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Relationships between late developing concrete operations and information integration factors in nine and eleven year olds

Falkner, Russell A., Ph.D.
The Ohio State University, 1987
RELATIONSHIPS BETWEEN LATE DEVELOPING CONCRETE OPERATIONS AND INFORMATION INTEGRATION FACTORS IN NINE AND ELEVEN YEAR OLDS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of The Ohio State University

by

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The Ohio State University
1987

Reading Committee: Approved by
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Department of Psychology
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To Debbie
ACKNOWLEDGMENTS

I would like to thank my academic adviser, Philip M. Clark, for the incisive guidance that he has provided. He has been invaluable in helping to shape and direct my efforts. I also thank the other members of my Reading Committee, Gerald A. Winer and John C. Gibbs, who were helpful with their suggestions and constructive criticisms of my work. I also thank my statistical and computer consultants, Jenn-Yun Tein and Joe Groom, whose assistance turned the ethereal into something visual and concrete.

I also would like to express my thanks to Roger Lulow, the superintendent of the Willoughby-Eastlake City Schools, without whose interest and assistance in allowing me to come into that school system this project would never have been. Thanks are also extended to the principles and teachers of the elementary and middle schools. Thanks are also given to parents, who gave their consent for their children to participate and to all the students who participated in this study.

Thanks are also in order to the numerous persons who helped by serving as monitors during group data collection sessions. These individuals lent valued assistance and were too numerous to list here.
I want to thank my mother and stepfather for their support and generous assistance. Finally and most importantly, I thank my wife, Debbie, and daughter, Tamar, whose unending love and support have seen me through the many twists and turns of the process. Thank you.
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CHAPTER I
INTRODUCTION

Significance of the Problem

A current trend in developmental psychology is towards the investigation of processes underlying various hypothetical constructs, e.g., cognitive structures. The basis of this trend was advanced, in part, by the seminal work of Wohlwill (1973), who emphasized the examination of underlying processes as the most heuristic way of studying development. Flavell (1977) furthered this notion when he stated that process-oriented work is essential if phenomena such as cognitive development are to be described, explained and understood. In particular, he provided a notable explication of cognitive development by combining the structural-organismic perspective of Piaget and the information-processing view which he described as:

... programs consist(ing) of intricately interrelated and sequenced cognitive operations or processes that construct or create, receive, transform (recode, reduce, elaborate), store, retrieve, and otherwise manipulate units of information or knowledge. (Flavell, 1977, p. 5)

Others subsequently have called for more work examining processes underlying specific Piagetian operations. In particular, Thayer
and Collyer (1978) suggested in their review of transitive inference that the study of cognitive development might be furthered best through the use of a "modelling approach" such as that proposed by advocates of the information-processing view (e.g., Trabasso, 1975). Further, in his review of class inclusion reasoning, Winer (1980) concluded by stating:

> Of particular value here might be the information processing models used in research of Klahr and Wallace (1973, 1976) and of Trabasso et al. (1978). (p. 325)

The cognitive development literature is replete with work done wherein specific information-processing views have been adopted (Eimas, 1970; Klahr & Wallace, 1973, 1976; Neimark & Lewis, 1967, 1968; Neimark, 1970, 1974; Reitman, 1965; Simon, 1962; Trabasso, 1975; and Trabasso, Isen, Dolecki, McLanahan, Riley & Tucker, 1978). Much of this work has been directed towards providing a clearer understanding of processes underlying or associated with Piagetian operational constructs through an understanding which implicitly draws the analogy of man-as-a-complex-machine.

In contrast to this man-as-a-complex-machine analogy is the work done by Das and his associates (e.g., Das, Kirby & Jarman, 1979). Rather than viewing cognition and problem-solving as being governed by a "... 'program'—quite similar in organization to a computer program" (Simon, 1962, p. 151), the information-integration model (Das et al., 1979) views problem-solving as being related to and directed by three processes,
i.e., simultaneous coding processes, successive coding processes and planning processes, which previously were identified by Luria (1966, 1973). Each of these processes initially was identified as being related to specific sites of neurological lesions in brain injured war veterans. Simultaneous coding processes are associated with the occipito-parietal regions of the cerebral cortex. Successive coding processes, on the other hand, are associated with fronto-temporal cortical regions while planning processes are related to the frontal cortical region of the brain. These three processes reportedly are interdependent inasmuch as "without coded information, planning is empty, and in the absence of a plan, information is blind" (Das, 1984, p. 38).

Wohlwill also recommended correlational analysis as "... the method par excellence for developmental study" (Wohlwill, 1973, p. 240). Das and his associates consistently have used correlational analyses in the form of factor and component analyses of the data from their studies. Their studies typically have included measures associated with the simultaneous and successive coding processes, e.g., Raven's Coloured Progressive Matrices and the Memory for Designs Test for simultaneous coding processes, and Digit Span and Serial Recall for successive coding processes. Occasionally measures associated with planning processes may be included, e.g., Trail Making A and B. In addition to examining simultaneous and successive coding processes of children from various intelligence levels (e.g., Das, 1972; and Jarman & Das, 1977) and various
disabilities (e.g., Jarman, 1978; and Kirby & Das, 1977), Das and his associates also occasionally have studied factor patterns comprised of simultaneous and successive coding process measures as well as measures of various Piagetian structures (Cummins & Das, 1978; Cummins, 1979; Mwamwenda, 1981; and Mwamwenda, Dash & Das, 1984).

The import of classificatory and group structures in the concrete operational stage has been appreciated by proponents of the information-integration model. Consequently, one of the structural hallmarks of this stage, i.e., class inclusion reasoning, consistently has been employed in the various studies wherein Piagetian theory and the information-integration model are combined. Results from these studies have been mixed, however. Specifically, Carlson and Wiedl (1977) reported that class inclusion reasoning loaded primarily on a factor comprised of measures designated as representing successive coding processes. Cummins and Das (1978) reported class inclusion reasoning loaded primarily on an independent factor which also contained secondary loadings of "marker" tests representing simultaneous coding processes. Finally, subsequently reported investigations (e.g., Cummins, 1979; Mwamwenda, 1981; and Mwamwenda et al., 1984) reported class inclusion reasoning as being loaded primarily on a factor comprised of measures associated with simultaneous coding processes.

The ambiguities discussed above are further compounded by information compiled and presented by Winer (1980) in a review of
class inclusion reasoning. One of the important findings reported in this review was that class inclusion reasoning appears to develop completely at a later age than suggested by Piaget (1952, 1963). Thus, while Piaget had suggested that class inclusion reasoning developed around 7 or 8 years of age, empirical evidence was indicating that class inclusion reasoning was not developed until 9 or 10 years of age or later. Subjects in at least two of the previously cited studies, i.e., Mwamwenda (1981) and Carlson and Wiedl (1977) had samples comprised of significantly younger subjects, i.e., average ages of 7 years 5 months and 6 years 3 months, respectively.

Purpose of the Present Study

This study elaborates on and extends previous research by further investigating later developing concrete operational thought and factors associated with the information-integration model. To investigate this, three measures of later developing concrete operational thought, i.e., class inclusion, co-univocal multiplication of classes, and bi-univocal multiplication of relations, will be included in the study. Consistent with the idea of including measures of later developing concrete operational thought, subjects for this study will be older than those typically included in previous studies using the information-integration model, i.e., 9 and 11 years of age. Finally, while theoretical consideration has been given to the interdependence of simultaneous coding, successive coding and planning processes, previous studies typically have included only
representative measures of simultaneous coding and successive coding processes which then have been described as being orthogonal to each other. In an effort to be theoretically consistent and parsimonious in the analysis and explanation of resulting data, the present study will include measures that have been associated with planning processes, e.g., the Trail Making Test, and will analyze and present data that reflects possible relationships between simultaneous coding, successive coding, and planning processes.

The following hypotheses will be the primary focus of this investigation:

1. "Marker" tests will form three distinct factors, e.g., simultaneous coding, successive coding, and planning processes, when factor analyzed.

2. Coding and planning factors will be related when analyzed using a factor analysis with an oblique rotation.

3. Later developing concrete operations will be associated primarily with measures of coding processes and secondarily with planning processes at the younger age level, i.e., 9 years of age.

4. Later developing concrete operations will be associated primarily with measures of planning processes and secondarily with measures of coding processes at the older age level, i.e., 11 years of age.
CHAPTER II
LITERATURE REVIEW

As stated in the previous chapter, more work examining processes underlying Piagetian operational constructs has been called for (Thayer & Collyer, 1978; Winer, 1980). While the highly original work generated by Piaget and his associates as well as the work done by many other investigators in his stead is enormous, processes underlying various operational constructs continue to be poorly understood. This chapter will provide a brief review of Piagetian theory including discussion of the techniques used by Piaget and his associates to investigate cognitive development as well as a discussion of the information-integration theory. The latter half of the chapter specifically will review previous investigations wherein the information-integration theory has been employed to study processes associated with Piagetian theoretical constructs.

General Discussion of Piagetian Theory

The theory of development proposed by psychologist Jean Piaget is one that synthesizes and capitalizes on aspects of other types of theories, i.e., maturational or learning theories,
that have been proposed as ways of characterizing development. Drawing on his early interest and training in biology, Piaget believed that development, specifically cognitive development, is viewed most efficaciously as a special case of biological activity. This perspective consequently led Piaget to discuss cognitive development in the biologically-oriented terms of invariant and inseparable operations, i.e., adaptation and organization (Piaget, 1952). This was not to suggest an isomorphism between biological and cognitive systems. Indeed, while cognitive systems are able to attain endogenously generated elaborations, biological systems are unable to attain elaborations without exogenously derived contents.

Adaptation is a unitary operation consisting of two complimentary processes, i.e., assimilation and accommodation. The assimilatory process functions to incorporate outside elements into sensorimotor schemata or conceptual structures. Accommodation, on the other hand, allows for the consideration of the unique characteristics of elements to be assimilated. Additionally, accommodation serves as an ongoing process of modifying schemata or structures to new inputs. "Intellectual adaptation, like every other kind of adaptation, consists of putting an assimilatory mechanism and a complimentary accommodation into progressive equilibrium" (Piaget, 1952, p. 4).

Equilibration, or equilibrium, represents a point where a system, in this instance a cognitive system, is relatively free
from conflict or self-contradiction, i.e., a balance between assimilation and accommodation obtains. In addition to "progressive equilibrium", other forms of equilibration have been discussed (Piaget, 1977). It is possible, for example, to assimilate various action schemata to objects. Equilibration also may result from the interaction between subsystems within the larger system. This may be particularly evident due to the differing speeds with which various cognitive operations, or subsystems, are acquired. Thus, while seriation, transitivity and class inclusion each represent operations, or subsystems, within a larger system, i.e., the stage of concrete operations, each becomes fully operational at differing times within the development of the concrete operational stage. In such an instance, equilibration depends on the coordination of various subsystems which leads to the discovery of commonalities between the subsystems, as well as partial negations of noncommon portions of the subsystems of the system. Finally, progressive equilibrium obtains when the various characteristics of the subsystems within a system are compared and differentiated. Based on this comparison and the negation which is a part of differentiation, the subsystem characteristics then are integrated into a newly enlarged, total system. Each of the above equilibrations is a product resulting from a balance obtaining between the assimilation and accommodation processes.

Organization, which is inseparable from adaptation, refers to the totality formed by the multiple interrelationships among
the various schemata or operational structures. In such a totality, every schema or operational structure is related to all of the other schemata or operational structures. Organizational systems, i.e., stages, arise from the totality of the interrelationships between schemata and operational structures, which, in turn, change with development. Piaget (1950) discussed stages of development as follows: Children initially are in a sensorimotor stage wherein cognition may be characterized as moving from reflexes present at birth to various motor activities, e.g., primary circular reactions to tertiary circular reactions, and the invention of new means of assimilating and accommodating to objects through mental combinations. The sensori-motor stage is followed by a stage characterized by a developing symbolic function which includes various communicatory functions, e.g., language. In the latter portion of this stage, symbolic and "preconceptual" thought are most evident. Thought herein may be characterized as being irreversible, action-ridden, intuitive and concrete. Around 7 or 8 years of age children enter the concrete operational stage wherein cognitive structures assume greater formality and cognition increasingly becomes more reversible. Additionally, while children still may need to see and handle objects, cognitive operations on the objects increasingly become internalized and invariant. Finally, the last stage, i.e., formal operations, was characterized as being organized by reflective intelligence and increasingly formalized groupings.
Complementing Piaget's work, Tanner and Inhelder (1956) have specified various critical aspects of the stage concept. As evident from the previous discussion of organizational totalities, stages follow an invariant sequence. While related factors, e.g., intellectual, experiential and cultural factors, may alter the timing of the appearance of the various stages, the sequence remains the same. The structural organization defining a given stage forms an integrated totality, referred to by Piaget as a structure d'ensemble. There also purportedly are structural relationships between successive stages such that structural organizations defining earlier stages are integrated into the structural organization of following stages. The initial period of a stage, i.e., the preparatory period, purportedly has a looser organization relating to the ongoing processes of formation and organization. The loose organization which a stage initially is characterized by during this preparatory period represents a disequilibration between the assimilation and accommodation processes. Disequilibration, in turn, engenders structural conflicts or self-contradictions which lead to the "progressive equilibration" of accommodatory and assimilatory processes resulting in the full achievement of the stage. Finally, stages purportedly contain what Piaget referred to as horizontal and vertical decalages. Horizontal decalage refers to the sequential application of available cognitive structures to solve first one problem or task then to solve another similar problem or task during the same developmental stage. Vertical
Decalage, on the other hand, entails the application of available cognitive structures to solve a problem or task during one developmental stage then subsequently applying formally similar cognitive structures in the solution of a similar problem or task at a distinctly different stage.

The Method Clinique

In his own investigations of cognitive development, Piaget relied primarily on two techniques, e.g., naturalistic observation and the method clinique, or clinical method. In his earliest booklength publication, Piaget (1926) reported about meticulously made observations of verbal behavior. Naturalistic observations were used by Piaget primarily in his investigations of "cognition" in infants and gave rise to his development of various tasks which resulted in increasingly more systematic observations (Piaget, 1952). For example, noting that his daughter grasped things in front of her to draw them closer to look at them, Piaget began placing small objects, e.g., his watch, a spoon etc. in her hand when it lay at her side and observed as she increasingly brought the object up before her eyes to look at it. Piaget reportedly used such tasks in a S-R-S-R manner (Flavell, 1963).

In addition to naturalistic observation, Piaget relied on an experimental technique which he termed the method clinique, or clinical method. With this method the investigator conducting the investigation is called upon both to attempt to follow the thinking used by children in their problem solving as well as to
request and follow the explanations of their thinking that children are asked to provide. Through observations of problem-solving behaviors and explanations given by children about these behaviors, Piaget was able to focus his attention on a critically important aspect of his theory, i.e., cognitive structures.

Piaget (1929) expressed an awareness of at least some of the problems entailed in his investigatory method. For example, he stated the need for extensive training in observation as follows:

... it is our opinion that in child psychology as in pathological psychology, at least a year of daily practice is necessary before passing beyond the inevitable fumbling stage of the beginner." (Piaget, 1929, p. 8)

Such "practice" was to include both training of observational prowess as well as training in interviewing and experimentation. Despite this extensive period of "practice", Piaget was aware of possible problems such as leading children by unwitting suggestion to attempt increasingly more correct problem solutions. It also was and is possible to overlook nascent cognitive structures which may have a significant bearing on solutions and explanations given for those solutions of particular problems. Since the clinical method was used for the specification of structural characteristics shared by children at a particular point in their development, it was important to pass over atypical, idiosyncratic or infrequently occurring behaviors that children may exhibit. Finally, Piaget expressed an awareness of the danger of over- or underestimating the
structural level presented by a child on an "observational profile" kept of solutions given to various problems.

In addition to concerns about the correct application of the clinical method expressed by Piaget (1929), others more recently have begun to criticize the clinical method for different reasons (e.g., Braine, 1959; Brainerd, 1973, 1977; Gray & Hofmann, 1976; Miller, 1976; Keating, 1979; and Kingma, 1984). Specifically, it has been suggested that the judgment (solution) plus explanation procedure of the clinical method requires more, than the minimum necessary evidence needed to imply the presence of a particular cognitive structure (Brainerd, 1973). This, consequently, runs the risk of masking the presence of particular cognitive structures (Kingma, 1984). The judgment (solution) plus explanation procedure, moreover, may increase the likelihood of committing a Type II error (Brainerd, 1973; Miller, 1976), thus weakening the validity of the procedure itself (Keating, 1979). Finally, Brainerd (1973) and Gray and Hofmann (1976) have suggested that the clinical method is inherently circular and consequently is biased because it provides data that automatically are congruent with the theory.

The stage of concrete operational thought has been treated more exhaustively than any other stage by Piaget as well as by other investigators. This stage gains its theoretical importance due to its "transitional period" status between preoperational and formal operational thought. Its lower bound is marked by the sensori-motor stage and begins with an extended preparatory
subperiod wherein semiotic processes, e.g., language, are emerging. At this point, thought also is linked closely to perception and consequently has been characterized as being intuitive. At its upper bound the concrete operational subperiod is confined by propositional or formal operations. While formal operations enable children to become increasingly more abstract in their problem solving, there is no distinct dividing point between concrete and formal operations (Inhelder & Piaget, 1958).

Operational thought, whether concrete or propositional, refers to internalized representations of coordinated actions. From this perspective, sensori-motor schemata serve as the precursors of operational structures. Operational structures are organized into larger, coordinated systems referred to as gropements, or groupings. Groupings represent the superordinate structures of the concrete operational stage inasmuch as they subsume and interconnect all of the logical operational structures during this period (Flavell, 1970; Hooper, Sipple, Goldman & Swinton, 1979; Hooper, Swinton & Sipple, 1979; and Wohlwill, 1963). Groupings also have a "transitional" status in that they have group properties that are consistent with concrete operations as well as lattice properties that typically are associated with formal operational thought. Specifically, concrete operational properties which are used to describe groups include composition, e.g., $1 + 1 = 2$, $2 + 1 = 3$, $3 + 1 = 4$ etc., associativity, e.g., $(1 + 1) + 1 = 1 + (1 + 1)$; general identity, e.g., $(1 + 1 = 2) + (0 + 0 = 0) = (1 + 1 = 2)$; and reversibility.
e.g., $1 + 1 = 2$ and $-1 + (-1) = -2$ therefore $(1 + 1 = 2) + (-1 + (-1) = -2) = 2 + (-2) = 0$. The formal operational properties of special identities, e.g., $(A + A^1 = B) = (B + B^1 = C)$ and $(B + B^1 = C) + (D + D^1 = E) = (D + D^1 = E)$, which are indicative of a special identity with itself and a special identity wherein the right hand member is the superordinate of its own right hand class.

Nine distinct groupings were postulated by Piaget (1942, cited in Flavell, 1963), i.e., one minor grouping and eight primary groupings. Of the eight primary groupings, four are concerned with logical classes while the other four are concerned with logical relations. Class groupings imply an ability to perform both composition and the inverse, i.e., subtraction, simultaneously. Specifically, this implies the capacity to add the subordinate classes to obtain the superordinate class as well as to subtract one subclass from the superordinate class to obtain the remaining subordinate class. Relations groupings imply a capacity to be able simultaneously to be aware of equivalence and difference relations, e.g., $A < B$ and $B < C$ simultaneously implies $A < C$ and $C > A$. Finally, primary groupings also subsume what Piaget termed infralogical operations, i.e., operations concerned with space, geometry, time, velocity and movement as well as distance (Piaget & Inhelder, 1956).

Despite their organizational significance in the concrete operational stage, the treatment of groupings in the research
literature has been limited. A search of the relevant literature, for example, revealed only three examples that had included measures of groupings (Klausmeier & Hooper, 1974; Gray, 1979; and Klausmeier & Sipple, 1982). While Klausmeier has included grouping measures with other measures of concrete operations in work done with subjects between the ages of 5 and 12, Gray (1979) included grouping items on "How is Your Logic?", a group test of both concrete and formal operational thought, that was designed and typically would be used with older subjects. The "How is Your Logic?" test ostensibly imbues groupings with a "transitional" status through its inclusion of items purporting to measure both concrete and formal operational thought. The Klausmeier studies, on the other hand, examine relationships of groupings with other concrete operational measures only. While both approaches contain some accuracy, both also include some flaws. Specifically, Klausmeier and Hooper (1974) and Klausmeier and Sipple (1982) did not require subjects to provide explanations of their responses to various individually administered operations and groupings measures which they included in their studies. This approach may have resulted in the inflation of Type I errors, i.e., errors which mistakenly reject the null hypothesis, particularly with younger subjects. Gray (1979), on the other hand, asks subjects taking the "How is Your Logic?" test to respond to items as well as to choose from a number of possible explanations which provide a rationale for their response. Such an approach relies on there being a match
between rationales that subjects may have for their responses and
the ways in which rationales objectively are presented. The
possible occurrence of Type II errors on the "How is Your Logic?"
test, when administered to 9 and 11 year old subjects, may have
contributed to lowered correlations between specific group test
items purportedly measuring Groupings IV and VII as well as class
inclusion and individually administered measures of the same
operations when no response explanation was required (Falkner,
1986). In particular, correlations ranged from 0.21 for class
inclusion to 0.63 for Grouping IV.

In addition to the ubiquitous organizational properties
conferred on groupings, other indicators of concrete operations,
e.g., class inclusion reasoning, have been thought of as being
particularly representative of the stage. In his 1980 review of
class inclusion reasoning, Winer noted an important aspect of
class inclusion reasoning which had not been appreciated widely,
i.e., class inclusion reasoning develops later than originally
thought by Piaget (Inhelder & Piaget, 1964). In particular,
while Inhelder and Piaget (1964) suggested that class inclusion
was developed by 7 or 8 years of age in most children, studies
which had included measures of class inclusion reasoning often
were reporting that it had not developed in the majority of
children even as late as 9 years of age (e.g., Ahr & Youniss,
1970; Carlson, 1971; Winer & Kronberg, 1974; Carlson &
Abrahamson, 1976; Hooper, Sipple & Goldman, 1979; Lovell,
Mitchell & Everett, 1962). Each of these studies reported that
their subjects exhibited approximately 50% success on class inclusion problems at 9 years of age or older.

In addition to the later development of class inclusion reasoning than originally had been suggested, various factor analytic studies of numerous variables, including class inclusion reasoning (e.g., Carlson & Wiedl, 1977; DeVries, 1974; Lunzer, Dolan & Wilkinson, 1976; Rubin, Brown & Priddle, 1978; Stephens, McLaughlin, Miller & Glass, 1972), have provided a notable pattern of findings. Specifically, class inclusion reasoning often loads on a factor that other concrete operational measures are not associated with. For example, Stephens et al. (1972) reported five clearly defineable factors, i.e., a psychometric measures factor, an operational thought factor, a classificatory thought factor which included measures of class inclusion reasoning, a spatial operations factor and a visual perceptual synthesis factor. Thus, while three of the factors were defined by various Piagetian measures, one of those three Piagetian factors was defined by class inclusion reasoning.

More recently, Klausmeier and Sipple (1982) reported findings from their cross-sequentially designed study in which they had included 12 concrete operational and 8 grouping measures. Part of their complex, factor analytic findings indicated that measures of class inclusion reasoning were independent of other measures at the third grade level and associated with the grouping measures of bi-univocal multiplication of relations and co-univocal multiplication of
classes at the fourth and fifth grade levels, respectively. Differences between this study and previously cited studies include a greater number of subjects of an older age range and the inclusion of more Piagetian variables than other studies.

**Information-Integration Model**

The information-integration model of Das and his associates (Das et al., 1975, 1979) drew on the work of Luria (1966) who discussed three functional units of the brain: the arousal and attention unit associated primarily with the upper brain stem and reticular formation; a second unit concerned with the input, recoding and storage of information associated with the occipital, parietal and fronto-temporal cortical regions; and a third unit concerned with the planning and programming of behavior associated with the frontal lobe. Luria also discussed two forms of integrative activity which he associated with the cortices of the second unit, i.e., successive and simultaneous syntheses. Each of these two forms of integrative activity were thought to be associated with different cortical regions. Specifically, simultaneous synthesis is associated with the occipital and parietal cortices and successive synthesis is associated with the fronto-temporal cortex. Simultaneous integration refers to the processing of information through the integration of individual stimuli into groups which essentially allow for surveyability of any portion of the group regardless of its position in the whole. Successive integration, on the other hand, refers to the processing of information in a temporal or
serial order. Thus, with successive processing, information to be processed is not totally surveyable at any point in time.

As specified by Das et al. (1975) in their model of information-integration, the integration of information involves four hypothetical units: input, sensory register, central processes and output. The third unit, i.e., the central processor, represents the location in their model of three component processes analogous to units two and three in Luria's work. Specifically, this is where both simultaneous and successive integration, or coding, processes as well as planning processes are located.

The first stage of the Das model, i.e., the input unit, is where information enters the model. Entering information may arrive in the system through any of the senses and then be transmitted to the sensory register unit. This unit reputedly serves as a buffer through which all stimuli must pass. The sensory register unit in turn functions by transmitting information to the central processing unit. The central processing unit has three major components: two coding processes, i.e., simultaneous and successive coding processes, and a third component which entails planning and decision making processes. Both coding processes are concerned with the coding and storage of information. Planning processes, on the other hand, constitute what may be referred to as "thinking" inasmuch as they use previously coded information to determine plans for action based on this information. The fourth unit of the model,
i.e., the output unit, goes forward with the coordination and performance of action(s) in accordance with the particular task or situational requirements at hand.

Most of the research done by Das and his associates has been concerned with the major components of the central processing unit. Data generated by these studies typically have been submitted to factor analyses and consistently have demonstrated the presence of at least two factors, i.e., simultaneous and successive coding processes, in groups varying on a number of characteristics, e.g., children from different age groups (Das & Molloy, 1975); children from backgrounds differing in socioeconomic and cultural factors (Das, 1972; Mwamwenda, Dash & Das, 1984); children from differing levels of nonretarded intelligence (Jarman & Das, 1977); the presence or absence of learning disabilities (Cummins & Das, 1978; Das, 1983) the presence or absence of mental retardation (Das, 1972; Das & Cummins, 1978; Jarman, 1978; Snart, O'Grady & Das, 1982).

While findings of the studies above consistently have indicated the presence of at least two factors, i.e., factors corresponding to simultaneous and successive coding processes, they are open to numerous criticisms. First, the above cited studies typically are conducted with relatively small numbers of subjects for the number of measures used. While the number of measures used in the above studies are fewer than what often may be used in other studies wherein data are factor analyzed, the subject-variable ratio in the above studies may contribute to
instability in the data. Despite similar results across samples varying in specified characteristics, little evidence is available regarding efforts made to date to compare systematically the conceptual definitions given to factors from the information-integration model with factors from other theories. Consequently, there remains a strong unexplained resemblance between the successive factor of the information-integration model, which includes measures with various memory and verbal characteristics, and other verbal and memory tests (Widaman, 1982). Finally, while Das recently has made efforts to discuss the planning component of the central processing unit (Das, 1984a; Das, 1984b; Das & Heemsbergen, 1984) the use of measures which may be associated with a "planning factor" remain limited.

As previously mentioned, there is a confusion relating to previous efforts to combine the information-integration model with Piagetian theory. Specifically, representative measures from the information-integration model, e.g., Coloured Progressive Matrices, Serial Recall and Digit Span, consistently have been combined with and analyzed with measures from concrete operations (Carlson & Wiedl, 1977; Cummins & Das, 1978; Mwamwenda, 1982). While each of these studies has included measures of class inclusion reasoning, studies conducted by Carlson and Wiedl (1977) and Mwamwenda (1982) also included other concrete operational measures, e.g., conservations of substance, number, and volume, as well as matrices and transitive inference.
Carlson and Wiedl (1977) found that measures of conservation of substance and of number as well as matrices were associated primarily with the factor specified as being the simultaneous processes factor. As with other factor analytic studies with multiple concrete operational variables, they found that their measures of class inclusion reasoning loaded modestly on another factor, i.e., the successive processing factor. The average age of their 180 member sample was 7 years 5 months.

Cummins and Das (1978) reported that class inclusion loaded on a component by itself with secondary loadings of measures associated with simultaneous processes. Measures that typically are associated with the factor of simultaneous coding processes loaded primarily on this in this study. Their subjects were older than those in the Carlson and Wiedl (1977) study, i.e., mean age 9 years; however, they had a disturbingly small sample, i.e., N = 60. Finally, Mwamwenda (1981) used several measures of concrete operational coding, i.e., conservation of volume, transitive inference and class inclusion reasoning, and found that each of these loaded on a factor comprised primarily of measures associated with simultaneous coding processes. While his sample was relatively large, i.e., N = 178, the average age of his subjects was 6 years 3 months.

Of these three studies, only one (Cummins & Das, 1978) included subjects whose ages were consistent with findings reported by Winer (1980), i.e., class inclusion reasoning typically has not developed for most children before 9 years of
age. Results from this study were weakened, however, by the smaller sample size. These findings were further obfuscated by findings from the other two studies, which while having adequately large samples for the factor analyses performed included subjects younger than would be expected to have success in responding to class inclusion problems (Winer, 1980).

Hypotheses

The Hypotheses investigated related both to the information-integration model and to the combination of the information-integration model with concrete operations, specifically later developing concrete operations. The information-integration model would be strengthened if variables associated with each of the three major components in the central processing unit, i.e., simultaneous and successive coding processes as well as planning processes, obtained as factors for two different age groups, e.g., normal 9 and 11 year old subjects. This model also would gain support if it could be shown that there was an interrelationship between the three hypothesized factors. It is hypothesized, therefore, that:

1. "Marker" tests for each of the three major components in the central processing unit of the information-integration unit will form three distinct factors, i.e., a simultaneous coding processes factor and a planning processes factor at both age levels.
2. Factors obtaining for planning and simultaneous and successive coding processes will be related when the factors are rotated obliquely.

Consistent with previous findings (e.g., Cummins & Das, 1984; Carlson & Wiedl, 1977; Mwamwenda, 1982) later developing, concrete operations, e.g., class inclusion reasoning, should be associated primarily with coding processes at the younger level. It, therefore, is hypothesized:

3. Later developing, concrete operations will be associated primarily with factors defined by "marker" tests of either simultaneous or successive coding processes and secondarily with the factor defined by "marker" tests associated with the planning factor for 9 year old subjects.

Consistent with development, including development of the brain, later developing, concrete operations should be associated primarily with planning processes which are associated with the frontal lobe of the brain. It, therefore, is hypothesized:

4. Later developing, concrete operations will be associated primarily with the factor defined by "marker" tests associated with planning and secondarily with the factors of simultaneous and successive coding processes for 11 year old subjects.
CHAPTER III

METHOD

Subjects

Children participating in the study were students in the Willoughby-Eastlake City Schools. This school system is the public school system for the communities of Willoughby, Eastlake and Willowick, Ohio, which are three eastern suburbs of Cleveland, Ohio. A total of 180 9 and 11 year old students from four elementary schools and two middle schools in the school system participated in the study (Tables 1 and 2). Possible subjects were identified at each of the four elementary and two middle schools by the investigator using computer listings of all the children in the school who were either 9 or 11 years of age. Each of the identified 9 or 11 year old students attending each of the elementary and middle schools participating in the study was given an explanatory cover letter and an attached Consent for Participation in Social and Behavioral Research form (Appendix A) to take home to his/her parents or guardians. A total of 423 cover letters and consent forms were sent home with students (Appendix A). A total of 194
### Table 1

#### Distribution of 9 Year Old Subjects Across Participating Elementary Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Numbers of Subjects by Sex</th>
<th>Mean Age</th>
<th>Standard Deviation of Age</th>
<th>Range of Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grant Elementary School</td>
<td>Female</td>
<td>9-2</td>
<td>3 months</td>
<td>9-0 to 9-7</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>9-8</td>
<td>2 months</td>
<td>9-3 to 9-11</td>
</tr>
<tr>
<td>Jefferson Elementary</td>
<td>Female</td>
<td>9-3</td>
<td>2 months</td>
<td>9-1 to 9-5</td>
</tr>
<tr>
<td>School</td>
<td>Male</td>
<td>9-7</td>
<td>2 months</td>
<td>9-1 to 9-9</td>
</tr>
<tr>
<td>Longfellow Elementary</td>
<td>Female</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>School</td>
<td>Male</td>
<td>9-4</td>
<td>3 months</td>
<td>9-0 to 9-7</td>
</tr>
<tr>
<td>Washington Elementary</td>
<td>Female</td>
<td>9-7</td>
<td>4 months</td>
<td>9-0 to 9-11</td>
</tr>
<tr>
<td>School</td>
<td>Male</td>
<td>9-6</td>
<td>3 months</td>
<td>9-0 to 9-10</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>45</td>
<td>9-4</td>
<td>9-0 to 9-11</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>45</td>
<td>9-7</td>
<td>9-0 to 9-11</td>
</tr>
<tr>
<td>Total 9 year old subjects</td>
<td></td>
<td>90</td>
<td>9-5</td>
<td>9-0 to 9-11</td>
</tr>
</tbody>
</table>
Table 2

Distribution of 11 Year Old Subjects Across Participating Elementary and Middle Schools

<table>
<thead>
<tr>
<th>School</th>
<th>Female Subjects</th>
<th>Male Subjects</th>
<th>Mean Age</th>
<th>Standard Deviation of Age</th>
<th>Range of Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grant Elementary School</td>
<td>Female 1</td>
<td>Male 3</td>
<td>11-3</td>
<td>1 month</td>
<td>11-2 to 11-3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eastlake Middle School</td>
<td>Female 24</td>
<td>Male 18</td>
<td>11-8</td>
<td>4 months</td>
<td>11-1 to 11-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11-3</td>
<td>3 months</td>
<td>11-1 to 11-11</td>
</tr>
<tr>
<td>Jefferson Elementary</td>
<td>Female 3</td>
<td>Male 1</td>
<td>11-2</td>
<td>1 month</td>
<td>11-1 to 11-4</td>
</tr>
<tr>
<td>School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Washington Elementary</td>
<td>Female 2</td>
<td>Male 5</td>
<td>11-2</td>
<td>1 month</td>
<td>11-1 to 11-4</td>
</tr>
<tr>
<td>School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Willowick Middle School</td>
<td>Female 15</td>
<td>Male 18</td>
<td>11-9</td>
<td>5 months</td>
<td>11-2 to 11-11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11-6</td>
<td>4 months</td>
<td>11-2 to 11-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female 45</td>
<td>Male 45</td>
<td>11-7</td>
<td>3 months</td>
<td>11-1 to 11-11</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Female 45</td>
<td>Male 45</td>
<td>11-4</td>
<td>2 months</td>
<td>11-1 to 11-10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total 11 year old subjects</td>
<td></td>
<td>11-6</td>
<td>3 months</td>
<td>11-1 to 11-11</td>
</tr>
</tbody>
</table>
Consent to Participate in Social and Behavioral Research forms, or 46% of all consent forms, were signed by parents or guardians and returned to the school by the students, i.e., their daughters or sons. Thirteen of the 194 students who returned signed consent forms were not included in the study for the following reasons: 2 students were 8 years old, 1 student was 10 years of age, 4 students were 12 years of age and 6 students including 2 nine year old girls, one nine year old boy and 3 eleven year old girls were extra subjects. One eleven year old girl refused to participate in the study and was replaced by another eleven year old girl. Replacement entailed selecting the first girl who had brought in a signed consent form of the 3 extra 11 year old girls. A total of 180 students participated in the study, i.e., ninety 9 year olds ($\bar{X}$ age = 9-6 years, range 9-0 to 9-11 years, and ninety 11 year olds ($\bar{X}$ age = 11.4 years, range 11-1 to 11-11 years). Participation in the study was predicated on returning a signed Consent for Participation in Social and Behavioral Research form and by there being 90 subjects at each of the two age levels. The 90 subjects of each age level were divided equally such that there were 45 girls and 45 boys in each of the two age groups. Treatment of subjects in this study was in accordance with the Ethical Standards of the American Psychological Association (APA, 1981).
Materials Used

Nine measures were administered to all subjects in this study (Appendix B). Three of the measures were drawn from Piagetian theory, i.e., measures of later developing concrete operations. Specifically, measures of class inclusion (CI); Grouping IV, co-univocal multiplication of class (CO); and Grouping VII, bi-univocal multiplication of relations (Bi), were used. Six measures were drawn from or consistent with the information-integration theory. Specifically, the following measures were used: Raven's Coloured Progressive Matrices (CPM), Spatial Memory (Spamem), Digit Span Forward (DS), Word Series (WS), the Trail Making Test A and B (Trail A or Trail B) and the Word Finding Test (WFT). Descriptions of the preceding measures are as follows:

Class Inclusion (CI) (Piaget, 1952): This concrete operational measure contained three items in which the subject was presented with a line drawing, e.g., 6 dogs and 2 cats, and asked "Are there more dogs or more animals?". The three items were counterbalanced to reveal the use of a response set. Specifically, the superordinate term, e.g., "animals" in the above question, was the last term in questions one and three and the first term in question two. The scores provided on this measure were 1 (pass) or 0 (fail) for each item with a passing of at least two of the three items in a manner not indicative of a
response set, e.g., questions 1 and 2, 2 and 3 or 1, 2 and 3, needed to obtain an overall score of 1. The subject's verbal response to each item was used as the basis for the assignment of a score.

**Co-univocal multiplication of classes (CO)** (Piaget, 1942, cited in Flavell, 1963): This concrete operational measure was specified by Piaget as grouping IV and refers to classes derived by establishing a correspondence between one class with many members and another class with a single member. This particular measure consisted of two items in which the subject was presented with a class of several members, e.g., seven baseball cards with pictures of pitchers, and a second class with a single member, e.g., a single baseball card with the picture of a catcher, and directed to show all the pairs of pitcher and catcher that could be tried together. The scores provided on this measure were 1 (pass) or 0 (fail) for each item with a passing of at least one of the two items needed to obtain an overall score of 1. No verbal interaction was required in response to each item consequently the subject's observed manipulation of the test materials was used as the basis for the assignment of a score.

**Bi-univocal multiplication of relations (Bi)** (Piaget, 1942, cited in Flavell, 1963): This concrete operational measure was specified by Piaget as grouping VII and refers to establishing a one-to-one correspondence between two or more series of
asymmetrical relations. This particular measure consisted of two items in which the subject was presented 16 cards varying on two dimensions, e.g., 4 different sizes of circles with one to four lines drawn from the edge to the center of each circle. Thirteen of the 16 cards were spread randomly around in front of the subject while the remaining 3 cards, i.e., 1 large and 2 small circles containing different numbers of lines, were placed in corner positions of an imaginary square pattern which the subject was directed to construct using the remaining 13 cards. The scores provided on this measure were 1 (pass) or 0 (fail) for each item with a passing of at least one of the two items needed to obtain an overall score of 1. No verbal interaction was required in response to each item consequently the subject's observed manipulation of the test materials was used as the basis for the assignment of a score.

Raven's Coloured Progressive Matrices (CPM) (Raven, 1956; Raven, Court & Raven, 1977): This measure is described by Raven (1956) as a nonverbal measure of intellectual ability and served as a "marker" test of simultaneous coding processes (Das et al., 1975, 1979). The measure consists of 36 visual matrices with each matrix missing a single piece. Subjects were directed to select one of the six alternative responses pictured above the matrix which would complete the matrix correctly. The scores provided by this measure were the total number of correct responses given.
Spatial Memory (Spamem) (Kaufman and Kaufman, 1983): This measure served as a "marker" test of simultaneous coding processes. This measure consists of 22 items with pictures displayed in different positions in each item. Subjects were directed to view a slide of each item, and the different arrangement of pictures in each item, for 5 seconds. After the slide (item) had disappeared, subjects responded by marking a blank grid with a check or an "x" where each picture had been seen. The scores provided by this measure were the total number of correctly completed items.

Digit Span (DS): This measure served as a "marker" test of successive coding processes and consisted of groups of numbers ranging from three to nine digits. The numbers were presented on an audiotape at the speed of one digit per second. After listening to each group of numbers in its entirety, subjects responded, as previously directed, by immediately writing down the digits that they had listened to in the order that the digits had been presented. The score provided by this measure was the total number of groups of numbers that had been written in the order in which they had been presented.

Word Series (WS) (Das et al., 1979): This measure served as a "marker" test of successive coding processes and consisted of twenty-four groups of four words. All of the words in the groups of words are familiar three and four letter words, e.g., "cat", "big", "stop" etc. The groups of words were presented on an audiotape at the speed of one word per second. After listening to each group of four words in its entirety, subjects responded, as previously directed, by immediately writing down the words that they had listened to in the order that the words had been presented. The score provided by this measure was the total number of groups of words that had been written in the order in which they had been presented.

Trail Making Test (Trail A or Trail B) (Armitage, 1946; Reitan, 1979): This measure served as a "marker" test of planning processes and consists of two parts, i.e., A and B, which are performed under time pressure. On part A, the subject was directed to connect as quickly as possible the numbers from 1 to 15 arranged on a page. On part B, the subject was directed to connect as quickly as possible a numeric and alphabetic series alternating between the two series, e.g., 1 to A then A to 2 then 2 to B etc. The score provided by this measure was the total number of seconds needed to complete each part.

Children's Word Finding Test (WFT) (Pajurkova, Orr, Rourke & Finlayson, 1977; Rourke & Gates, 1980): This measure is a test
of verbal problem solving and served as a "marker" test of planning processes. This measure consists of 13 items, each comprised of 5 sentences containing a nonsense word, "grobnick". Subjects were read each sentence and directed to determine the meaning of the nonsense word through their understanding of the verbal context. After listening to each sentence and before the next sentence was read, subjects responded by writing down their response, i.e., what the nonsense word was thought to represent. The scores recorded were the total number of correct responses given.

Procedure

According to their age, subjects were placed in one of two groups, i.e., the 9 year old group or the 11 year old group. Individual subjects were seen on three separate occasions. Specifically, all of the subjects were involved in two group data collection sessions with groups ranging in size from 3 to 14 subjects, $\bar{X} = 9.5$ subjects. Each group data collection session lasted 30 to 35 minutes and was separated by at least 7 days from any other data collection session. The specific composition of groups varied from session to session depending on subject availability, i.e., if there were no conflicting school requirements such as a field trip, a test, or a student assembly, or if particular subjects happened to be absent from school. Group data collection sessions were counterbalanced in a session
1, session 2 order if 2 or 3 groups of subjects were seen successively during a particular day to lessen the likelihood of subject contamination ensuing from information or misinformation about the various measures being passed from subject to subject. If more than one group data collection session was conducted in a day and there was more than a thirty minute gap between group data collection sessions, the data collection sessions were counterbalanced in a session 1, session 2 order to lessen the likelihood of subject contamination ensuing from information or misinformation about the various measures being passed from subject to subject.

In addition to two group data collection sessions, each subject also was seen in an individual data collection session. The individual data collection sessions took from 10 to 15 minutes and were separated for each subject by at least 7 days from either of the other two data collection sessions. Subjects who participated individually on any particular day were selected from single classrooms. Before the individual data collection sessions were conducted, the investigator would discuss with the classroom teacher the optimal ordering of subjects to minimize the likelihood of subject contamination ensuing from information or misinformation about the various measures being passed from subject to subject.
In the individual data collection session, four of the nine total measures were administered in the following order: the Trail Making Test parts A and B, the first of two co-univocal multiplication of classes items, the first of two bi-univocal multiplication of relations, 3 class inclusion items, the second of two bi-univocal multiplication of relations items and the second of two co-univocal multiplication of classes items (see measure instructions, Appendix B). Five of the nine total measures were collected in the two group data collection sessions. In one group data collection session, the following measures were administered in the following order: Digit Span, Word Series and Raven's Coloured Progressive Matrices. In the other group data collection session, the following measures were administered in the following order: Spatial Memory and the Children's Word Finding Test (see measure instructions, Appendix B).
CHAPTER IV
RESULTS

Differences Between 9 and 11 Year Olds

The data were initially analyzed to determine whether or not significant differences existed between the two age groups on the 9 measured variables in this study. The 6 variables designated as being associated with the information-integration model were analyzed using a t-test. Results for these comparisons are presented in Table 3 and indicate the existence of significant differences favoring the 11 year old group on the following measures: Word Finding Test, $t = -2.11, p < 0.04$; Spatial Memory, $t = -2.93, p < 0.003$; Digit Span, $t = -5.63, p < 0.0001$; and Word Series, $t = -3.72, p < 0.0003$. The concrete operational measures were analyzed using the test for significance of the difference between two proportions (Bruning & Kintz, 1977). Results of these comparisons are presented in Table 4 and indicate significant differences between the proportions of correct responses given on the measures of class inclusion and co-univocal multiplication of classes, i.e., $z = 2.12, p < 0.05$. 

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Table 3

*t-test Comparisons for 9 and 11 Year Old Groups on 6 Representative Variables of the Information-Integration Model*

<table>
<thead>
<tr>
<th>Variable</th>
<th>9 Year Olds</th>
<th></th>
<th>11 Year Olds</th>
<th></th>
<th>t-test Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard Deviation</td>
<td>Mean</td>
<td>Standard Deviation</td>
<td></td>
</tr>
<tr>
<td>Word Finding Test</td>
<td>32.83</td>
<td>6.60</td>
<td>34.83</td>
<td>6.08</td>
<td>-2.11*</td>
</tr>
<tr>
<td>Trails B</td>
<td>36.49</td>
<td>17.91</td>
<td>31.16</td>
<td>22.20</td>
<td>1.77</td>
</tr>
<tr>
<td>Coloured Progressive Matrices</td>
<td>30.18</td>
<td>4.42</td>
<td>31.20</td>
<td>4.09</td>
<td>-1.61</td>
</tr>
<tr>
<td>Spatial Memory</td>
<td>13.29</td>
<td>3.30</td>
<td>14.68</td>
<td>3.05</td>
<td>-2.93**</td>
</tr>
<tr>
<td>Digit Span</td>
<td>5.27</td>
<td>1.77</td>
<td>6.79</td>
<td>1.85</td>
<td>-5.63****</td>
</tr>
<tr>
<td>Word Series</td>
<td>7.42</td>
<td>4.50</td>
<td>9.98</td>
<td>4.70</td>
<td>-3.72***</td>
</tr>
</tbody>
</table>

*p < 0.05  **p < 0.005  ***p < 0.0005  ****p < 0.0001
Table 4

Significance of Differences Between Proportions of Correct Responses Given to Measures of Later Developing Concrete Operational Thought by 9 and 11 Year Old Age Groups

<table>
<thead>
<tr>
<th>Measures</th>
<th>9 Year Olds</th>
<th></th>
<th>11 Year Olds</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Responses</td>
<td>%</td>
<td>N</td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>90</td>
<td>42</td>
<td>.467</td>
<td>90</td>
</tr>
<tr>
<td>Co-Univocal Multiplication of Classes</td>
<td>90</td>
<td>32</td>
<td>.356</td>
<td>90</td>
</tr>
<tr>
<td>Bi-Univocal Multiplication of Classes</td>
<td>90</td>
<td>22</td>
<td>.244</td>
<td>90</td>
</tr>
</tbody>
</table>

* $p < 0.05$  ** $p < 0.01$
and $z = 4.16, p < 0.01$, respectively, favoring the 11 year old group. There was no significant difference, however, between the proportions of correct responses given to the bi-univocal multiplication of relations measure by the two age groups.

**Confirmatory Factor Analyses of 9 and 11 Year Old Data**

The data also were analyzed to test four hypothetical questions. First, "marker" tests will form three distinct factors, i.e., a simultaneous coding processes factor, a successive coding processes factor and a planning processes factor. This analysis was accomplished using a confirmatory factor analysis of the six "marker" measures for each of the two age groups in this study (Joreskog & Sorbom, 1981). Second, planning and coding processes factors will be related when the resulting factors are rotated obliquely. This analysis was done using a confirmatory factor analyses of the six "marker" measures for each of the two age groups in the study. A further exploratory factor analysis of the six "marker" measures was performed for the 9 year old group. Third, late developing concrete operations will be associated primarily with measures of coding processes and secondarily with measures of planning processes for the younger of the two age groups in this study, i.e., the 9 year old age group. Data for the 9 year old group initially were analyzed using the LISREL confirmatory factor analysis program, then the SAS exploratory factor analysis
program and finally the correlation matrix of the 9 measured variables was examined (Joreskog & Sorbom, 1981; SAS, 1985). Fourth, late developing concrete operations will be associated primarily with measures of planning processes and secondarily with coding processes for the older of the two age groups in this study, i.e., the 11 year old age group. This analysis was accomplished using a confirmatory factor analysis of the 9 measured variables (Joreskog & Sorbom, 1981).

The 3 latent variables, i.e., Simultaneous Coding Processes, Successive Coding Processes and Planning Processes, predicted to be defined by the 6 manifest variables, i.e., the Children's Word Finding Test (FT), the Trail Making Test (Trail B), Raven's Coloured Progressive Matrices (CPM), Spatial Memory (Spamem), Digit Span (DS) and Word Series (WS), are presented as a structural model in Figure 1. Separate confirmatory factor analyses were performed on the data collected for the six manifest variables in each of the two age groups (Figures 2 and 3).

While the structural model for the 11 year old group was compatible with the data, the same model was not compatible with the data for the 9 year old group. As indicated in Table 5, the null model for the 11 year old group represents a better fit of the 6 manifest variables to the specified model than the null model for the same 6 manifest variables for the 9 year old group.
Table 5
Null Models for the 9 and 11 Year Old Groups

<table>
<thead>
<tr>
<th>Model</th>
<th>$x^2$</th>
<th>df</th>
<th>Prob.</th>
<th>$Q$</th>
<th>rho</th>
<th>GFI</th>
<th>RMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Null model for 9 year old group</td>
<td>-950.53</td>
<td>6</td>
<td>1.00</td>
<td>-950.53</td>
<td>---</td>
<td>-4.196</td>
<td>1.793</td>
</tr>
<tr>
<td>Null model for 11 year old group</td>
<td>123.16</td>
<td>15</td>
<td>0.00</td>
<td>8.21</td>
<td>---</td>
<td>0.629</td>
<td>0.291</td>
</tr>
</tbody>
</table>

The inferential measure, i.e., $x^2$, is not particularly useful to consider inasmuch as it is very sensitive to sample size and tests for the exact fit of $H_0$. On the other hand, the other measures in Table 5, i.e., $Q$, GFI and RMR are descriptive statistics and consequently are more useful to employ in the present situation.

In particular, $z$ is provided by $x^2/df$. The larger the value associated with $Q$, as in the 9 year old group above, the less accurate the fit of the model is. The Goodness of Fit Index (GFI), which is provided by $GFI = ss$ of model/$ss$ of data and the root mean squared residual (RMR) are useful to employ when the data being analyzed are correlations rather than covariances, as was the case in this situation. Specifically, greater absolute values associated with RMR indicate a decrease in the
representativeness of the model for the data. In Table 5, the RMR value for the 11 year old group (e.g., RMR = 0.291) is indicative of a better fit of the model than the RMR values for the 9 year old group (e.g., RMR = 1.793).

While the data for the 6 manifest variables of the 11 year old group ostensibly are more representative of fit with the predicted structural model than the 6 manifest variables from the 9 year old group, this model does not provide any information about which latent variable, if any, the later developing concrete operational variables may be associated with. The hypothesis that manifest, late developing concrete operational variables would be associated primarily with the latent, planning processes variable and secondarily with the latent simultaneous or successive processes variables was tested using a confirmatory factor analysis (Joreskog & Sorbom, 1981). To do this, five different structural models were analyzed and compared including a null model, or model 1; a model wherein the manifest, later developing operational variables were specified as being associated with the planning processes latent variable, or model 2 (Figure 4); a model wherein the manifest, late developing concrete operational variables were specified as being associated with the simultaneous coding processes latent variable, or model 3 (Figure 5); and a model wherein the manifest, late developing concrete operational variables were specified as being associated
with the successive coding processes latent variable, or model 4 (Figure 6). Because of the marginal fit that any of these models, i.e., models 1 through 4, had with the manifest, late developing concrete operations variables, a fifth model, model 5 (Figure 7), was tested. For model 5, the manifest, late developing concrete operational variables were specified as being associated with each of the three latent variables to ascertain the amount of variance accounted for by each latent variable for each manifest, late developing concrete operational variable.

The indices of goodness of fit for each of the five models discussed above are provided in Table 6.

### Table 6
Eleven Year Old Group's Indices of Goodness of Fit for 5 Structural Models Derived from 3 Latent Variables and 9 Manifest Variables

<table>
<thead>
<tr>
<th>Model</th>
<th>$\chi^2$</th>
<th>df</th>
<th>Prob.</th>
<th>$Q$</th>
<th>rho</th>
<th>GFI</th>
<th>RMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1 (Null model)</td>
<td>175.95</td>
<td>36</td>
<td>0.000</td>
<td>4.888</td>
<td>---</td>
<td>0.629</td>
<td>0.291</td>
</tr>
<tr>
<td>Model 2</td>
<td>35.35</td>
<td>24</td>
<td>0.063</td>
<td>1.473</td>
<td>0.878</td>
<td>0.915</td>
<td>0.076</td>
</tr>
<tr>
<td>Model 3</td>
<td>37.66</td>
<td>24</td>
<td>0.038</td>
<td>1.569</td>
<td>0.853</td>
<td>0.912</td>
<td>0.080</td>
</tr>
<tr>
<td>Model 4</td>
<td>45.98</td>
<td>24</td>
<td>0.004</td>
<td>1.916</td>
<td>0.764</td>
<td>0.887</td>
<td>0.086</td>
</tr>
<tr>
<td>Model 5</td>
<td>22.38</td>
<td>18</td>
<td>0.216</td>
<td>1.243</td>
<td>0.938</td>
<td>0.952</td>
<td>0.059</td>
</tr>
</tbody>
</table>
Inspection of the Table 6 columns under the descriptive statistics of Q, rho, GFI and RMR reveals that the lowest values for Q and RMR, i.e., 1.243 and 0.059, respectively, are associated with model 5 while the highest values for rho and GFI, i.e., 0.932 and 0.952, respectively, also are associated with model 5.

The correlations between the latent variables Planning, Simultaneous Coding and Successive Coding Processes, as well as the correlations between the 3 latent variables and the 9 manifest variables for the 11 year old group are presented in Figure 5. First, the correlations between the Planning and Simultaneous Coding Processes latent variables (i.e., $r_{\text{plan . simultaneous}} = 0.40$) and between the Planning and Successive Coding Processes latent variables (i.e., $r_{\text{plan . successive}} = 0.34$) are both greater than the correlation between the Simultaneous and Successive Coding Processes latent variables (i.e., $r_{\text{simultaneous . successive}} = 0.19$). Second, and consistent with the fourth hypothesis, while the manifest, late developing concrete operational variables are related to all 3 latent variables, the path weights between each latent and the manifest, late developing concrete operational variables are greatest for the paths between the planning processes latent variable and the three manifest, late developing concrete operational variables.
Exploratory Factor Analysis of 9 Year Old Data

A further analysis of data from the 9 year old group was done using an exploratory factor analysis of 0 order correlations with the final factor retention based on eigenvalues $\geq 1.00$. Based on this a priori retention procedure, 3 factors were retained and initially an oblique rotation of the factors was performed. The significantly lowered interfactor correlations of the 3 obliquely rotated factors indicated the efficacy of performing an orthogonal rotation of the 3 retained factors. The factor loading patterns for the 3 orthogonally rotated factors are presented in Table 7.

The factor loading patterns for the 3 orthogonally rotated factors were such that they have little apparent meaning. In particular, Factor I has primary loadings from the Word Finding Test, Class Inclusion, the Trail Making Test (Trail B) and Word Series measures and consequently may be called the Planning Factor. Factor II, on the other hand, has primary loadings from the Spatial Memory, Bi-univocal multiplication of relations, Digit Span and Coloured Progressive Matrices measures and consequently may be called the Simultaneous coding processes factor. Finally, Factor III has a primary loading from the Co-univocal multiplication of classes measure as well as weak secondary loadings from the Trail Making Test (Trail B) and Digit Span measures and consequently may be called the X factor. Aside
<table>
<thead>
<tr>
<th>Test</th>
<th>Factor I</th>
<th>Factor II</th>
<th>Factor III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word Finding Test</td>
<td>0.80</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>Trail B</td>
<td>0.61</td>
<td>0.01</td>
<td>0.47</td>
</tr>
<tr>
<td>Coloured Progressive Matrices</td>
<td>0.42</td>
<td>0.42</td>
<td>0.02</td>
</tr>
<tr>
<td>Spatial Memory</td>
<td>0.10</td>
<td>0.80</td>
<td>0.01</td>
</tr>
<tr>
<td>Digit Span</td>
<td>0.06</td>
<td>0.51</td>
<td>0.46</td>
</tr>
<tr>
<td>Word Series</td>
<td>0.51</td>
<td>0.44</td>
<td>0.08</td>
</tr>
<tr>
<td>Class Inclusion</td>
<td>0.68</td>
<td>0.01</td>
<td>0.15</td>
</tr>
<tr>
<td>Co-Univocal Multiplication of Classes</td>
<td>0.26</td>
<td>0.09</td>
<td>0.80</td>
</tr>
<tr>
<td>Bi-Univocal Multiplication of Relations</td>
<td>0.16</td>
<td>0.67</td>
<td>0.04</td>
</tr>
</tbody>
</table>
from the apparent uninterpretability of these factors, it is notable that each measured concrete operational variable loads primarily on a factor independent of the other late developing concrete operational measures. Specifically, the class inclusion measure loads primarily on Factor 1 which also includes measures typically associated with planning processes. The Bi-univocal multiplication of relations measure loaded primarily on Factor II which also includes measures often associated with simultaneous coding processes. Finally, the Co-univocal multiplication of classes loads primarily on Factor III with weak loadings from measures frequently associated with planning and successive coding process, i.e., the Trail Making Test (Trail B) and Digit Span Measures, respectively.

Analysis of Correlational Data for 9 Year Olds

A final analysis of data collected from the 9 year old group entailed examining the correlation matrix (Table 8) of the 9 measures with particular emphasis on correlations between each of the 3 late developing concrete operations measures and the 6 other measures. In particular, class inclusion was related most significantly to the Word Finding Test, \( r = 0.39, p < 0.0002 \), and the Trail Making Test (Trail B), \( r = 0.21, p < 0.05 \). Both of these measures, it will be remembered, were "marker" tests relating to planning processes for the 11 year old group.
Table 8
Correlation Matrix of 9 Measures for the 9 and 11 Year Old Groups*

<table>
<thead>
<tr>
<th></th>
<th>WFT</th>
<th>Trail B</th>
<th>CPM</th>
<th>Spamem</th>
<th>DSP</th>
<th>WS</th>
<th>CI</th>
<th>CO</th>
<th>Bi</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFT</td>
<td>1.00</td>
<td>-0.37</td>
<td>0.38</td>
<td>0.36</td>
<td>0.3</td>
<td>0.22</td>
<td>0.37</td>
<td>0.32</td>
<td>0.22</td>
</tr>
<tr>
<td>Trail B</td>
<td>-0.29</td>
<td>1.00</td>
<td>-0.38</td>
<td>-0.36</td>
<td>-0.39</td>
<td>-0.14</td>
<td>-0.10</td>
<td>-0.06</td>
<td></td>
</tr>
<tr>
<td>CPM</td>
<td>0.34</td>
<td>-0.16</td>
<td>1.00</td>
<td>0.57</td>
<td>0.10</td>
<td>0.32</td>
<td>0.36</td>
<td>0.14</td>
<td>0.22</td>
</tr>
<tr>
<td>Spamem</td>
<td>0.038</td>
<td>-0.06</td>
<td>0.30</td>
<td>1.00</td>
<td>0.07</td>
<td>0.20</td>
<td>0.20</td>
<td>0.16</td>
<td>0.15</td>
</tr>
<tr>
<td>DSP</td>
<td>-0.00</td>
<td>-0.11</td>
<td>0.10</td>
<td>0.23</td>
<td>1.00</td>
<td>0.46</td>
<td>0.06</td>
<td>0.14</td>
<td>-0.06</td>
</tr>
<tr>
<td>WS</td>
<td>0.45</td>
<td>-0.18</td>
<td>0.22</td>
<td>0.17</td>
<td>0.25</td>
<td>1.00</td>
<td>0.16</td>
<td>0.18</td>
<td>0.11</td>
</tr>
<tr>
<td>CI</td>
<td>0.39</td>
<td>-0.21</td>
<td>0.22</td>
<td>-0.01</td>
<td>0.08</td>
<td>0.16</td>
<td>1.00</td>
<td>0.31</td>
<td>0.36</td>
</tr>
<tr>
<td>CO</td>
<td>0.17</td>
<td>0.01</td>
<td>0.07</td>
<td>0.03</td>
<td>-0.10</td>
<td>0.20</td>
<td>0.24</td>
<td>1.00</td>
<td>0.16</td>
</tr>
<tr>
<td>Bi</td>
<td>0.19</td>
<td>-0.13</td>
<td>0.21</td>
<td>0.34</td>
<td>0.18</td>
<td>0.27</td>
<td>0.14</td>
<td>0.06</td>
<td>1.00</td>
</tr>
</tbody>
</table>

* The 11 year old group correlation matrix of 9 measures is in the top half of the table.
Additionally, the class inclusion measure was related significantly to the Coloured Progressive Matrices, $r = 0.22$, $p < 0.05$. This measure, it will be recalled, was described by Raven (1956) as a nonverbal measure of intellectual ability.

The co-univocal multiplication of classes measure was related significantly to only one nonconcrete operational measure, i.e., Word Series, $r = 0.20$, $p < 0.05$. The co-univocal multiplication of classes measure was related most significantly to the class inclusion reasoning measure, $r = 0.24$, $p < 0.02$.

Finally, significant relationships were apparent between the bi-univocal multiplication of relations measure and Spatial Memory, $r = 0.34$, $p < 0.001$, and Coloured Progressive Matrices, $r = 0.21$, $p < 0.05$. Both of these measures, it will be remembered, were "marker" tests relating to simultaneous coding processes for the 11 year old group. The bi-univocal multiplication of relations measure also was related significantly to the Word Series measure, $r = 0.27$, $p < 0.01$. 

The results obtained in this study were mixed inasmuch as they bore out some of the hypotheses and did not support other hypotheses. First, there were age differences on 6 of the 9 measures which reasonably could be expected to ensue through development. Specifically, 11 year old subjects had significantly better performances on the Word Finding Test, Spatial Memory, Digit Span, Word Series measures as well as better performances on two measures of later developing, concrete operations, i.e., class inclusion reasoning and co-univocal multiplication of classes. While these findings are clearly expected, differences in their significance are not immediately apparent without further elaboration which will be provided below.

The confirmatory factor analysis of the 6 "marker" tests began to provide meaning for the findings of differences between various measures favoring the 11 year old group. When submitted to a confirmatory factor analysis of the 6 "marker" tests, which
incidently were presumed to be associated with specific cerebral areas, to confirm the prediction of there being 3 latent variables that would obtain, this hypothesis was only partially confirmed. While the existence of 3 latent variables, i.e., simultaneous coding, successive coding and planning processes, was confirmed for the 11 year old group this did not obtain from the confirmatory factor analysis on data from the 9 year old group. An obvious implication of this finding might be that the brains of 11 year old children are more developed, i.e., the brains of 11 year old children are differently organized.

The fact that the obliquely rotated factors obtained from the confirmatory factor analysis further elaborated the previously discussed findings. Specifically, while 3 latent variables obtained for the 11 year old group, these latent variables were significantly related, i.e., the planning processes latent variable was significantly related to both the simultaneous coding and the successive coding processes latent variable. In the parlance of information-integration neuropsychology, the planning processes, which ostensibly are related to the frontal lobes, are more disposed to provide organizing and directive functions for 11 year olds than they are in 9 year olds. In particular, the implication is that these functions arise in the course of development.
The role that the planning processes play was further clarified by the findings relating to the third and fourth hypotheses. In particular, it was hypothesized that late developing concrete operations would be primarily associated with one or both of the coding processes in the 9 year old group. This particular prediction was only partially confirmed. First, three factors from an exploratory factor analysis of the data from the 9 year old group did not form recognizable factors from an information-integration perspective, i.e., planning, successive coding and simultaneous coding process factors. Second, and perhaps more interesting, was the finding that each late developing, concrete operation was individually associated with its own factor. Thus, the measure of class inclusion reasoning was associated with a factor comprised of measures associated with planning processes, i.e., the Word Finding Test and Trail B as well as the Coloured Progressive Matrices and Word Series measures. Bi-univocal multiplication of relations, on the other hand, was associated with another and different factor comprised of measures typically associated with both simultaneous and successive coding processes, i.e., Coloured Progressive Matrices and Spatial Memory as well as the Digit Span and Word Series measures. Finally, the measure of co-univocal multiplication of classes loaded primarily on a third factor, separate from the first two factors, and had a secondary loading
of the Digit Span measure which typically is related to the successive coding processes factor. The significance of these results cannot be fully appreciated without also considering the results from the 11 year old group. Herein the late developing, concrete operations were related to all of the latent variables, with the primary relationship being with the planning processes latent variable. These multiple relationships between late developing, concrete operational measures and each of the latent variables presents the strongest case for the organization and directive functions which emanate from the frontal lobes.

Conclusions

Measures associated with the information-integration model were used in this study in an attempt to obtain a better understanding of processes underlying late developing concrete operations. The findings reported above, moreover, served to resolve an apparent confusion arising from results of previous investigations (e.g., Carlson & Wiedl, 1977; Cummins & Das, 1978; and Mwamwenda et al., 1984). Specifically, Carlson and Wiedl (1977) reported class inclusion reasoning to be modestly related to successive coding processes while Cummins and Das (1978) reported a loading of class inclusion reasoning on a factor independent of both successive and simultaneous coding processes. Mwamwenda et al. (1984), on the other hand, reported that class
inclusion reasoning was primarily associated with simultaneous
coding processes.

The above confusions could have arisen, in part, from
subject ages. In particular, Carlson and Wiedl (1977) had a
sample comprised of 180 subjects whose average age was 7 years 5
months while Mwamwenda et al. (1984) had a sample comprised of
178 subjects whose average age was 6 years 3 months. Winer
(1980) reported that class inclusion reasoning develops later
than originally theorized, i.e., around 9 or 10 years of age
instead of around 7 or 8 years. Finally, Cummins and Das (1978)
had a sample comprised of subjects whose average age was 9 years,
the relatively small subject to variable ratio, i.e., 3.7 to 1,
easily could have rendered their results unstable.

With the above pattern of confusing results and the
relatively late development of class inclusion reasoning it was
reasonable to hypothesize that other information-integration
model processes, i.e., planning processes, might contribute more
to class inclusion reasoning than either simultaneous coding or
successive coding processes. The results of the present study
indicated that class inclusion reasoning is primarily associated
with planning process measures, i.e., the Word Finding Test and
the Trail Making Test Parts A and B, at both 9 and 11 years of
age. These process measures, it should be remembered, are
indicative of both abstract thinking and flexibility which often
accompanies abstract thinking. Abstract thinking also seems to have served as a mediating variable facilitating an equilibration of the subsystems represented by the 3 measures of late developing concrete operations in this study, i.e., class inclusion reasoning, co-univocal multiplication of classes and bi-univocal multiplication of relations. This was particularly evident for the 11 year old group in this study. Thus, while each of the 3 late developing concrete operations included in this study was associated with an independent factor at the 9 year old age level, an organization of these operations was obtained at the 11 year old level, as indicated by their primary association with the planning processes latent variable (factor) at this older age level. This particular finding, moreover, is consistent with Piagetian theory inasmuch as grouping operations reputedly entail properties associated with both concrete and more abstract operations, i.e., formal operations, for their successful solution.

Further research in the form of short term, longitudinal studies of emerging late developing concrete operations is needed, particularly of groupings and their association with other concrete operations, e.g., conservation of volume, to provide a clearer understanding of relationships between these operations and groupings and how these relationships may vary over time. It also would be useful for research to be done
investigating the relationships between groupings and various early developing formal operations. Investigations such as these could serve to clarify the ways in which transitions from concrete to formal operational thought obtain. Finally, continued investigations of processes underlying both concrete and formal operational thought are needed.
LIST OF REFERENCES


Carlson, M. T., & Abrahamson, A. (1976). Some members are more equal than others; the effect of semantic typicality on class-inclusion performance. Child Development, 47, 1186-1190.


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of the Piagetian stage of concrete operations. Contemporary Educational Psychology, 7, 161-180.


Pajurkova, E. M., Orr, R. R., Rourke, B. P., & Finlayson,


Trabasso, T., Isen, A. M., Dolecki, P., McLanahan, A. G.,


Figure 1: Structural Model of 5 manifest variables and 3 latent variables
Figure 2: Model for 6 Information-Integration Model Variables - 9 year olds
Figure 3: Model for 6 Information-Integration Model Variable - 11 year olds
Figure 4: Model 2-3 Manifest Piagetian variables associated with the Planning Processes latent variable
Figure 5: Model 3-3 Manifest Piagetian variables associated with the Simultaneous Coding Processes latent variable
Figure 6: Model 4-3 Manifest Piagetian variables associated with the Successive Coding Processes latent variable
Figure 7: Model 5-3 Manifest Piagetian variables associated with Planning, Simultaneous Coding and Successive Coding Processes.
APPENDIX A

COVER LETTER AND CONSENT FORM
Dear Parent(s) or Guardian(s),

This letter is being sent to you to explain a study being conducted at your child’s school. The Willoughby-Eastlake Superintendent of Schools, Roger Lulow, Ph.D., and the Principal of your child’s middle school have agreed to allow this study to be conducted. Your child has been identified as a possible participant in this study because he or she attends Eastlake Middle School and he or she is 11 years of age.

The study is called "The Changing Relationship Between Later Developing Concrete Operational Thought and Successive, Simultaneous and Planning Processes." The study is concerned with some of the specific things that may contribute to the way in which elementary school children are able to solve problems. Children participating in this study will be asked to solve problems that rely on remembering numbers, words and pictures that they will be exposed to. Other problems that participating children will be asked to solve will include quickly connecting circles containing letters or numbers, choosing from patterned shapes to complete a larger pattern and figuring out the meaning of a nonsense word (grobnick) when read sentences using the nonsense word. Finally, participating children also will be asked to solve problems where they will need to arrange line drawings of circles and squares into patterns as well as sort, combine and organize pictures of flowers, marbles and people.

In the present study, each child will participate for approximately 90 minutes in all. The 90 minutes will be broken up into 3 30 minute group problem solving sessions in which children will be asked to solve the previously described problems using paper and a pencil. Each child will be seen individually for approximately 5 minutes to perform the task of connecting circled letters or numbers. Your child's participation in the study will remain confidential unless you specify otherwise.

Please read over the attached “Consent for Participation in Social and Behavioral Research” form. If you have any questions you are invited to contact Russell A. Falkner, M.A., the Authorized Representative of the study, at the following number: 921-1770. When you have read over the attached form and had any questions answered that you may have, please sign the form and return it to your child's teacher.

Thank you so much for your attention to this matter.

Sincerely,

Russell A. Falkner, M.A.  Philip M. Clark, Ph.D.
Authorized Representative  Principal Investigator
CONSENT FOR PARTICIPATION IN
SOCIAL AND BEHAVIORAL RESEARCH

I consent to participating in (or my child's participation in) research entitled:
The Changing Relationships between Later Developing Concrete Operations and Successive, Simultaneous and Planning Processes

or his/her authorized representative has explained the purpose of the study, the procedures to be followed, and the expected duration of my (my child's) participation. Possible benefits of the study have been described as have alternative procedures, if such procedures are applicable and available.

I acknowledge that I have had the opportunity to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. Further, I understand that I am (my child is) free to withdraw consent at any time and to discontinue participation in the study without prejudice to me (my child). The information obtained from me (my child) will remain confidential unless I specifically agree otherwise by placing my initials here.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: _______________________ Signed: ________________________

Signed: ________________________
(Principal Investigator or his/her Authorized Representative)

Signed: ________________________
(Person Authorized to Consent for Participant - If Required)

Witness: ________________________

HS-027 (Rev. 12-81) — To be used only in connection with social and behavioral research.
APPENDIX B

"MARKER" AND PIAGETIAN TEST INSTRUCTIONS
DIGIT SPAN

I AM GOING TO SAY SOME NUMBERS. LISTEN CAREFULLY, AND WHEN I AM THROUGH WRITE THEM RIGHT AFTER ME.
PLEASE NOTE:

Copyrighted materials in this document have not been filmed at the request of the author. They are available for consultation, however, in the author's university library.

These consist of pages:

Appendix B MARKER and Peagetian Test Instructions Pages
80-99.

University
Microfilms
International
300 N Zeeb Rd., Ann Arbor, MI 48106 (313) 761-4700