for various tasks. When conservation is present, there is a marked change of pattern such that extensive coupling is present and minimal centration effect occurs.

Wohlwill's notion of a progressive continuum from perception to conception is also well defined by the data in the conserver groups. If a continuum does exist, it appears to be accelerated as the subject approaches conservation. More evidence of partial centration by conservers might have been expected than was found. It is possible, however, that analysis of conservation responses in terms of certainty and quality of the concept might do more justice to Wohlwill's position. If his continuum holds it could be expected that EMP differences would be defined within conservers.

The effect of the conserver results on Bruner's conceptualization of the problem also requires further investigation since the methodology employed may have weighed against him. The training procedure carried out prior to task presentation should have resulted in clarifying the nature of the tasks to subjects who might otherwise have provided answers affected by semantics. There was, of course, no screening employed in the study, therefore, all prevention of iconic misrepresentation of the elements had to be provided by the subject.

Further, since each classification followed Piaget's technique rather than Bruner's, interpretation of the initial results cannot justifiably proceed beyond a check of Piaget's theory. Nevertheless, the data do indicate ways in which the varying approaches to conservation attainment may be investigated, and these will be discussed later.

The consistency of occurrence of the same traits and general EMPs for groups from task to task is a pertinent factor in the study. Reference to Tables 16 and 17 indicates that the NC1 group was remarkably consistent over all variables on all tasks. In fact on 16 separate analyses they failed to demonstrate fixation preference for the chosen stimulus element on one occasion only. In mean length of run over total time on conservation of area the

NC1 group fixation on the chosen element failed to reach significance. There seems no doubt that this group exhibits a strong and consistent centration effect.

No less consistent are the conservers. Only one within group test indicated a significantly greater number of fixation points on one of the stimulus elements. This suggests that a fairly high degree of confidence might be placed in the assumption that non-conservers 1 and conservers display quantitatively and qualitatively different EMPs according to their classification and over a variety of conservation tasks. This difference is further substantiated when reference is made to the between group comparisons. With but one exception (conservation of quantity in solids) the NC1 group was found to be different from the conservers on every variable over every task on which the groups were compared. Moreover, these differences were very highly significant, usually at the .001 level or greater. It is felt that these data present very strong evidence that non-conservers of type 1 may be clearly distinguished from conservers on the basis of differential EMPs.

The apparently transitional group, NC2, did not, however, provide equally consistent EMPs across all tasks. Indeed, their performances varied noticeably according to both the variable considered and the task itself. The data seem contradictory at times and this perhaps underlines the state of cognitive conflict which appears to be characteristic of NC2 subjects. The present writer feels uninclined to argue that this group (NC2) might be definable on the basis of EMPs beyond investigation of the actual plots of patterns. There seems some indication that qualities of dual centration, fewer couplings from element to element and evidence of measuring strategies are characteristic of NC2 subjects, but it is suggested that the present data are not sufficiently refined to accurately and confidently identify NC2 subjects on the basis of EMPs.

A further interesting factor of the results which should be noted, is the size of the t values in the within group variables, especially those of NC1 and NC2 groups. Generally, the t is much larger for NC1 than NC2 (13 out of 16 cases) and this suggests that the NC1 group displays the associated centration effects much more strongly than NC2 subjects. This distinction could be further investigated and clarified by research comparing within stimulus centration effects across non-conservation groups and by examining relative amount of fixations on elements across the same groups.

In summary thus far, it is felt that the EMPs obtained indicate a clear distinction between non-conservers and conservers, that they suggest within non-conserver differences relating to level of conservation attainment and that they generally do not conflict with Piaget's view of conservation. But, the results in their present form do not provide evidence to contradict either Wohlwill or Bruner. Instead, they suggest ways in which the various views may be further investigated and these are now discussed.

While Bruner has been taken to task by Piaget on the score of his understanding of the conservation problem, there remains considerable empirical evidence that perceptual screening devices are effective in inducing "conservation", and further, that the development of language concepts assists in acquisition. How much this acquisition depends upon adequate classification of subjects as non-conservers is obvious. If the experimenter trains subjects classed as non-conservers on their verbal responses and then accepts non-logically justified "conservation" responses as indicating a change of status his results are surely questionable. The present data suggest ways of checking both the initial classification and supposed change of status.

Future research using EMPs as an independent check on conservation classification and attainment could provide less equivocal results. Since there appears to be clearly definable patterns characteristic of pre-operational subjects and of conservers, such studies could employ a variety of training procedures which, if effective, would be expected to produce EMPs similar to those obtained from conservers in the normal course of development. Indeed, this transition from non-conserver to conserver type EMPs should accompany the results of all conservation training techniques claiming a development of reversible operations.

Wohlwill's continuumtheory should be testable through isolation of subjects at varying levels of conservation attainment, provided that such levels can be found to exist. Further, it will likely be necessary to present the subject with more complex stimuli if Wohlwill's ideas of redundancy and selectivity are to be properly investigated. The emphasis in the present study was upon sharply defined stimulus elements so that centration and coupling effects could be clearly observed. Hence, a subject was not required to exercise extensive selectivity in choosing from a complex stimulus array. This was especially so in the two-dimensional tasks of length and area.

Wohlwill's theory is presently most acceptable at either end of the continuum. There does seem to be perceptual error in the case of non-conservers of type 1 and conceptual certainty among conservers. Thus, further investigation of non-conservers 2 would likely be profitable. Should his theory hold, this group would be required to demonstrate less redundancy (i.e. less centration) and contiguity (similar to perceptual activity) in EMPs on the stimulus.

As indicated earlier in this chapter, a further line of research might be extended into the conserver group. Despite Piaget's claim that conservation comes rapidly, and often suddenly, if there is such a continuum as that proposed by Wohlwill there should be some evidence of within-conserver variation in EMPs and this variation should be related to strength of conservation conceptualization.

Extended research in terms of EMPs is also possible in Piaget's theory. The inconclusive nature of the results for non-conservers 2 creates doubt regarding the feasibility of determining the presence of substages of non-conservation, yet there is evidence in the results for the existence of intermediary states between intuitive and operational thought. The complexity of this problem is increased by difficulty experienced in identifying type 2 non-conservers allied with the presumed suddenness of the concept acquisition.

Of greater importance, however, is the effect of EMs on the subject's interpretation of the data. Piaget has already been reported in this chapter as suggesting non-conservation is not a matter of perceptual illusion, yet his own studies on the nature of such illusions consistently find that centration on a given property regularly over-estimates it. The extent of the centration on the "greater" line in the length task, for example, might well be interpreted in terms of the creation of an illusion. Piaget's view of the transformed stimulus presenting the non-conserver with an essentially new display, unrelated to the pre-transformed stimuli, allows an interpretation of the results from a perceptual illusion basis. Indeed, Piaget may well be self-contradictory in arguing that on the one hand non-conservers do not possess the concept of identity and hence cannot conserve the original state of the stimulus, while on the other that they are not confronted essentially with an illusion. It seems to the present writer that the absence of identity infers a discrete transformed stimulus which may be as much liable to systematic distortion through centration as any other perceptual illusion.

The present data demonstrate that there is a very marked change in centration and perceptual activity from non-conservation to conservation. Whether or not this change is causative or reflective cannot be determined from the present study, but the results indicate that the question should be researched.

If centration on a given element does bring about over-estimation and thus overwhelm latent conceptualization of conservation, as Bruner seems to suggest, then inducement of scanning activity by tracking devices might be expected to produce an estimation of the elements as equal. This would be consistent with Piaget's position on illusions, in which he regards perceptual activity as reducing the extent of the illusions. Further, if non-conservation is largely perceptual as Bruner et al, (1966) have argued, removal of the illusory qualities of the stimulus should have a substantial effect on the conservation status of the subject. On the other hand, if Piaget is correct in assuming that the perceptual relations are well established and that any distortion of the elements is not the critical factor, then reduction of the perceptual illusion should have little or no effect. In such a case, it would be expected that the subject would merely report that the stimulus elements looked the same without being able to provide a justification. It is apparently such subjects as these that Bruner regards as conservers and whom Piaget considers capable of covariance without compensation and thus are pseudo-conservers.

The relationship of EMPs to level of conservation development has some implications for developmental theory in general and Piaget's stage concept in particular. In line with this several key features of the data bear repetition.

There appears to be a reflection of the development of cognitive structure from pre-operations to concrete operations in the EMPs of girls at this period of concept formation. While any causative properties of input data derived by EMs cannot be established from the present research, it is clear that as conservation is attained EMPs undergo recordable changes. Pre-operational girls fixate on the stimulus element they perceive as greater. They take little or no account of the other element and perceive it as a peripheral entity. Thus centrated, they do not appear to consider the stimulus as a transformation of a prior state but may regard it instead as a discrete presentation of two elements either of which is greater or lesser than the other. Therefore, they are likely to make a judgment on the basis only of the immediate perceptual qualities of the stimulus. Accordingly, their judgment is affected by illusory qualities of the stimulus field. They are, in effect, seemingly unable to decenter from the dominant element. They do not display perceptual activity and hence may be unable to effectively compensate intellectually for perceptual distortion.

Gelman's (1968) research on discrimination and learning set, and that of Zeaman and House (1963) suggest that inattention to relevant cues may be a factor in non-conservation and perceptual error. Certainly the present data indicate that concentrated attention to one or the other stimulus elements is characteristic of non-conservers and that this centration effect is not present in conservers. Thus there is implicit support for Gelman's position, at least in the attention given by the subjects to the transformed elements. The question of attention to relevant details, however, has not been considered in the present study and, again, this suggests an area of further research in which the EMPs of subjects in all groups before transformation might be recorded and investigated. If Gelman's thesis is tenable there should be found differential areas of attention to stimuli corresponding to level of conservation. A similar procedure might also be applied to further investigate Wohlwill's ideas of cue selectivity since the pre-transformed stimuli also offer sources of redundant cues.

In considering a transitional period between pre-operations and concrete operations, the author is led by the data to suggest that this transition occurs rapidly after the appearance of dissatisfaction with the initial response. Indeed, it seems likely that once conservation appears the subject has very little need for the display of the transformed elements.

The absence of marked consistent perceptual activity in the non-conserver 2 group makes it difficult to confidently define a steadily increasing perceptual activity leading to decentration and hence conservation, but the conservers do demonstrate considerable scanning activity within a very few number of fixations, in sharp contrast to non-conservers. Hence it can be claimed that such activity is concomitant with a conservation state if not necessarily causative. Moreover, there is support in the data for a suggestion of quickly developing schemata in the case of transitional and conserver groups such that the EMPs reflect a search strategy which is beset by conflict in the case of non-conservers 2 and which is characterized by perceptual activity in the form of checks on the identity of the elements in the case of the conservers.

Conservers thus appear to differ from non-conservers in that they possess some conceptual certainty that the stimulus elements remain invariant in the face of transformation. Such certainty is held to be reflected in EMPs which are characteristic of conservers and which may be reflecting a rapid verification process rather than problem solving (i.e. are the transformed elements visually equal?) process.

In summary, conservers appear to have overcome the distortion of the perceptual cues and do not display the centration effects characteristic of non-conservers, possibly as a result of the development of reversible operations which are themselves reflected in a series of changing search patterns. Moreover, although differential

EMPs do exist between non-conservers at different levels of conservation attainment, it is felt that the EMs will change rapidly after the onset of conflict in the subject's response to the stimulus, thus producing patterns incorporating characteristics of both non-conservation and conservation responses. Once this conflict occurs, however, conservation is rapidly and completely attained so that conservers demonstrate few of the characteristics of the EMPs of non-conservers. Further, the data generally are consistent with Piaget's position on cognitive development, although they do not provide evidence directly contrary to the theories of Wohlwill and Bruner.

In terms of implications for education the present study must rely on a proposition that the work of Piaget, Bruner and, to a lesser extent Wohlwill, is relevant to modern educational theory and practice. Accordingly, any clarification of concepts as basic as the transition from non-conservation to conservation is, in the long term, likely to have relevance to educational psychology. This is of special importance in reference to training in concept acquisition. What this study has done is to indicate the existence of behavioral output in terms of EMPs which are highly related to conservation acquisition and which are very likely to be of use in determining the effectiveness of training procedures.

Finally, it seems reasonable to conclude that the study is in agreement with those investigators (Mackworth and Bruner, 1966; Zaporozhets and Zinchenko, 1966; Mackworth, 1967) who propose that cognitive development can be investigated through the study of EMPs.

CHAPTER 8

Summary and Conclusions

Three questions asked in the study concerned the identification of eye-movement patterns (EMPs) in non-conservers and conservers of the Piagetian type, the potential relationship of these EMPs to conservation status and their relevance to the conservation problem in general. Literature indicating a reflection of cognitive development in EMPs was reviewed and, in conjunction with a discussion of current research and thought in conservation, and perception, a rationale postulating a reflection of conservation attainment in EMPs was presented. Specifically, it was hypothesized that groups of girls at different levels of conservation attainment in each of four Piagetian tasks (length, area and continuous quantity in solid and liquid) would display differential EMPs in terms of fixation number and position, couplings of stimulus elements, and length of run.

Ninety-two Edmonton girls in the first three grades of an elementary school were tested on the conservation tasks while their eye-movements were recorded from point of stimulus transformation to decision. Stimuli were presented on a specially prepared 16mm movie which had been previously tested for similarity to experimenter adminstered tasks. Efforts were made to insure that every subject was comfortable in the apparatus and understood clearly the verbal instructions.

Classification of the girls into two non-conserver groups and one conserver group was performed by two examiners and was made on the basis of post-decision questioning similar to that employed by Piaget. Subjects' verbal responses were recorded and later re-analyzed to check doubtful classifications.

EMP recordings were scored by two independent examiners and later spot checked for accuracy. Analysis of the data was conducted in two series--total time data and EMs made shortly after transformation (approximately 2 seconds). Analysis of co-variance, with age covariate, was applied to data on variables obtained across groups, and subsequent Newman-Keul's tests on ordered pairs of means were applied on significant results. Within group comparisons were made by t-tests on means of correlated samples. Eighty-one percent of the formal hypotheses (100) were supported beyond the .05 level by the data and of these most were very highly significant ($p < .0001$).

It was concluded that differential eye-movement patterns existed between non-conservers and conservers on almost every variable, but that differences between groups of non-conservers were not as substantial and less consistent. A discussion of the relevance of the findings to present theories of conservation development was presented and a synthesis of viewpoints was attempted. Several implications for future research were suggested.

It is concluded that the study demonstrates a relationship between eye-movement patterns and the development of conservation, especially at the gross non-conserver versus conserver level. The study fails, however, to strongly distinguish between levels of non-conservation on the basis of clearly defined EMPs, although some difference undoubtedly exists. This may be a result of the techniques used, or it may suggest that conservation is very much a separate state from non-conservation. By contrast with conservers, non-conservers may be, as a class, beset by highly stable perceptual distortion. The question is still open, as is the question of possible EM causation of the distortion.

Finally, no one theory of conservation attainment has been completely supported by the results, but certain elements of various theories do seem to be consistent with the present data. Specifically, the concepts of perceptual activity and perceptual selectivity appear to be relevant. At the level of conservation the EMPs indicate apparent internalization of the problem elements which suggests that the results are consistent with Piaget's theory of thought-action reversibility.

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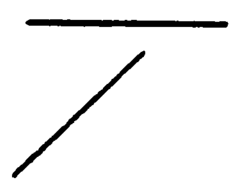
APPENDICES

APPENDIX 1

Tasks Adapted for Movie Presentation

Length

Two strips of black cardboard each 30 cms. by 1 cm. were presented horizontally, approximately 5 inches apart. The strips were first brought together so that the end points were shown to coincide. At this time the subject was informed that the strips were the same length and asked if she agreed that this was so. The top strip was moved back to its original position. The bottom strip was placed at an angle of approximately 45° and approximately 1-1/2" below the centre of the top strip, thus:



At this point the movie projection was stopped and the subject was asked to decide whether the strips were equal in length or whether one was longer or shorter than the other. Eye movement recordings were made from the point of transformation to eye closure by the subject.

After eye closure the subject was removed from the bite-bar, the screen was darkened and the subject was asked for her answer. Questioning then proceeded along three general paths.

If the subject indicated that the lines were equal she was asked for an explanation of her answer. Those subjects who replied that the lines were the same to begin with, or were not changed in any way, or were the same because they would be the same length if replaced, were immediately classified as conservers.

Subjects who gave "conservation" responses but did not immediately justify were questioned initially with the following:

Why are they the same?

Do you think they will always be the same?

In what way could one be longer than the other?

If any of these questions produced a reference to identity or equivalence the subject was classed as a conserver. Subjects who continued to give a "symptom" response were then to be asked a further series of questions which varied according to their responses until they were unable to add further information. In practice this did not occur. Subjects who gave non-conservation responses were asked to explain their answer. After stating which line was longer or shorter the subject was asked a series of questions as follows:

Why are the lines different?

Do you think they will always be different?

Which one do you think is longer?

Which one do you think is shorter?

Were they the same length to start with?

Were they the same length after I moved them?

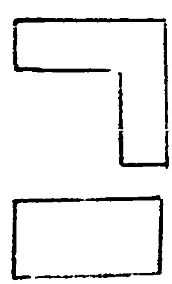
Which one was longer?

Subjects who were firm in their decision were classified as non-conservers 1.

Subjects who were unsure and changed their mind were classified as non-conservers 2. A few subjects (3) who initially gave NC2 answers and then changed to conservers were questioned according to conserver responses. Two were reclassed as conservers, 1 was left in NC2.

<u>Area</u>

Two rectangular (10 cms. by 5 cms.) strips of black cardboard were shown, one above the other, approximately 3 inches apart. They were then brought together and placed one on top of the other so that they were shown to be equal in amount of area (black). The subject was at this point instructed that each rectangle (piece) had the same amount of black and asked to agree that this was so. The top strip was then removed and cut lengthwise into halves. These were then formed into an ⌝ shaped figure. The untransformed shape was placed below the ⌝ thus:



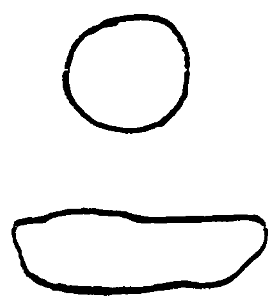
The subject was then asked whether both shapes had the same amount of black or if one had more or less than the other.

Questioning proceeded as for length with the exception that more or less black was incorporated in the questions instead of longer or shorter.

Continuous Quantity - Solid

Two balls of plasticine, approximately 2-1/2" in diameter were presented, one above the other, to the subjects.

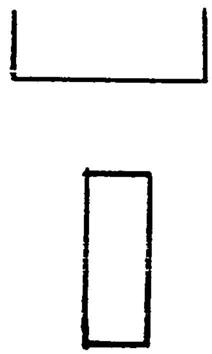
The balls were then placed side by side and turned round so that they could be seen to be equal. They were then held up and the subject was informed that they were equal in amount of plasticine and asked to agree whether this was so. The lower ball was then rolled into a sausage shape and placed below the untransformed ball thus:



Questioning proceeded, with appropriate substitution of "more or less plasticine", as in the case of length and area.

Continuous Quantity - Liquid

Four beakers in all were used for this task. The subject was shown 2 beakers side-by-side, 4 parts filled with liquid and informed that there was the same amount of water in each beaker. She was asked to agree that this was the case. She was then shown two empty beakers, one wide and flat placed above another taller, thinner beaker thus:



The content of the beaker on the left was poured into the flat container. The right hand beaker was poured into the tall container. Until this point all beakers were in full sight. After transformation the empty beakers were removed and the subjects were asked if the two containers now held the same amount of water or if one held more or less than the other.

After eye closure, questioning proceeded in the same manner as for the other tasks.

APPENDIX II

Pilot Studies Report and Data

Pilot Study 1

Forty grade 1 subjects from an Edmonton school were divided into 2 groups (Group 1 and Group 2) and tested on 4 Piagetian tasks (Appendix 1). The subjects were classified into non-conservers and conservers. Two weeks later Group 1 was re-tested under similar conditions. Group 2 was transported to the University of Alberta eye-movement laboratory and tested for conservation on a movie representation of the tasks.

Pilot Study 2

Forty subjects were selected randomly from the experimental sample after classification on the basis of film presentation. They were divided into two groups (Group 3 and Group 4). Since both groups initially viewed the movie, it was re-shown to Group 3 while Group 4 was retested with the actual materials used in the movie. Thus the same materials used for Group 1 and Group 2 were again employed.

Raw data, Chi Square analyses, Phi coefficients and percentages of agreement for all groups are presented below.

Table A

Raw Data for Group 1

Subject	Group 1 Pre-test				Group 1 Post-test			
	L	A	CQS	CQL	L	A	CQS	CQL
1	NC	NC	NC	NC	NC	NC	NC	NC
2	NC	NC	NC	NC	NC	C	C	NC
3	NC	C	C	NC	NC	C	C	NC
4	C	C	NC	C	C	C	C	C
5	NC	NC	NC	C	NC	NC	NC	NC*
6	NC	NC	NC	NC	NC	NC	NC	NC
7	C	C	C	C	C	C	C	C
8	NC	C	NC	NC	NC	NC*	NC	NC
9	NC	NC	NC	NC	NC	NC	NC	NC
10	C	C	C	C	C	C	C	C
11	NC	NC	NC	NC	NC	NC	NC	NC
12	NC	NC	NC	NC	NC	NC	NC	NC
13	NC	NC	NC	NC	NC	NC	NC	NC
14	C	NC	NC	NC	C	C	C	NC
15	C	C	NC	NC	C	C	C	C
16	C	C	C	C	C	C	C	C
17	C	C	C	C	C	C	C	C
18	NC	NC	NC	NC	C	C	C	NC
19	NC	NC	NC	NC	NC	NC	NC	NC
20	NC	NC	NC	NC	NC	C	C	NC
C	7	8	5	6	8	9	9	6
NC	13	12	15	14	12	11	11	14

* Regression from conservation to non-conservation

Table B

Raw Data for Group 2

	Group 2 Pre-test				Group 2 Movie Task			
Subject	L	A	CQS	CQL	L	A	CQS	CQL
1	NC	NC	NC	NC	NC	NC	NC	NC
2	NC	NC	NC	NC	NC	NC	NC	NC
3	NC	NC	NC	NC	NC	NC	NC	NC
4	NC	NC	NC	NC	C	NC	NC	NC
5	C	C	C	C	C	C	C	C
6	NC	NC	NC	NC	NC	NC	NC	NC
7	C	C	C	C	C	C	C	C
8	NC	NC	NC	NC	NC	NC	NC	NC
9	C	NC	NC	NC	C	C	NC	NC
10	NC	NC	NC	NC	NC	NC	NC	NC
11	NC	NC	NC	NC	NC	NC	NC	NC
12	NC	NC	NC	NC	NC	NC	NC	NC
13	C	C	NC	C	C	C	C	C
14	C	C	NC	NC	C	C	NC	C
15	NC	NC	NC	NC	NC	NC	NC	NC
16	NC	NC	NC	C	NC	NC	NC	C
17	C	C	NC	NC	C	C	NC	NC
18	C	C	C	C	C	C	C	C
19	NC	NC	NC	NC	NC	NC	NC	NC
20	NC	NC	NC	NC	C	C	NC	NC
C	7	6	3	5	9	8	4	6
NC	13	14	17	15	11	12	16	14

Table C

Summary of Chi Square Analyses for Groups 1 and 2

Chi Square	Length	Area	CQS	CQL
Pretest	.000	.439	.625	.125
Posttest	.102	.000	2.85	.000

Table D

Summary of Phi Coefficients for Groups 1 and 2

Group	Length	Area	CQS	CQL
1 (Test-retest)	.90	.53	.52	.76
2 (Equiv. Forms)	.80	.90	.84	.88

Table E

Summary of Percentages of Agreement for Groups 1 and 2

Group	Length	Area	CQS	CQL	$\bar{X}$%
1	95	75	70	90	82.5
2	90	95	95	95	93.8

Table F

Raw Data for Group 3

Subject	Pretest (Film) L	A	CQS	CQL	Posttest (Film) L	A	CQS	CQL
5	NC	NC	NC	NC	NC	NC	NC	NC
10	NC	C	C	C	NC	C	C	C
13	NC	NC	NC	NC	NC	NC	NC	NC
14	NC	C	C	C	NC	NC	C	C
18	NC	NC	C	NC	NC	NC	C	C
19	NC	NC	NC	NC	NC	NC	NC	NC
31	NC	NC	NC	NC	NC	C	NC	NC
33	NC	NC	NC	NC	NC	NC	NC	NC
39	NC	NC	NC	NC	NC	NC	NC	NC
40	C	C	C	C	C	C	C	C
49	C	C	C	C	C	C	C	C
57	NC	NC	C	C	NC	C	C	C
64	C	NC	NC	C	C	NC	C	C
65	NC	NC	NC	NC	NC	NC	NC	NC
68	NC	C	C	C	C	C	C	C
78	C	C	C	C	C	C	C	C
85	C	C	C	NC	C	C	C	C
86	NC	C	C	C	C	C	C	C
88	C	C	C	C	C	C	C	C
95	C	C	C	C	C	C	C	C
C	7	10	12	11	9	11	13	13
NC	13	10	8	9	11	9	7	7

Table G

Raw Data for Group 4

Subject	Pretest (Film) L	A	CQS	CQL	Posttest (Clinic) L	A	CQS	CQL
2	NC	NC	NC	NC	NC	NC	NC	NC
16	C	C	C	C	C	C	C	C
17	NC	NC	NC	NC	NC	NC	C	C
21	C	C	C	C	C	C	C	C
27	C	NC	NC	NC	C	NC	NC	NC
32	NC	NC	NC	NC	NC	NC	NC	NC
37	C	NC	NC	NC	C	C	NC	C
42	NC	NC	NC	NC	NC	NC	NC	NC
45	NC	NC	NC	NC	NC	NC	NC	NC
51	C	C	C	C	C	C	C	C
52	C	C	C	C	C	C	C	C
54	NC	NC	C	C	NC	C	NC	C
60	C	C	C	C	C	C	C	C
73	NC	NC	NC	NC	NC	NC	NC	NC
74	NC	NC	NC	NC	NC	NC	NC	NC
75	C	C	NC	NC	C	C	NC	C
80	NC	C	NC	C	C	C	NC	C
82	NC	NC	C	NC	NC	NC	NC	NC
90	C	C	C	C	C	C	C	C
94	NC	NC	NC	NC	NC	NC	NC	NC
C	9	8	8	8	10	10	7	11
NC	11	12	12	12	10	10	13	9

Table H

Summary of Chi Square Analyses for Groups 3 and 4

Chi Square	Length	Area	CQS	CQL
Pretest	.417	.404	1.600	.902
Posttest	.100	.100	3.600*	.417

* $.10 > p > .05$

Table I

Summary of Phi Coefficients for Groups 3 and 4

Group	Length	Area	CQS	CQL
1 (Test-retest)	.81	.70	.89	.81
2 (Equiv. Forms)	.90	.82	.68	.74

Table J

Summary of Percentages of Agreement for Groups 3 and 4

Group	Length	Area	CQS	CQL	$\bar{X}$%
3	90	85	95	90	90
4	95	90	85	85	88.8

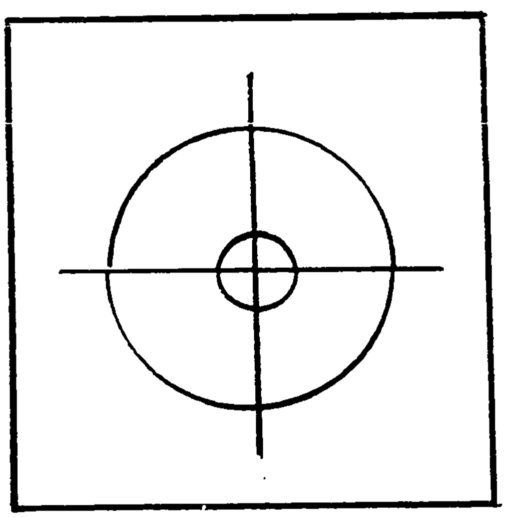
APPENDIX III

Calibration

Calibration of the EM recorder and correlation of corneal reflection and line of sight were made as follows:

The subject was shown card 1 and instructed to keep looking inside the circle. After the reflection was located, the subject was rested and card 2 inserted. The subject was then required to look steadily at the center + and subsequently at each corner in order of numbers. This procedure was repeated before each segment of the movie.

CARD 1



CARD 2