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FACTORS INFLUENCING GRADE I MATH ACHIEVEMENT.

University — Université

ALBERTA.

Degree for which thesis was presented — Grade pour lequel cette thèse fut présentée

M. Ed.

Year this degree conferred — Année d'obtention de ce grade

1981

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April 20, 1981

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NL-91 (4/77)

THE UNIVERSITY OF ALBERTA

FACTORS INFLUENCING GRADE I MATHEMATICS ACHIEVEMENT

BY

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A THESIS

PRESENTED TO
THE FACULTY OF GRADUATE STUDIES
AND RESEARCH IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
DEGREE OF MASTER OF EDUCATION
IN
COUNSELING PSYCHOLOGY

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

SPRING, 1981

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR . . . LORRAINE H. FAIRHALL

TITLE OF THESIS . . . FACTORS INFLUENCING GRADE I MATHEMATICS ACHIEVEMENT

DEGREE FOR WHICH THESIS WAS PRESENTED . . . M.ED.

YEAR THIS DEGREE GRANTED . . . 1981

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ABSTRACT

The purpose of this study was to isolate factors influencing grade one mathematics achievement. Those factors chosen for investigation were:

1. Age and sex of subjects.
2. Right-Left orientation.
3. Auditory sequential memory.
4. The concept of conservation. Specifically conservation of discontinuous quantity; lasting equivalence of number; spontaneous correspondence; seriation; and ordination and cardination.
5. Auditory attention span.
6. Visual-motor integration.

Selection of the above factors stemmed from an interest in the research of Jean Piaget: Particularly in the importance he gives to conservation as a prerequisite for acquiring number concept. The second area of interest was the field of learning disabilities and the emphasis placed on the role of perceptual processes in learning.

Two analyses were performed: A correlational analysis investigated the relationship of each variable to mathematics achievement; then a multiple stepwise regression technique was

used to determine the amount of variance in math scores accounted for by combinations of predictor variables.

The major results of the study were:

1. There is no significant relationship between grade one mathematics achievement and the following factors: Age and sex; right-left orientation; auditory sequential memory; the concept of conservation as measured in discontinuous quantity, spontaneous correspondence, seriation, and ordination and cardination.

2. There is a significant relationship between grade one mathematics achievement and the following factors: Visual-motor integration; conservation as measured in lasting equivalence of number; and auditory memory span.

3. In combination, performance on visual-motor integration, lasting equivalence, auditory memory span, and right-left orientation account for a significant amount of variance in mathematics scores.

ACKNOWLEDGEMENTS

This study evolved from the cooperative efforts of many participants. Grateful appreciation is extended to Dr. Carolyn Yewchuk for her encouragement and guidance as thesis advisor. The writer would also like to thank Dr. Lillian Whyte and Dr. George Cathcart for their helpful and perceptive criticisms.

Mr. W. Novak, Superintendent of Schools, Medley, was instrumental in allowing for the research to take place. His cooperation and professional attitude are acknowledged with thanks. A special note of appreciation is extended to the grade one teachers and pupils who eagerly participated in the study.

Finally, the writer wishes to thank Sherry Rutledge for her assistance with the testing, and Donna Stephens for her typing skills and patient efforts during the preparation of the manuscript.

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CHAPTER I

INTRODUCTION

This study has resulted from an interest in three wide-ranging areas of educational research: The theories of Jean Piaget; grade one mathematics programming; and the field of learning disabilities. Consequently, a substantial amount of literature was reviewed in an attempt to reveal possible factors influencing grade one mathematics achievement.

Perhaps the greatest impetus for research came from the investigations of Jean Piaget. His emphasis on the developing child's unique view of the world presents a challenge to the educator: It challenges the teacher to recognize this unique view; and it challenges the curriculum developer to present the subject matter with the child, not the material, in mind. In short, Piaget claims that the subject matter of learning must be appropriate to the child's cognitive level. If this is so, then learning will occur. For Piaget, the child is the dynamic and central element of the learning process. Piaget's theory of sequential and hierarchical stages of cognitive growth suggests a maturational approach to teaching and learning. Children are seen as having a preset rate of growth, each following a general pattern, yet unique to the individual. The child arriving in grade one may, or may not, have the cognitive skills which allow for reading or mathematical readiness. Ames (1968) has commented:

> The outstanding cause of school difficulty in our experience is immaturity. The majority of children experiencing learning problems as seen by our clinical service have been overplaced in school. This presents a serious hazard since overplacement or lack of readiness not only aggravates learning problems when they exist, but causes problems in cases where there is potential for performance (in Lerner, 1976:321).

The concept of school "readiness" has led to the second major area of interest in this study; that of grade one mathematics programming. It is not the intent here to evaluate the grade one program currently in use in Alberta schools. The focus is on the individual child's adaption to the program. Certain key assumptions have been made: That the grade one teachers involved in the research have followed the curriculum guidelines, and that the testing resulted in a fair measure of achievement of those curriculum guidelines. The terms "arithmetic" and "mathematics" have both been used. The Concise Oxford Dictionary (1964) defines arithmetic as the "science of numbers; computation", whereas mathematics is defined as the "science of space, quantity and numbers". The term "mathematics" was selected for the title as the program and the testing covered a broader range than straight computation. Elements of time, space, etc., were included just as they are in the Program of Studies outline (Appendix A).

The third major interest area, the field of learning disabilities, has inherently focused on individual differences in learning. Histoi i‹ ally, learning disabilities research has highlighted the role of perceptual processes. Diagnosis typically involves description in perceptual terms: dyslexia, dyspraxia, dyscalculia, dysphasia are but some examples. Similarly, remediation frequently involves emphasis on the development of perceptual modes. Research has shown that children who display problems in mathematics learning also exhibit deficiencies in one or more perceptual process. If deficiencies in these processes result in poor performance, then perhaps acuity in perceptual modalities should successfully influence grade one mathematics achievement.

It must be acknowledged that the attempt to synthesize research from such broad areas has resulted in a limited treatment of each. The general nature of the topic under consideation has necessitated wide, but selective research. The und ying concern o study has been the individual child in the school situatic Mc specifically, the intent is to mphasize the need for idualized approach to instruc particularly in grade o iematics.

With a minor substitution which does not alter the intent, Lerner (1976) has summed up appropriately:

> It has been noted, ironically, that with all our attempts to be "scientific" about discussions made in education, one of the most important-when to teach a child mathematics-is based on the science of astrology. The star under which the child is born, the birthdate, is the key determining factor or this crucial decision because this determines when the child begins formal school learning. 325.

CHAPTER II

THE RESEARCH

The Acquisition of Mathematics Knowledge

The development of mathematical concepts in the early school grades takes second place behind the need to learn to read. This point is acceptable to most educators. To operate effectively in school the child must be able to read. The controversial issue here is that varying mathematical abilities are not always acknowledged by the primary teacher. Children are tested and grouped according to some measure of reading "readiness". Seldom is mathematics "readiness" recognized. It is the contention of this study that children do differ significantly in both the cognitive and perceptual skills which they apply to learning mathematics.

The extensive research of Jean Piaget has focused on the role of cognition in the learning process. He has observed logico-mathematical thought to develop at predetermined stages which can be roughly equated with chronological age. Piaget's research has highlighted age 7 as the approximate age of the emergence of the concrete operational thought which allows for a true understanding of number concept. For Piaget, learning is at once dependent on the child's cognitive level, and upon vigorous interaction with the environment. The child does not simply absorb information like a sponge; instead, he brings an active intellect into exchange with his environment.

The importance of perceptual processes in learning has been outlined in the current learning disabilities literature: (Cruickshank & Hallahan, 1975; Hallahan & Kaufman, 1976; and Lerner, 1976). This literature emphasizes the uniqueness of the individual child, particularly in the possible range of visual, motor, and auditory perceptual acuity which he brings to the school setting.

Research has pointed to efficient methods of instruction as well as to the cognitive levels of the developing child and the influence of perceptual processes. In two recent texts (Riesman, 1977; and Kramer, 1978), the authors outline the theories which continue to influence the field of mathematics teaching. The major theorists in this field appear to focus on the method of presentation of material, rather than on the learner.

Jerome Bruner has identified three methods of presenting the mathematics curriculum; The inactive (concrete) levels whereby the learner manipulates materials. This is considered the "lowest" form of learning and suggested as the introductory step, particularly in the primary grades: The second level is the iconic, or picture level. Here information is presented in the form of pictures, diagrams or mental images: The "highest" level of presentation is the symbolic where ideas are taught in mathematical symbols, including numerals.

> For Bruner, it is the method of learning, the process, that is most significant. His goal is discovery. Discovery does not necessarily result in something that is new to the learner; it is, rather an internal reorganization of something that was already present in the person...Bruner's hypothesis on readiness for learning is that any subject can be taught effectively in some intellectually honest form to any child at any stage of development (Kramer, 1978:41).

Bruner's emphasis is on the method of presentation. He does not ignore individual differences in learners, but believes these differences can be met by effective organization of the material to be taught.

Robert Gagné has devised an elaborate "stage-learning" process whereby mathematical knowledge is acquired. Beginning with "signal learning" the child can be moved through an increasingly complex learning sequence. Where Bruner has focussed on the processes of learning, Gagné is concerned with the behavior displayed during learning:

> He states in behavioral terms what he wants the child to do...Pretests determine the level of the child. Then it is decided what subject matter must be presented and a tight sequential program is prescribed. The child is guided step by step. The child is to move from the lowest levels of development, and learning, through concepts and principles, to the highest level, the solving of problems...According to Gagné, a child is ready for a new concept when all the concepts that are prerequisite to that concept are mastered (Kramer, 1978: 43).

Gagné has certainly allowed for individualized programming. However, his emphasis is on the sequencing of knowledge, rather than on the learner. Similarly, William Brownell (1950, in Riesman,

1977) has developed a hierarchical model which emphasizes the quality of material to be learned, rather than the learner. Brownell has labeled his simplest level as "arbitrary association" which refers to the learning of basic facts that have no inherent meaning: Symbols and words are classed as arbitrary associations. The child is moved to "concepts" the second level involving ideas and abstractions such as size and color. The level of "principle learning" involves the understanding of rules and laws, while "problem solving", the most complex level, requires the learner to analyse and synthesize material.

Z. P. Dienes (in Kramer, 1978) has outlined four principles of mathematical learning. These provide a guide for effective presentation of material to be learned. Dienes' "dynamic principle" is the understanding that the child moves from undirected play situations to structured activities and then to a practice stage in which concepts are learned and applied. Dienes contends that constructive thinking precedes analytical thinking. Thus the child should be exposed to situations where learning can take place in a discovery atmosphere. He calls this awareness the "constructive principle". In a third principle, called the "mathematical variable", Dienes maintains that mathematical concepts should be taught through a wide variety of examples. Finally, his "perceptual variable principle" contends that the perceptual presentation of concepts should be as varied as possible. For example, when teaching parallelograms, the instructor should present them on paper, on the chalkboard, and laid out with elastics, etc. It appears obvious that Dienes' approach favors the concept that children will learn if taught in an effective manner. Thus his focus too is on content and presentation rather than on the individual learner.

Piaget's Theory of Cognitive Development

It is interesting to note that both Reisman (1977) and Kramer (1978) begin discussion on the improvement of mathematics instruction with mention of the work of Jean Piaget. Reisman has noted that Piaget's studies on the conceptual thinking of children have important implications for teaching number concepts to young children. Piaget's approach emphasizes the actions of the child rather than the materials, or the methods of instruction. The child is the active element:

> ...when we are acting upon an object, we can also take into account the action itself, or operation if you will, since the transformation can be carried out mentally...The abstraction is drawn not from the object that is acted upon, but from the action itself...This is the basis of logical and mathematical abstraction (Piaget, 1970, in Reisman, 1977:27).

Thus, Piaget's focus is on the learner and the cognitive structures he brings to the learning environment.

Piaget's theory of cognitive development presents the child as a dynamic organism in continual interaction with the environment. The basic theme of his theory is the systematic development of cognitive structures through adaption to a changing physical world.

The child's experiences are organized into schemas which provide him with the potential to engage in increasingly complex behaviors. The developing child is viewed as an "inwardly motivated" organism. Beginning with a purely physical interaction, then building on this foundation to later abstract thinking, the child constructs a hierarchy of stimuli.

Piaget has presented a notion of constant, irreversible stages of cognitive development. The four major stages he has outlined are for him the fundamental process of cognitive growth in the child. Piaget's stage-theory has been outlined and investigated in many major works (Lowell, 1961; Flavell, 1963; Isaacs, 1964; Furth, 1970; and Elkind, 1976). His concept of irreversible developmental stages has been supported by research (Fleischmann, Gilmore & Ginsburg, 1966; Reiss, 1967; Goldschmid, 1967; Dudek & Dyer, 1972).

Phillips (1969) reminds us:

> ...the concept of stage can be useful if we keep in mind three things (1) that different children may pass through the sequence of stages at different rates, (2) that each stage is named for the process that has most recently become operative, even though others may be operating at the same time, and (3) that each is the formation of a total structure that includes its predecessors within it as necessary structures (:18).

[illegible] or stages during which the child acquires the [illegible] n increasingly complex modes will be discussed at [illegible]. O[illegible]ticular relevance to this study is the [illegible] proposed by Piaget-that of "concrete operations".

At approximately age 7 years, the child reaches this period. Compared to the sensorimotor infant of the first stage, the child who has reached the concrete operations stage is flexible and abstract. However, compared to the adolescent, the "concrete operational" child is still "concrete" in his thinking.

Piaget contends that the features associated with concrete operational thinking must be present before the child can truly "know" the basic logico-mathematical concepts. These features include:

> Conservation--The realization that the number, length, substance, or area has not changed although it may be presented in a number of different ways. The ability to conserve requires the use of reversible operations...
>
> Reversibility--The process of reversing thought. For example, one can mentally pour liquid from one container to another, and then reverse the process by mentally pouring the liquid back into the original container (Hergenhahn, 1975:283).

Piagetians maintain that the concepts of conservation and reversibility are essential for the child to be able to cope with addition and subtraction.

Crawford (1967) states:

> Even when the child is fluent in his use of numbers and words, and can do rote counting, this does not allow us to conclude that he knows what he is talking about... children must realize that the part is never greater than the whole. Until they do they are incapable of understanding addition or subtraction (in Sullivan, 1967:19).

For Piaget, the development of number concept is directly linked to the concept of cognition. His theory postulates the concrete operational stage as being significant in intellectual development. The child who has reached this stage can be taught through operational instructional methods. For Piaget (1970) "special talents" are not relevant. Children who display varying abilities are simply at different stages of intellectual development, and consequently at different levels in their abilities to handle arithmetic processes.

Piaget has designated 6 to 7 years (R. Lerner, 1976) as the age at which most children develop the ability to conserve and reverse operations. Piaget's age limits are not absolute: Some children will reach this stage early, while others may manifest signs of preoperational thinking at age 9 (Goldschmid, 1967; Whyte, 1977). Piagetian type tests have been discussed as significant indicators of grade one achievement (Dudek, Lester & Goldberg & Dyer, 1969; Kaufman & Kaufman, 1972).

Age 7 is an important milestone in current educational practices. Most children in Alberta are admitted into Kindergarten no younger than 4½ years (age 5 on February 28th is usually the cut-off date). Consequently, at entry, grade one children range in age from 5½ to almost 6½ years. Thus, in Piagetian terms, grade one children might still be in the second, or "preoperational stage", or perhaps have moved into certain frames of the concrete operational stage. Piaget (1952) has stated that the child does not gain the ability to make conservations in all quantitative dimensions at one time. Number and length conservations appear first, then area, while volume conservation usually appears last.

Number concept has been the subject of extensive Piagetian research. Piaget has been concerned with the capabilities which allow for certain assumptions about the nature and behavior of numbers. Those features of number obvious to the adult are not always available to the child until the development of concrete operational thought. Isaacs (1960) summarizes the adult view:

> To us...number is for a start, any member of a systematic counting scheme which begins from one and proceeds one-by-one; and it is the number of all sets or collections that can be formed by the same counting process carried to the same point...this leads to further stages of counting in groups, instead of one-by-one, combining groups and separating them-whilst maintaining its basic character of one-by-one countability (11).

For Piaget (1952) number is essentially a fusion or hesis of two logical entities: class and asymetrical relation. If a set of objects is counted, thus establishing its cardinal number value (ie. "6 objects there"), the objects are treated as if they are alike (ie. of one class). However, there is also a sense in which they can be differentiated one from another: They have an order jects must be first, second, third and so on. This process is termed ordination:

> The objects arranged in the order in which one enumerated them form a true series, a set of asymetrical relations, exactly analogous to a series of sticks of graded lengths. However, the objects appear different, not in length, but in ordinal position (Flavell, 1963:311).

Piaget has demonstrated that the notion of a unit, basic to understanding of all mathematics, is gradually constructed out of the child's active attempts at classification and seriation. Classification refers to the grouping of objects according to some common distinguishing characteristic. As the child classifies objects according to such characteristics as color and size, he develops a notion of cardinality. As this process becomes more complex, then seriation will become a variable as the child organizes materials in graduating sizes, shapes, etc., thus forming a series. Objects and numbers then adopt another feature as they become first, second, ninth and so on, establishing an ordinal sequence. For aget, a child must integrate the qualitative notions of classification, seriation, ordination, and cardination, before he can learn the number system. Elkind (1976) has stated that one of Piaget's greatest contributions to our understanding of learning is the notion that the child must grasp these qualitative concepts before he can make quantitative judgements.

Piaget has thus been concerned with the child's ability to classify objects and group them into sets. He has also investigated the child's grasp of essential additive and multiplicative properties of numbers. He stresses the importance of an understanding of a one-to-one correspondence, although noting that such understanding does not signal an understanding of the reversible qualities of number. For example, a child may be able to count out six pennies to buy six candies at a penny each.

However, he might not be able to put the pennies into two groups of three and hold the concept "6 pennies".

Piaget and his researchers have investigated several areas of number concept. One main area of investigation was to find out if any real notion of number existed by varying the shape, appearance, size and spacing of groups of objects. If the child was able to conserve and reverse, then the test revealed an appreciation of the constancy of number. One note here is that this test also involved the measuring of cognitive development as opposed to perceptual appearances. For example, previously counted beads were poured into a narrow container. Children who did not have an idea of number constancy believed that there were more in this container because the beads were "taller"

In another cardinal experiment Piaget examined whether children could match one counted group with another and thus establish a "one-to-one" understanding. A third group of tests involved children arranging and rearranging two unequal heaps into equal ones, or appreciating that if two equal sets were sub-divided differently, that they would still stay equal. These tests checked ideas of reversibility and constancy of number necessary for a true understanding of addition and subtraction processes.

Piaget's research involved many such experiments as described above. As well as those involving cardination, he was interested in the other major aspect of number-ordination. Using graded dolls and correspondingly size-graded walking sticks he asked children to match one from each group-thus establishing their ideas of coordination. In these he provided evidence that:

> ...children's understanding of ordinal numbers and relations depends on their developing grasp of cardinal ones (Isaacs, 1960:26).

During this investigation Piaget (1952) established three stages in the development of number concept. As he believed such development to be dependent upon the attainment of concrete operational thinking, his investigations included children from 5 to 7 years of age. He established "Stage 1" thinkers who had no one-to-one correspondence, displaying a complete lack of any number concept. "Stage 2" thinkers exhibited some uncertain decisions before coming to the correct conclusion. (Piaget observed their responses often to be "intuitive" rather than based on logical thought). "Stage 3" thinkers exhibited normal adult-type responses. Age was not a determining factor in Piaget's number experiments. Some 6 year olds revealed Stage 3 thinking, while Stage 1 conclusions were reached by others almost 8 years old.

Other researchers have developed tests based on Piaget's original work in Geneva (Pinard & Laurendeau, 1964; Marks, 1972). Goldschmid (1967) has been critical of the development of some Piaget-type tests, as he sees too much freedom and insufficient guidelines in construction, while recommending careful investigation of such tests before important conclusions are reached.

Piaget's emphasis has been on the dynamic aspects of cognitive development. He views the child in constant interaction with his surroundings. Lerner (1976:283-284) has briefly outlined the important elements in Piaget's theory of cognitive development:

1. Assimilation-responding to the environment accordin to existing cognitive structures. A kind of "knowing".

2. Accommodation-cognitive structures are gradually modified to assimilate new experiences with the environment: roughly equated with "learning".

3. Disequilibrium-the cognition imbalance created by accommodation means adjustment is required to stabilize the organism.

4. Equilibration-the need for harmonious balance between the organism and its environment.

The process of organizing the environment is constructed from these elements. Piaget sees "intelligence" as this dynamic process.

> Intelligence constitutes the state of equilibrium towards which tend all the successive adaptions of a sensorimotor and cognitive nature, as well as all assimilatory and accommodatory interactions between organism and environment (Piaget, 1960:11).

In his description of the first or sensorimotor stage, (birth to 2 years), Piaget concentrates on the child's adaption to his environment. Unlike lower forms of life, the human infant shows an ability to organize his environment through cognitive processes rather than instincts. Cognition is generated in the infant by "innate schema". For Piaget, these schema are the essential components of cognitive development. These congenital schema are believed to be present at birth and motivate the infant to interact with his environment. Unlike instinctive, or reflex actions, schema are not primitive or mysterious in origin. They are purposeful in operation and potential to perform. Once schema are activated, they no longer remain innate. The infant builds up an increasingly sophisticated set of schema which he uses at will.

During the Peroperational Stage (2-6 years), the major cognitive development is the appearance of symbolic functioning, best exemplified by language. At this stage, the child's cognitive structure consists predominately of unidirectional schema. The young child is not able to reverse events. Consequently, he is not able to conserve.

The emergence of operational structures gives the child the knowledge that actions can be counteracted by reversing them. (An operation is an internalized action that is reversible. Elkind, 1976:93). The emergence of operations is equated with the beginning of Piaget's third stage. At approximately age 11 years, the child moves into the realms of the Formal Operations Stage. Here thinking becomes "adult-like" in logic and abstract thinking ability.

Piaget's View of Perception

In the context of general psychology, perception encompasses the processes by which we understand the information that comes through our senses. Piaget describes perception in a narrower framework than does this general approach. He views perception as an integral, though subordinate, aspect of the developing intellect. He does not offer explanations of the associated systems, such as perceptual-motor integration, as are so frequently mentioned in the learning disabilities literature.

Piaget describes perception as a developing system which becomes increasingly adaptive with age. For Piaget:

> ...perception is both developmentally subordinate and structurally inferior to intelligence as a class of adaption (Flavell, 1963:232).

In his research, intelligence and perception are sharply distinguished forms of adaption. What does emerge is that perception has some importance in the early stages of development, but it is left behind as cognitive processes become more complex:

> ...perception arises developmentally, not as an autonomous mode of adaption in its own right, but as a kind of dependent sub-system within the larger context of an evolving sensorimotor intelligence (Flavell, 1963:232).

Piaget concentrates on visual perception and offers an account of what he believes happens when the visual system centres on a simple stimulus such as a straight line. Piaget (1969) assumes that the perception of the line is a developing process which takes place over a brief period of time. The construction of the complete percept takes place across micro-intervals of time. Elements of the visual system are matched with elements of the stimulus (ie. the line). A second sampling matches further elements of vision and stimulus. Thus the complete line is eventually perceived through a process of matching and selections. Piaget has treated perception from a purely "physical" point of view. He does allow for weaknesses in the physiological system: "Elementary Error I" occurs when a line near or on the fixation point will appear longer than an equivalent one located away from the fixation point. Piaget also identified "Elementary Error II" as a relative over-estimation of the longer of two lines, when a visual display consists of two lines.

Of interest to this study, is Piaget's "positive" view of the perceptual process. That is, everything is supposed to function according to the proposed physiological plan. No mention is made of problems arising from the malfunction of the perceptual system.

For Piaget, perceptual processes are well established at birth. During the first month the infant responds selectively to different visual patterns and forms. These early perceptual processes are not sequential, or age related in their development. For Piaget, they are "field effects":

> These are gestalt-like organizational structures which are part of the infant's initial equipment. Field effects organize experience according to gestalt-like principles of good form, closure, and so on, and continue to do so in more or less the same way across the entire life span (Elkind, 1976:140).

In contrast to the appearance of these "field effects", perceptual performance proper begins only in the preschool years. Piaget believes that perceptual regulations begin to appear at about age three. Gradually, perceptual operations become refined in their functioning. With the development of perceptual operations, perception becomes active and spontaneously restructures the field into its many possible organizations.

In a series of studies, Elkind and associates (Elkind & Scott, 1962; Elkind, Koegler & Go, 1964; Elkind & Weiss, 1967) conducted research based on Piaget's theory of perception. Elkind & Scott (1962) take the positive view and present perception as an active force in the maturational process. In the young child perception is seen as passive and dominated by the "best" organization of the field.

> Piaget defines the "decentering of perception" as the development from the passive "best" form-dominated perception of the young child to the active, operation directed perception of the older child and adult (Elkind & Scott, 1962:618).

Results of studies have seemingly supported the above view:

> Results showed that success in perceiving ambiguous pictures increased significantly with age, generally supporting the premise that while centering occurs in childhood, decentering can be observed as age increases (Elkind & Scott, 1962:622).

Piaget has given perception an active, but minor role, in the child's interaction with his environment. Perceptual acuity sharpens with age, the older child being able to decenter and consider the various structural possibilities before making a judgement. Piaget does not offer descriptions of other perceptual modes. Flavell (1963) believes that for Piaget, this "decentering" and refinement of stimuli would occur in other modes (e.g. auditory).

In Piaget's conservation experiments the perceptual process is an operation. The child is asked to conserve a quantity of beads when the shape of the container is changed. Piaget sees inte gence as a triumph over perception. The child who can "reverse" properties will overcome a tendency to be fooled by a perceptual image. His descriptions suggest that the perceptual adaption involves cognitive adjustment. The role played by perception in knowledge has been clearly outlined:

> ...while operations elaborate general frameworks and tend to reduce the real structures of deducible transformations, perception is of the here and now, and serves the function of fitting each object or particular event into its available assimilative frameworks. Perception is not, therefore the source of knowledge, because knowledge derives from the operative schemes of actions as a whole. Perceptions function as connections which establish constant and local contacts between actions or operations on one hand, and objects or events on the other (Piaget, 1969:359).

It could be postulated that Piaget has given some importance to perception by acknowledging perceptions as important "links" or " connections". The child who suffers deficiencies in any of these links (particularly visual and auditory) could be expected to experience difficulties with the development of operations.

Other researchers have given perception a significant role in the acquisition of knowledge: Binet (1969) suggests defining intelligence as consisting of perceptions and functions based on perceptions:

> ...That which is called intelligence in the strict sense of the word, consists of two principal things: first, perceiving the exterior world, and second, reconsidering these perceptions as memories, altering them (Cruickshank & Hallahan, 1975:117).

It is worthy of mention here that the major psychological tests in current educational use include perceptual processes as components of overall intelligence: The Wechsler Intelligence Scale for Children-Revised (1974), The Stanford-Binet Intelligence Scale (1973), and the McCarthy Scales of Children's Abilities (1972) all place considerable importance on perceptual acuity.

Perception and Learning Disabilities

By contrast to Piaget's more limited and theoretical use of the term "perception", the learning disabilities research has expanded the term to encompass a variety of processes. Cruickshank (1978:11) has defined perception in a general sense as "an awareness of things around us". Similarly the learning disabilities literature has defined such operations as "perceptual-motor processes", and has used the term "integration" to describe the complex synchronization of motor responses and perceptual awareness. The intent of this study is to focus on the shift in emphasis from Piaget's use of the term perception to the more complex, yet practical descriptions of perceptual processes so frequently mentioned in the field of learning disabilities.

Cruickshank & Hallahan, 1975; Hallahan & Kauffman, 1976; and Lerner, 1976 have outlined the historical development of research in learning disabilities. It is not the intention here to engage in discussion of the various definitions of "learning disabilities". Those features described by the National Advisory Committee on Handicapped Children (1968) are appropriate in the context of this study:

> Children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or using spoken or written language. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, developmental aphasia, etc. They do not include learning problems which are due primarily to visual, hearing, or motor handicaps, to mental retardation, emotional disturbance, or to environmental disadvantage (in Lerner, 1976:9).

Underlying decades of research is the theme of the neurophysical basis of learning problems. The role of perceptual processes in learning or non-learning have been considered paramount.

Cruickshank (1978) states:

> If the geneology of learning disabilities is understood and recognized, the relationship of this problem to the neurological system becomes apparent immediately. It is a very simple truism. The neurological base to learning disabilities can only be rejected by those who do not know, or are unwilling to recognize either historical or neuropsychological facts. The faulty neurological system gives rise to the perceptual processing deficits out of which learning disabilities develop (:5)

Lerner (1976) states:

> The process of organizing raw data obtained through the senses and interpreting its meaning is called perception. Perceptual information, then, is a refinement of sensory information. (:171).

The educational process often assumes that the child is in "perceptual harmony" with his surroundings:

> To deal with symbolic materials the child must learn to make some rather precise observations about space and time and relate them to objects and events (Lerner, 1976:160).

Children who are perceptually disorganized cannot make these "precise observations". Conceptual learning is assumed to have a solid perceptual base. If it is not so, then learning may be difficult.

Kephart (1971) has contented that the child must establish a stable and efficient perceptual-motor world in order to learn successfully. He has proposed a theory of "Perceptual-Motor Match" in which he describes the development of eye-hand coordination in the young child.

According to Kephart, vision is the important perceptual function as the child moves from the "hand-eye" match (the hand guides the eye) to the "eye-hand" match (the eye becomes more dominant) and finally to the stage where the eye can independently explore the visual field. Initially, it is motor information which provides the basis for learning. Perception is matched to motor:

> To a large extent, so-called higher fo: 'ehavior develop out of and have their roots in arning (Kephart, 1971:79).

Kephart views the process of cognitive developn involving increasingly sophisticated patterns (or "gener. izations") which develop as a result of input from multiple perceptual sources. For Kephart, the child moves from a motor dominated world to a perceptual, and finally to a conceptual world which can operate independently at the abstract level. Basic to all of this is maximum development of the motor and perceptual levels.

In ar interesting paper, Wadsworth (1975), has compared the theoretical contructs of Kephart to Piaget's theory of development. Wadsworth sees a parallel between the two: While Piaget is classed as heavily theoretical, Kephart is viewed as more practi al-particularly for educational programming. The following figure is an abbreviated adaption of his comparison of their stages of development.

Figure 1

Piaget and Kephart

Parallel Stages of Development

Piaget	Kephart
Sensori Motor Period	Motor (Motor-Perceptual)
Preoperational	Perceptual
Concrete Operatior	Perceptual-Conceptual
Formal Operations	Conceptual

The comparison is very astute. The interesting aspect in view of this tudy, is the intimation that Piaget's early stages do depend on motor and preceptual development.

Getman (1965) has proposed a "visuo-motor" theory which also focuses on the development of visual perceptual dexterity. To Getman "vision" is the child's ability to interpret the world and his relationship to that world. Gradually, the child acquires the ability to understand things he cannot touch. Getman's theory presents an eight stage hierarchical model of the interactions between child and environment. Beginning with an innate response stage, he sees the child move into the locomotion period in which general movement is the main method of interaction. The third stage describes the more complex motor skills of eye-hand, hand-foot relationships.

During his "fourth stage" the ocular motor system is refined: Eye movements must be sufficiently sophisticated to allow for reading and writing skills to develop. For Getman, this stage coincides with the child's entry into the school system. Later stages move the child through development of effective speech-motor patterns, visual memory and visual acuity to a "synchronization" of visual-motor skills with cognitive development:

> The development of cognition and intellectual thought as presented in this (Getman) model, is the result of various levels of motor learning (Lerner, 1976:141).

Barsch (1968) has proposed a Movigenic Theory which focuses on the importance in learning of efficient movement. For Barsch: "...perception is movement and movement is perception" (in Lerner, 1976:148). Cruickshank & Hallahan (1975) have also pointed to the need for awareness of perceptual development. They have suggested the ideal of a "psychoeducational match":

> ...wherin teaching materials are developed which complement the perceptual characteristics of the child (:71).

Cruickshank & Hallahan are refering to more than visual perceptual characteristics. The other significant mode which must be considered is auditory perception. Hallahan (1975) has noted the paucity of current research on the auditory process. Aten & Davis (1968) found a group of children identified as having minimal cerebral dysfunction and learning difficulties to be deficient on a number of auditory memory tasks. Turton (in Cruickshank & Hallahan, 1975) notes:

> Auditory memory is also posited as an important variable in the acquisition of language and as a contributing factor to learning disabilities. Generally, this factor is measured on a digit span test and/or a sentence repetition task (:324).

Koppitz (1971), in a five year follow-up study of children with learning disabilities, has commented:

> Visual and auditory perception, intersensory integration, and the ability to translate that which has been perceived into motor responses, are all closely related to a child's overall performance and achievement in school (:16).

Mathematics Disability

Learning disabilities research has thus presented perceptual processes as an integral part of the learning process. Although the majority of investigations have focused on the reading process, considerable work has been done in relation to specific deficiencies in mathematics.

Children underachieving in arithmetic have been observed to exhibit perceptual deficiencies. These deficiencies have been associated with acalculia or dyscalculia defined as:

> ...a particularly severe form of arithmetic disability ...generally defined as a distrubance or impairment in the ability to do simple arithmetic, usually associated with neurological dysfunction or brain damage, and which interferes with quantitative thinking (Whyte, 1977:283).

Some characteristics identified with dyscalculia (Whyte, 1977, 1978), are spatial deficit, apraxia, disturbances in body image, and inability to distinguish shapes and sizes. It is interesting to note that non-conservation has also been observed in children with arithmetic disability (Kirkbride, 1977; Whyte, 1977). Poor visual and spatial organization are mentioned by Johnson & Myklebust:

> Occasionally disorientation accompanies dyscalculia; there is neither a strong distinction between right and left nor a strong sense of direction (1967:254).

Kirkbride (1977) found also that children displaying arithmetic disabilities were deficient in spatial tasks.

Recent research in arithmetic retardation has been detailed by Rourke (in Myklebust, 1978). This research has focused on a neuropsychological approach. In a series of studies Rourke and associates investigated the role of cerebral hemispheric integrity as observed in children described as learning disabled in arithmetic.

Rourke and Strang (1978) administered a number of motor, psychomotor, and tactile-perceptual tests to subjects. Findings are summarized as follows:

> (a) There were no significant differences evident on the simple motor measures.
>
> (b) The group with an outstanding deficiency in arithmetic (ie. group 3) performed in a markedly impaired fashion on the more complex psychomotor measures and on a composite tactile-perceptual measure.
>
> (c) There was some evidence that would be consistent with the view that the group 3 subjects were suffering from the adverse effects of relatively dysfunctional right cerebral hemisphere within the context of satisfactory left hemisphere functioning (:116).

Rourke's research has pointed to two significant features associated with arithmetic disabilities: Firstly, the etiology of the disability may be linked to right hemisphere dysfunction, thus deriving from a neuropyscholical basis: Secondly, Rourke notes that the isolation of deficiencies identified along with arithmetic underachievement has involved complex psychomotor rather than more simple motor tasks.

Koppitz (1974) has also cautioned against the use of simple visual-motor tests when attempting early identification of at risk children. She has noted:

> Most children with poor visual-motor perception, as measured by the Bender Gestalt Test, do not have problems with visual perception; their difficulties are mainly in the area of perceptual-motor integration rather than perception (:1).

Of interest here is Koppitz' emphasis on the "integration factor". Children who displayed arithmetic disabilities were observed by Koppitz to also display poor integration as measured by the Bender Gestalt Test.

Wedell (1973) reported on Bruner's 1967 study:

> ...the school subjects which presented the greatest obstacles to the children with visuo-motor handicap were spelling and arithmetic. In the case of arithmetic, difficulty lay less in connection with basic principles, than with written work (:104).

Wedell continues:

> It seems that sensory and motor organization difficulties are more likely to handicap a child in performing the mechanics of written computation and in the construction involved in the use of "concrete" materials, than in the comprehension of arithmetic principles as such (:104).

Benton (1959) has observed finger agnosia to be associated with arithmetic problems: According to Benton, right-left orientation and the ability to name and locate fingers show high correlation with the ability to calculate. Frequently we observe young children in the school situation who reverse numbers and letters. Often they display confused or mixed hand dominance. Harris (1957) has found that retarded readers could be differentiated from normal readers because of mixed hand dominance. However, Silver & Hagen (1960), and Coleman & Deutch (1964) have shown that laterality difficulties do not always accompany reading difficulties. It does seem significant for this study that research has pointed to a connection between laterality confusion and learning disabilities.

Auditory perception has been identified as a significant factor in arithmetic achievement. Johnson & Myklebust (1967) note:

> Two types of auditory memory problems interfere with mathematical performance. The first is a problem of reauditorization which prevents the child from quickly recalling numbers...(Secondly) Deficits in auditory attention span interfere with arithmetic in that the child cannot listen to story problems presented orally. He cannot hold and assimilate all of the facts in mind so he cannot work out the problems (:247).

Wedell (1973) reports that auditory preception is likely to be involved in number performance mainly through its relevance for language:

> Span of auditory attention and auditory memory are clearly of great importance in "mental" arithmetic. The poor digit memory, noted in many studies of children with learning disabilities, must be a handicap in a wide variety of mathematical classroom tasks (Wedell, 1973:107).

Nall (1970) has reported on a study of 137 subjects who were experiencing difficulties in arithmetic. All subjects were attending school and ranged in age from 6 to 18 years. Of particular interest here is that 94% of these subjects displayed deficiencies in auditory memory. Of the 25 children in the age range from 6 to 8 years, 80% had significant weaknesses in auditory memory. Nall comments:

> In view of the fact that much of the teaching of math in the average classroom is explained out loud to the children it is not surprising that these children with difficulties in auditory memory would also have difficulty in arithmetic (:45).

It is necessary here to discuss the "freedom from distractibility" factor which is tenuous in observable substance, but which may account for poor arithmetic performance in some instances. A child who cannot concentrate on auditory or visual stimuli for reasons such as hyperactivity could disply learning problems. Johnson & Myklebust have delineated two groups of arithmetic disabilities:

> In our remedial work we have found it necessary to separate children who fail in arithmetic because of language or reading problems from those who have disturbances in quantitiative thinking (:246).

In the first category they have observed children with auditory perceptual and reading difficulties. Children displaying visual perceptual disturbances resulting in confusion of numbers and letters have problems with arithmetic processes. Even if they understand concepts, the misguiding perceptual disturbances may result in incorrect answers.

Their second major category includes the "dyscalculic" who does not grasp mathematical principles even though he can record and write effectively. Such children may display problems with spatial organization, apraxia, etc. Children in this category have been observed to score considerably higher on verbal than on non-verbal tasks on such measures as the WISC-R. (This characteristic was also observed by Whyte, 1977).

Thus children displaying problems with mathematics come with a variety of disabilities. Johnson & Myklebust (1967:252) have concluded: "not all deficiencies in arithmetic are identical". They present an exhaustive list of deficiencies including such obvious categories as "inability to read", "inability to understand the principles of arithmetic problems". Of relevance to this paper are the following:

> Inability to establish one-to-one correspondence. Inability to grasp the principle of conservation of quantity. Inability to learn both the cardinal and ordinal systems of counting. Inability to associate the auditory and visual symbols. Inability to understand the arrangement of the numbers on the page (:252, 253).

Summary

The above list is not exhaustive. An overview of the research on how children do, or do not, learn mathematical concepts has been at best, brief. Two underlying themes have evolved upon which this study will focus.

Firstly, the Piagetian model contends that conservation is necessary for the true understanding of mathematical concepts. In particular, the concept of reversibility of properties is identified as significant. Piaget (1952) has listed several areas of conservation as being important: conservation of discontinuous quantities; lasting equivalence of numbers; spontaneous correspondence; seriation; and ordination and cardination. The above areas have been chosen for investigation in this study as they have been examined extensively in research (Dodwell, 1961, 1962; Elkind, 1961; Hood, 1962; Winfield, 1968; Marks, 1972).

Secondly, the literature has emphasized the role of perceptual processes in the development of mathematical skills. In particular, visual-motor and auditory memory skills have been discussed. This study has taken both themes and attempted to combine them in a practical search for factors influencing grade one mathematics achievement.

CHAPTER III

THE STUDY

The purpose of this study was to investigate the effects of certain factors upon grade one mathematics achievement. The selected factors were: auditory sequential memory; auditory attention span; left-right orientation; visual motor integration; Piaget's concept of conservation: specifically, conservation of discontinuous quantities, lasting equivalence, spontaneous correspondence, seriation, and ordination and cardination.

It was decided to include age and sex as factors in this study as they have been identified as variables in the learning process (Jansky & de Hirsch, 1972; Atkinson, 1974; Cruickshank & Hallahan, 1975; Lerner, 1976). As discussed earlier, age is usually the deciding factor regarding school entry. Educators generally assume that by the time a child reaches age five to seven his perceptuomotor, cognitive, social and emotional development will allow him to cope with school learning. Sutton (1976) in Jansky & de Hirsch (1972) has observed children who are ready to learn well before age 5. Other children do not respond to grade one teaching, and are forced to spend a second year in that grade. For these children, chronological age is not a suitable guideline for school entry.

Sex has been identified as a factor in the ability to learn mathematics skills ([illegible] ner, 1976). Girls are frequently more physically [illegible] cially [illegible] than boys and as well they tend to respond positi [illegible] ly [illegible] e female dominated grade one classroom. Boys display learning disabilities 4 to 6 times more often than do girls (Lerner, 1976), and could consequently display lags in mathamtics learning. Both the sex and age of subjects was easily obtained from class registers.

Research involved administering a series of tests to 96 grade one pupils of the Medley School District, Canadian Forces Base, Cold Lake. The original sample was intended to be 105 but 9 subjects were lost because of illness and other absenteeism. The 96 subjects came from five classes. All teachers were experienced in teaching grade one and the subjects appeared to be a representative group. Eight were repeating grade one, but these have not been identified in the results.

Testing took place during the period May 19 to June 20, 1980 and included the following:

1. The mathematics section of the Metropolitan Achievement Test (Primary 1 Battery). (Durost, W., Bixler, H., Wrightstone, J., Prescott, G., Balow, I.)

2. The Digit-Span subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R).

3. The Betts Auditory Memory Span Test. (Appendix B)

4. The right-left orientation subtest from the McCarthy Scales of Children's Abilities.

5. The Beery Developmental Test of Visual-Motor Integration.

6. The five Piagetian Tests were patterned after Marks (1972).

Test 1 was administe[illegible] by classroom teachers in a group situation during the [illegible] Tests 2, 3 and 4 were administered by a [illegible] was working only half days during the testing period. These tests were given on a one-to-one basis. Tests 5 and 6 were administered by this writer: Test 5 in a group situation and test 6 on a one-to-one basis.

Testing was organized as described for reasons of expediency. Time per subject spent on testing was approximately two hours. The testing period was limited to the 20 school days made available by the Medley School Board. Thus, it was necessary to engage help for the actual testing. During administration of the tests it was agreed that subjects appeared relaxed and willing to please. Overall, the atmosphere was pleasant and the children participated eagerly.

The Test Battery

The mathematics section of the Metropolitan Achievement Test, Primary 1 Battery (1971) was selected for the following reasons:

(i) This test has been recommended by the Alberta Department of Education as a general measure of grade one achievement. Consequently, these tests have been used in the Medley system and copies were available for this testing.

(ii) Teachers were satisfied with the test's effectiveness. Four items (of a total of 62) were criticized because American coins were used in 3, and the term "inches" was used in another. As all subjects were at a similar disadvantage, these items were left in. A quick survey of answers revealed that these were not the questions subjects had difficulty with.

(iii) The mathematics section of the Metropolitan Achievement Test appeared to cover material set out in the Curriculum Guidelines (Appendix A).

The Digit-span test of the WISC-R was selected as an instrument because of its availability, ease of administration, and relevance: Auditory sequential memory has been identified as a significant factor in arithmetic achievement. Johnson & Myklebust (1967) have discussed the problem in "reauditorization" which prevents the child from quickly recalling numbers. The Digit-span test is a measure of auditory sequential memory at the immediate recall level.

The Betts Auditory Memory Span test (Appendix B) is used in diagnosis of learning problems in the Medley School system. Betts (1934, 1946) was a pioneer in relating reading problems to poor auditory memory. Johnson & Myklebust (1967) have observed that deficits in auditory attention span interfere with arithmetic: The child who cannot grasp and hold the facts presented orally cannot solve the problems. The Betts Test measures the child's ability to remember meaningful sentences of increasing length.

The Beery Developmental Test of Visual Motor Integration (Beery, 1967) was selected as a reliable instrument for measuring:

> ...the degree to which visual perception and motor behavior are integrated in young children (Beery, 1967:11).

The development of this test was based on the research of Frostig (1964) and of Kephart (1960). The importance of visual-motor skills in the learning process has been outline r. The Beery Test is used in diagnosis in the Medley Schools. It was suitable for group administration and the scoring is fast and efficient.

The Right-Left orientation test from the McCarthy Scales of Children's Abilities (1972) is an excellent screening instrument. It assesses the child's awareness of body laterality and orientation in space:

> Many children who have learning deficits demonstrate confusion in laterality (McCarthy:10).

Johnson & Myklebust (1967) have stated:

> Occasionally disorientation accompanies dyscalculia; there is neither a distinction between right and left, nor a strong sense of direction (:254).

The five Piagetian tests were taken from Marks (1972). These tests are outlined fully in Appendix C. The areas chosen for investigation were included because of their relevance to mathematics achievement. Conservation of discontinuous quantities assesses the child's ability to "reverse operations", lasting equivalence is a concept which is proposed as necessary for understanding of addition and subtraction problems. Spontaneous correspondence checks the child's ability to use both a numerative and a qualitative correspondence; seriation is a very significant factor: For Piaget, a child must recognize the serial relationship of numbers and concepts before he truly understands the nature of the number system. The importance of ordination and cardin[illegible] A child should have a grasp of the multiplic[illegible]ies of number or he does not really understand the basic mathematical processes. The tests, questions, and scoring criteria are outlined in Appendix C.

Questions for Investigátion

As this study was designed to investigate the effects of certain factors upon grade one mathematics achievement, the questions under investigation were:

1. Will achievement in grade one mathematics correlate significantly with one of the following?

(i) Age or sex.

(ii) Right-left orientation.

(iii) Auditory sequential memory.

(iv) Piaget's concept of conservation: specifically conservation of discontinuous quantity; lasting equivalence of number; spontaneous correspondence; seriation; ordination and cardination.

(v) Auditory memory span.

(vi) Visual motor integration.

2. Will combinations of any of the above factors account for significant variance in grade one mathematics scores?

Analysis Of Data

At the completion of the testing period, marking was completed and raw scores recorded. Data was then analysed at the University of Alberta using the MULR08 program entitled "Stepwise Regression With Double Cross-Validation". (This program was developed by the Division of Educational Research Services, University of Alberta). Using mathematics scores as the criterion variable, correlations between factors were observed and through stepwise regression, variance was observed for combinations of factors.

Limitations of the Study

One limitation in the testing process was the nature of the Piagetian tests which were not normed. However, scoring guidelines were clear and the tests adhered closely to Piaget's original research. Similarly, the Bett's Auditory Memory Span Test does not appear to have current norms but was used because of its relevance.

The greatest limitation on this study's effectiveness was the lack of experimental control in several key areas: Teacher effectiveness is one important area in which no attempt at analysis was made. Professional conduct did not permit the comparison of teaching styles or general competence. The age of teachers involved in the study varied considerably, as did their teaching methods. Some used very traditional methods while others emphasized activity centres, etc. It must be noted, however, that all teachers had previously taught grade one in the Medley School System.

No attempt was made to confirm the extent to which the grade one curriculum had been covered. It was assumed that the guidelines set down by the Alberta Department of Education had been followed and that pupils had progressed to expected mastery levels. Class size was another uncontrolled variable. Classes ranged from 14 to 29 students. Interestingly enough, overall results did not indicate that subjects in the large class were at any disadvantage.

CHAPTER IV

RESULTS

Performance on the Tests

When testing was completed and results recorded, it was decided to use raw scores for all data. The Piagetian tests were scored 1, 2 and 3 according to the prescribed outlines (in Appendix D). All raw data are listed in Appendix D.

Age and Sex of Subjects

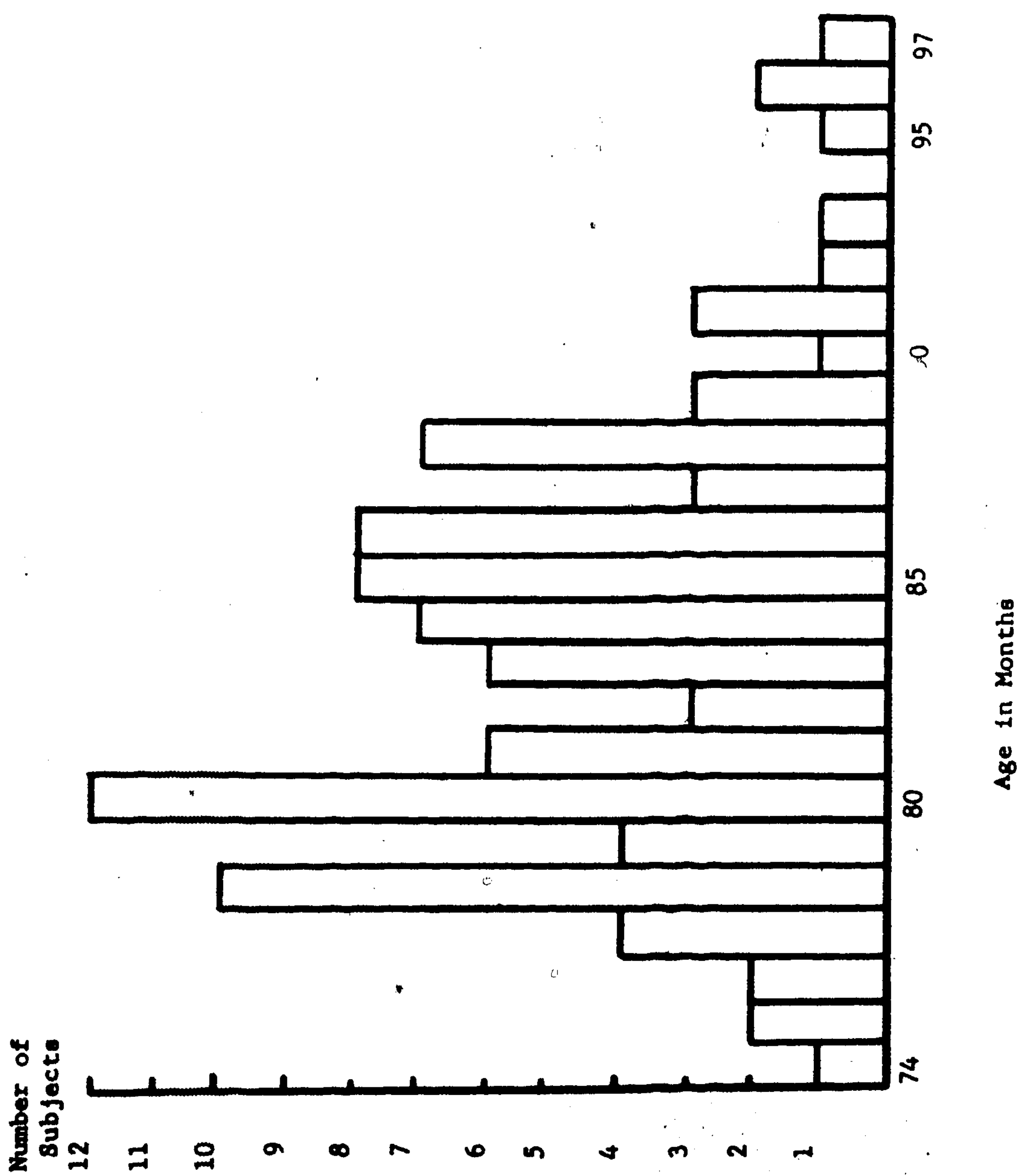
As indicated earlier, it was decided to include age and sex as variables in the study. The sex distribution of the 96 subjects was 45 males and 51 females. In age they ranged from 74 months (6-2 years) to 97 months (8-1 years). The distribution of ages is diagramed in Figure 2. Of particular interest to this study is the spread around 84 months which is proposed as the approximate age for the beginning of concrete operational thought. While 53.12 percent were 7 or older, 80.2 percent were in the range 6-6 to 7-6 years.

Mathematics Test Results

The mathematics section of the Metropolitan Achievement Test allows one point for each correct response to a maximum of 62 points. Results have been listed as raw scores (see

FIGURE 2

AGE DISTRIBUTION OF SUBJECTS



Appendix D). Figure 3 illustrates the stanine distribution of these scores. The "normal tendency" of the distribution is apparent with 34.37 percent of subjects scoring a stanine of 5.

Right-Left Orientation Results

The right-left orientation test of the McCarthy Scales allows the subject to score 1 point for each correct response. Figure 4 describes the distribution of scores which ranged from 0 to a maximum of 12. While 25 percent of subjects were able to score 12, 20.8 percent scored less than 6. Poor performance on this test was not always linked with poor performance on the mathematics test: Subject 89 scored 0 on the right-left orientation test, but achieved a raw score of 51 on the mathematics test. Similarly, maximum performance on the right-left test did not necessarily correspond with high scores in mathematics: Subject 43 scored 12 in orientation and only 31 points on mathematics. (See Appendix D).

Auditory Sequential Memory Results

The Digit-span subtest of the WISC-R allows one point for each correct response. Raw scores on this test ranged from 3 to 15 with a mean of 8.26. Figure 5 outlines the distribution of scores. Of note here is the comparison of performances on this test and the mathematics test: Subjects 16 and 17 both scored 44 in mathematics; subject 16 scored 15 on the digit-

FIGURE 3

DISTRIBUTION OF STANINES SCORED BY SUBJECTS ON MATHEMATICS SECTION OF THE METROPOLITAN ACHIEVEMENT TEST

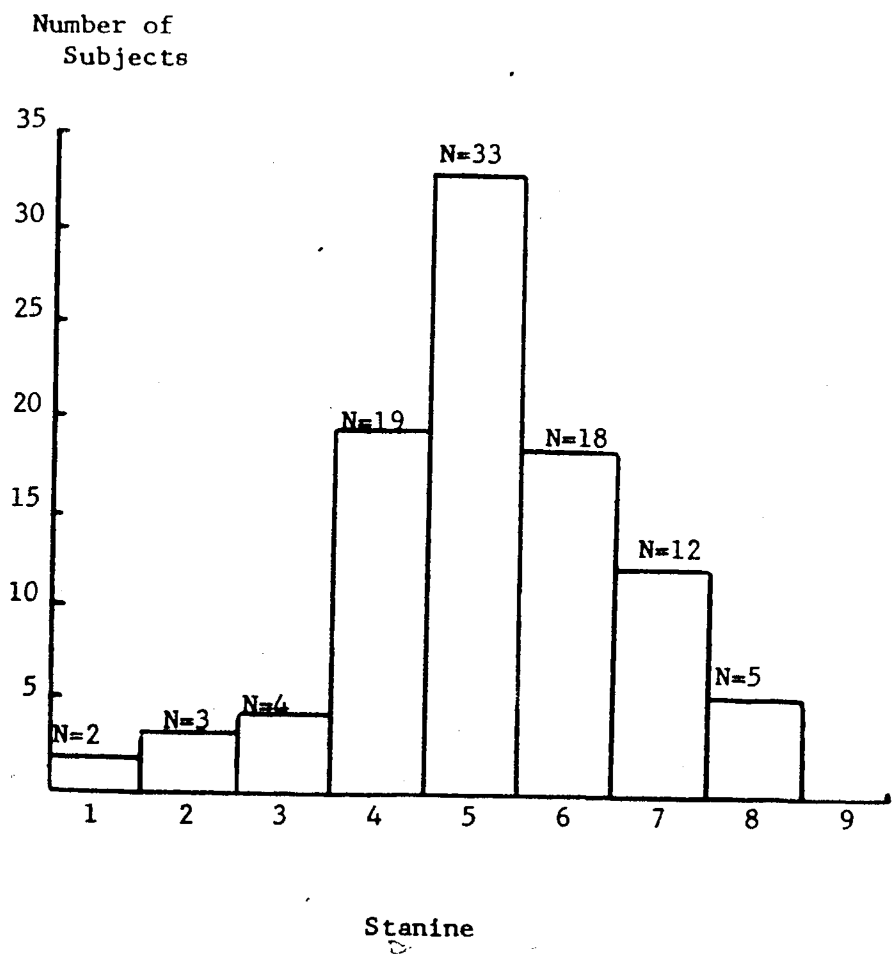


FIGURE 4

DISTRIBUTION OF SCORES ON RIGHT-LEFT ORIENTATION

TEST FROM THE

MCCARTHY SCALES OF CHILDREN'S ABILITIES

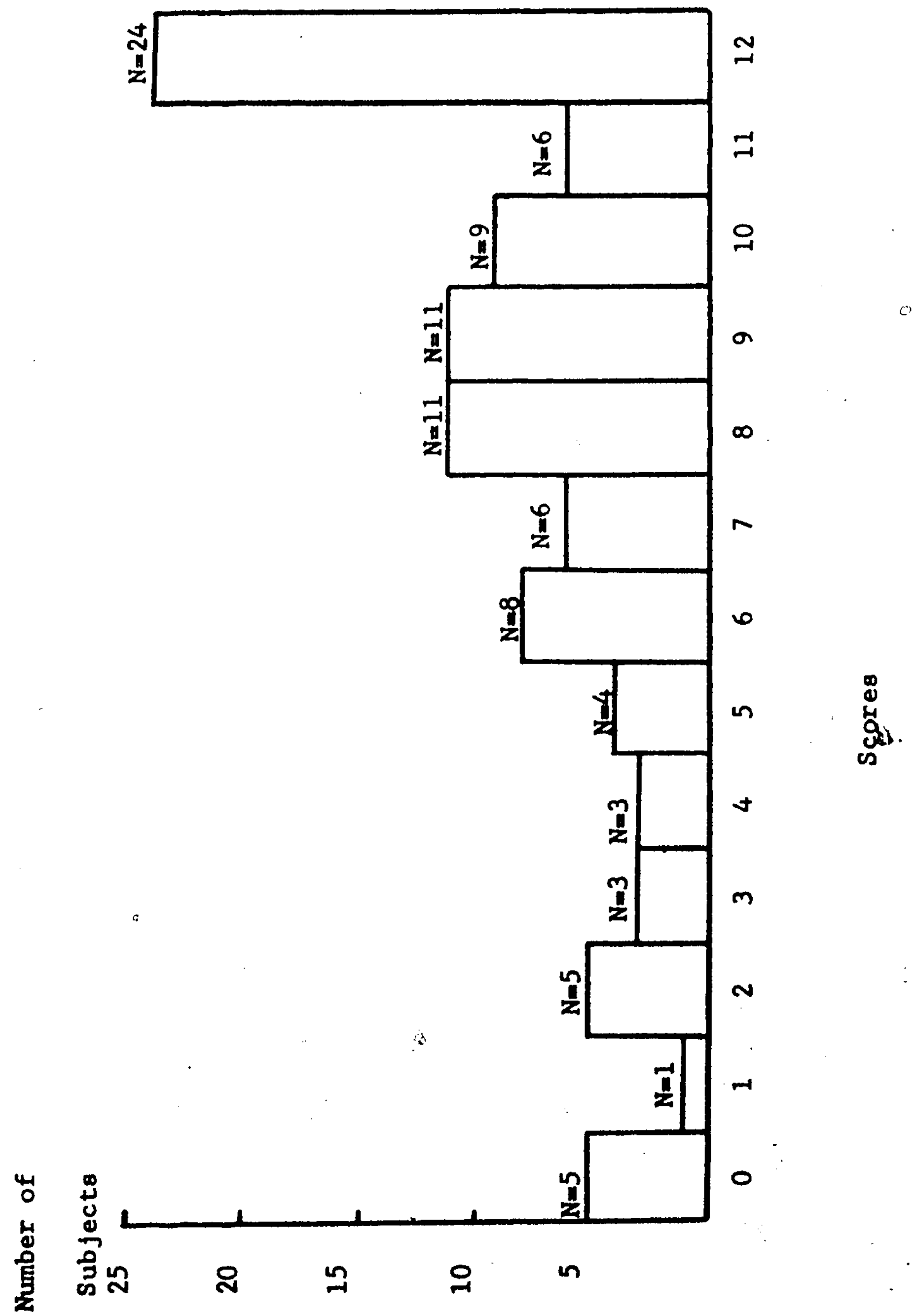
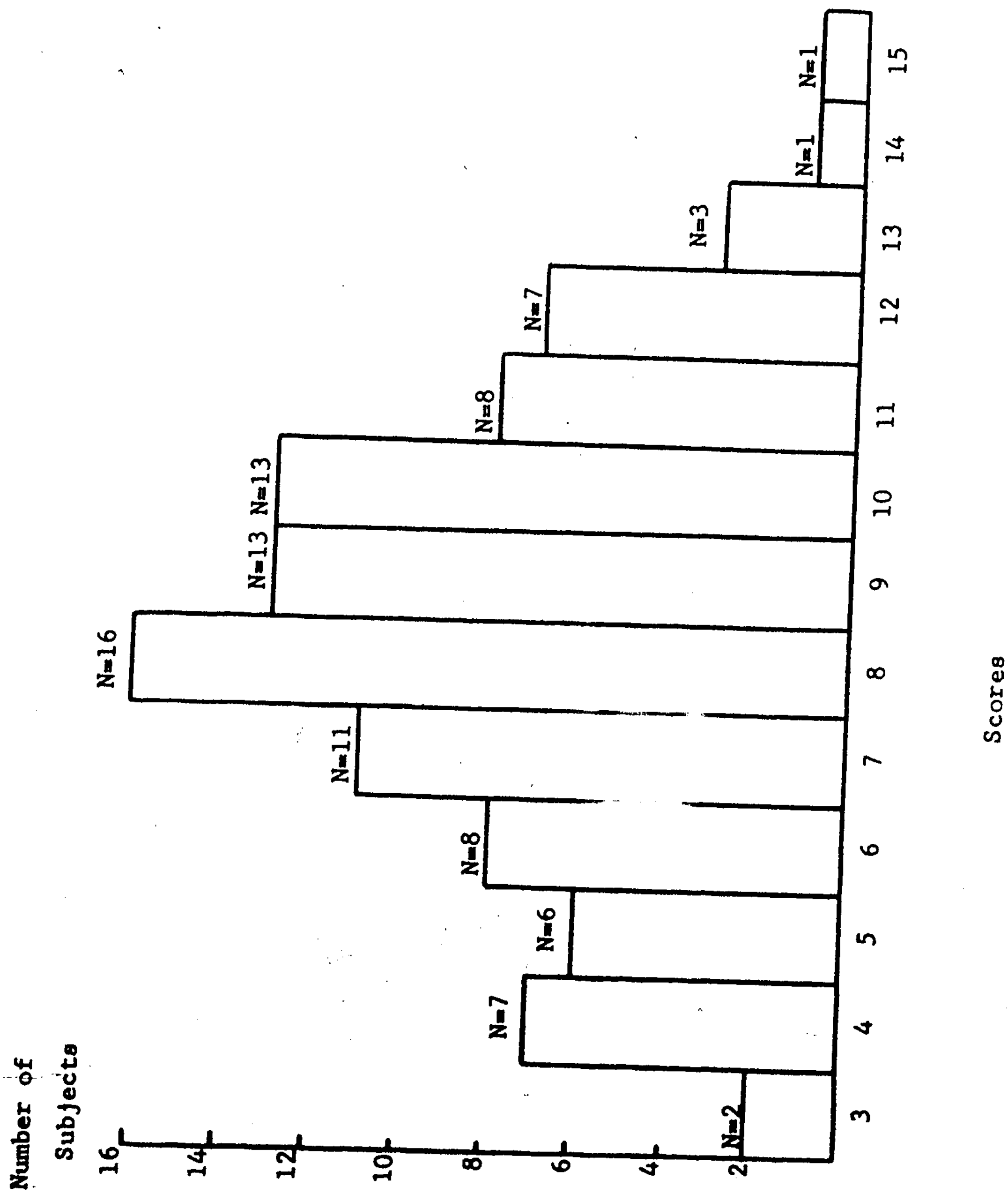


FIGURE 5

DISTRIBUTION OF RAW SCORES ON DIGIT-SPAN TEST

FROM THE

WECHSLER INTELLIGENCE SCALE FOR CHILDREN-REVISED



span test, while subject 17 scored only 3 on digit-span. (See Appendix D).

Piagetian Test Results

Results of the Piagetian tests are outlined in Table 1. These results are interesting in the variations. Not one subject was at Stage 3 in all five areas and conversely, not one was at Stage 1 in all five areas. Results show many different combinations (see Appendix D). Of particular interest was the number of subjects who were at Stage 2 in the conservation of discontinuous quantities. Subjects were unable to conserve quantity when the blue beads were poured into the long, narrow container. They stated that now there were more blue beads. Many subjects who were otherwise astute in their observations, made this error. In the task which tested Lasting Equivalence of numbers, 17.7 percent of subjects made a "global comparison" when asked how many pennies were required to buy six candies which cost one penny each. Answers ranged from 1 to 100!

No subjects were at Stage 1 on the Spontaneous Correspondence test. This was perhaps due to the nature of the task (see Appendix C). All were able to make the one-to-one responses required for Stage 2. Results of the seriation task are interesting: 59.4 percent of subjects were able to complete all tasks. Once they were able to arrange the dolls in order of size, they were able to complete all tasks successfully.

Seventy-five percent of subjects were able to display an awareness of ordination and cardination, but only 15.6 percent were able to recognize the true ordinal properties of numbers.

Auditory Memory Span Results

The Betts Auditory Memory Span Test scores one point for each sentence successfully recalled by the subject. Scores on this test ranged from 2 to 21 out of a possible maximum of 25 points. Figure 6 outlines the distribution of scores on this test. Betts has described five categories of scores ranging from "superior" to "failure". These categories are outlined in Table 2. Of interest here is that 43.75 percent of subjects scored in the "poor" range and 13.54 percent in the "failure" range. This could be linked to the immaturity of the subjects. An age factor is not built into this test and it is given to adult subjects as well as children. Perhaps, however, it does point to the immaturity of auditory attention span in the young subjects of this study.

Visual Motor Integration Results

The Beery Developmental Test of Visual-Motor Integration was scored according to Beery (1967). The test booklets used (Beery & Buktenica) allowed for the copying of 24 designs. Subjects scored one point for each correct response. Scores ranged from 7 to 17. Figure 7 outlines the distribution of

TABLE 1

PERCENTAGES OF SUBJECTS AT STAGES

1, 2 AND 3 ON PIAGETIAN TASKS

Stage	D.Q.	L.E.	S.C.	S.	O & C
1	19.8	17.7	0	21.8	9.4
2	62.5	34.4	60.4	18.7	75
3	17.7	37.5	39.6	59.4	15.6

D.Q. - Discontinuous Quantity

L.E. - Lasting Equivalence

S.C. - Spontaneous Correspondence

S. - Seriation

O & C - Ordination and Cardination

FIGURE 6

DISTRIBUTION OF SCORES ON

BETTS AUDITORY MEMORY SPAN TEST

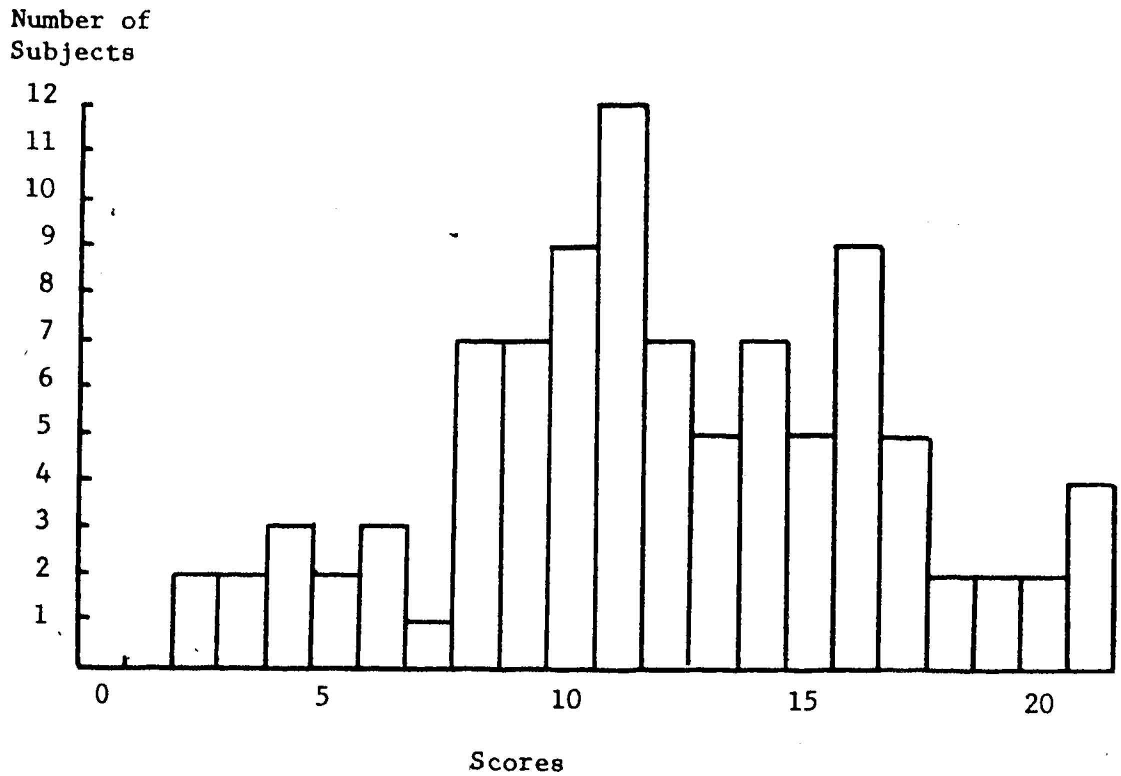


TABLE 2

PERCENTAGES OF SUBJECTS SCORING IN EACH

OF 5 CATEGORIES ON THE

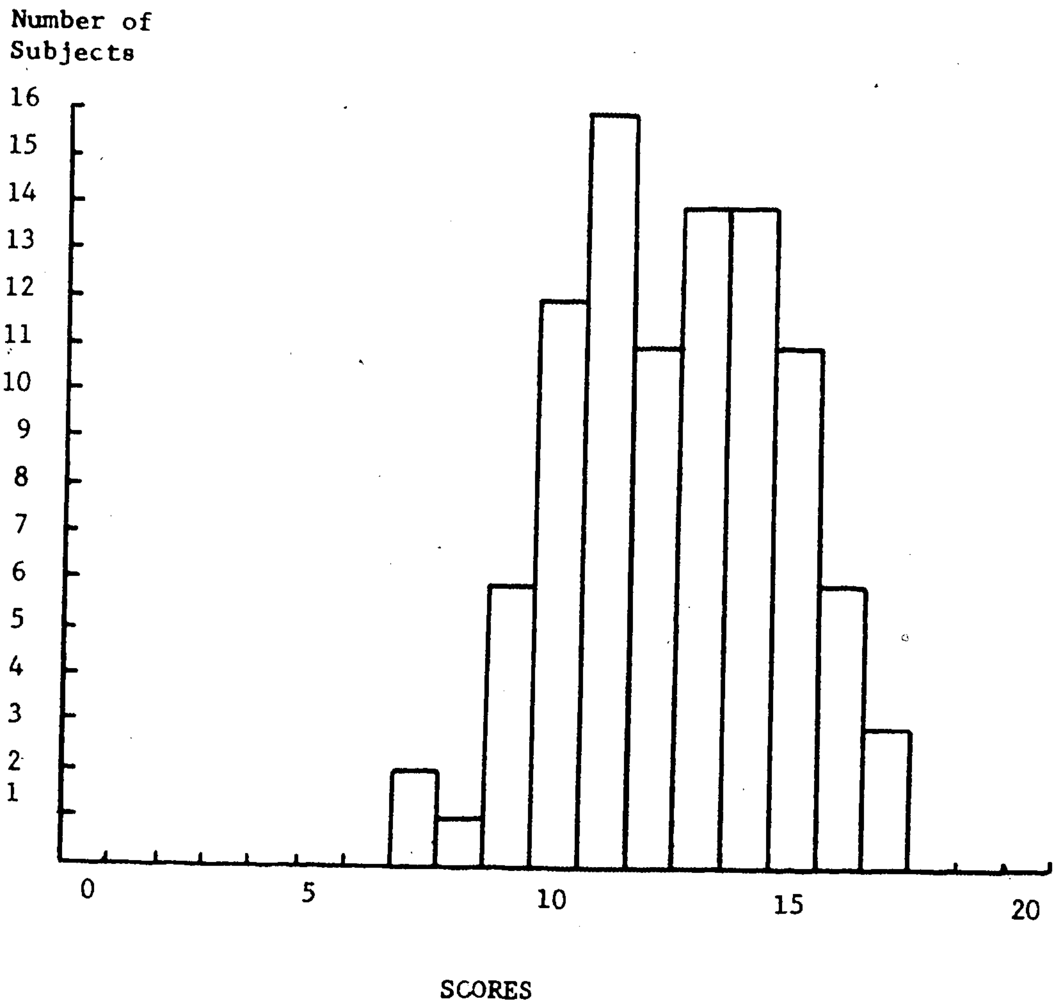
BETTS AUDITORY MEMORY SPAN TEST

Failure	Poor	Mediocre	Good	Superior
13.54	43.75	27.08	11.45	4.16

FIGURE 7

FREQUENCY DISTRIBUTION OF SCORES ON

BEERY DEVELOPMENTAL TEST OF VISUAL MOTOR INTEGRATION



scores. The mean for this distribution is 12.43 which is equated with a developmental age level in visual-motor integration of approximately 6 years 2 months for girls and 6 years 5 months for boys.

Statistical Analysis

The purpose of this study is to isolate factors which influence grade one mathematics achievement. The statistical analysis thus involved obtaining correlational data and then a multiple stepwise regression analysis was used to identify those factors which combined to account for significant variance in mathematics scores.

In the analysis, the mathematics score became the criterion variable, while the remaining variables became the eleven predictors. The object of this design was to isolate those variables which alone, or in combination, would demonstrate a significant relationship with the mathematics scores. The program used was MULR08 (developed by the Division of Educational Research at the University of Alberta).

The correlational data is listed in Table 3. (The means and variances of individual variables appear in Appendix D). The 0.01 level of significance was used to determine the level of significance of individual correlational data. This level was determined for reasons of greater accuracy and efficiency of research design. Popham & Sirotnik, 1973:383 list the value of the correlational coefficient (r) as:

0.260 with 95 degrees of freedom at the 0.01 level of significance

[illegible]alues of r were significant at this level:

[illegible]14 when visual-motor integration was correlated [illegible]ith the mathematics score.

r = 0.357 when lasting equivalence of number was correlated with the mathematics score.

r = 0.332 when audi[illegible]y memory was correlated with the mathematics score.

In this study then, the three factors displaying significant correlation with mathematics achievement were visual-motor integration, lasting equivalence of number, and auditory memory span.

Those factors which were not significant at the 0.01 level were:

Sex	(r = -0.99)
Age	(r = 0.110)
Right-left ori[illegible]ntation	(r = 0.225)*
Auditory sequential memory	(r = 0.232)*
Conservation tasks of:	
Discontinuous quantity	(r = 0.164)
Spontaneous correspondence	(r = 0.206)*
Seriation	(r = 0.254)*
Ordination and cardination	(r = 0.247)*

It is interesting to note that those variables above indicated thus * were significant at the 0.05 level (r=0.200 for 95 df at the 0.05 level: Popham & Sirotnik, 1973:383).

A stepwise regression analysis was then utilized to determine what factors alone or in combination, could be identified as significant predictors of mathematics scores. The stepwise regression approach increases the accuracy of results as it incorporates more than one predictor variable and yields smaller or more precise standard errors of estimate than studies employing only one variable (Popham and Sirotnik, 1973).

Significant results of the stepwise regression analysis are listed in Tables 4, 5, 6 and 7. These results indicate the following:

(1) Predictor variable 6 (visual-motor integration) alone accounts for 17.2 percent of the variance in mathematics scores ($r^2 = 0.172$: see Table 4).

(2) Predictor variables 6 and 8 (visual-motor integration and lasting equivalence of number respectively) in combination account for 24.7 percent of the variance in mathematics scores. ($r^2 = 0.247$: see Table 5).

(3) Variables 6, 8 and 5 (visual-motor integration, lasting equivalence of number, and auditory memory span respectively) in combination account for 31 percent of the variance in mathematics scores. ($r^2 = 0.310$: see Table 6).

(4) Variables 6, 8, 5, and 3 (visual-motor integration, lasting equivalence of number, auditory memory span, and right-left orientation respectively) account for 34 percent of the variance in mathematics scores ($r^2 = 0.340$: see Table 7).

Further regression data has not been discussed as inclusion of the additional variables did not significantly increase the variance (Appendix D includes complete data for variances not determined to be significant).

In the stepwise regression analysis it was observed that those variables which appeared as significant supported the correlational findings. That is, the "three best" predictors-visual-motor integration, lasting equivalence of number, and auditory memory span-were also the "three best" predictors in the regression analysis. The interesting variation was the inclusion of the right-left orientation variable which was not "fourth best" in the correlational analysis, but which proved to be the fourth most influential variable when combined with visual-motor integration, lasting equivalence of number, and auditory memory span.

TABLE 3 CORRELATIONAL DATA

Column Variable	1 Sex	2 Age	3 Left-Right Orientation	4 Auditory Sequential Memory	5 Auditory Memory Span	6 Visual-Motor Integration
Row						
1	1.000	-0.052	0.109	0.014	0.019	0.021
2	-0.052	1.000	0.067	-0.145	-0.046	0.169
3	0.109	0.067	1.000	0.060	0.095	0.103
4	0.014	-0.145	0.060	1.000	0.510	0.147
5	0.019	-0.046	0.095	0.510	1.000	0.151
6	-0.021	0.169	0.103	0.147	0.151	1.000
7	-0.032	0.067	-0.098	-0.003	0.202	0.199
8	-0.039	-0.014	-0.013	-0.008	0.114	0.213
9	0.035	0.182	0.011	-0.081	0.024	0.189
10	0.048	0.093	-0.021	0.042	0.247	0.406
11	0.076	-0.029	-0.114	0.246	0.257	0.333
12	-0.099	0.110	0.225	0.232	0.332*	0.414*

* $p < .01$

TABLE 3 (Continued) CORRELATIONAL DATA

Column Variable	7 Discontinuous Quantity	8 Lasting Equivalence	9 Spontaneous Correspondence	10 Seriation	11 Ordination Cardination	12 Math Score
Row						
1	-0.032	-0.039	0.035	[illegible]	0.076	-0.099
2	0.067	-0.014	0.182	0.093	-0.029	0.110
3	-0.098	-0.013	0.011	0.02[illegible]	-0.114	0.225
4	-0.003	-0.008	-0.081	0.042	0.246	0.232
5	0.202	0.114	0.024	0.247	0.257	0.332
6	0.199	0.213	0.189	0.406	0.333	0.414
7	1.000	0.104	0.028	0.140	0.004	0.164
8	0.104	1.000	0.100	0.019	0.368	0.357
9	0.028	0.100	1.000	0.149	0.156	0.206
10	0.140	0.019	0.149	1.000	0.275	0.254
11	0.004	0.368	0.156	0.275	1.000	0.247
12	0.164	0.357*	0.206	0.254	0[illegible]7	1.000

* $p < .01$

ABLE 4

REG SION ANALYSIS

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	1404.212	1	1404.212	19.489	0.00003
Residual	6769.254	94	72.013		
Total	8173.469	95			
Variable(s) Entered		6			
r-squared		0.172			

TABLE 5

REGRESSION ANALYSIS

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	2022.836	2	1011.419	15.293	0.0000
Residual	6150.629	93	66.136		
Total	8173.469	95			
Variable(s) Entered		6 8			
r-squared		0.247			

TABLE 6

REGRESSION ANALYSIS

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	2536.222	3	845.427	13.798	0.00000
Residual	5637.184	92	61.274		
Total	8173.469	95			
Variable(s) Entered		6 8 5			
r-squared		0.310			

TABLE 7

REGRESSION ANALYSIS

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	2781.264	4	695.316	11.734	0.0000
Residual	5392.203	91	59.255		
Total	8173.469	95			
Variable(s) Entered		6 8 5 3			
r-squared		0.340			

CHAPTER V

CONCLUSIONS

This study was designed to isolate factors influencing grade one mathematics achievement. Questions posed for investigation were:

1. Will achievement in grade one mathematics correlate significantly with one of the following:
   - (i) Age or sex.
   - (ii) Right-left orientation.
   - (iii) Auditory sequential memory.
   - (iv) Piaget's concept of conservation: Specifically, discontinuous quantity, lasting equivalence of number, spontaneous correspondence, seriation, and ordination and cardination.
   - (v) Auditory Memory Span.
   - (vi) Visual-motor integration.
2. Will combinations of any of the above factors account for significant variance in grade one mathematics scores?

Research of the above questions involved the administering of 10 separate tests to 96 grade one subjects. Results of this testing, reported in the previous chapter, have indicated some interesting trends:

1. Age and sex did not emerge as factors influencing grade one mathematics achievement.

2. While Piaget's stages were observed in all subjects, they did not necessarily follow the hierarchical sequence of stage development as outlined by Piaget.

3. Results indicated that auditory sequential memory, and the Piagetian concepts of spontaneous correspondence, seriation, and ordination and cardination may influence grade one mathematics achievement. It appears that further research in these areas would be worthwhile.

4. Those factors which emerged as significantly influencing grade one mathematics achievement were visual-motor integration, lasting equivalence of number, and auditory memory span. In combination with these factors, right-left orientation was also observed to be a significant factor.

Conclusions For Questions Investigated

The questions posed for investigation will now be answered specifically. Question 1. (i to vi) dealt with the correlational relationship between grade one mathematics achievement and individual factors under investigation.

1. (i) Will achievement in grade one mathematics correlate significantly with age or sex?

In this study neither age nor sex displayed a significant relationship to grade one mathematics achievement. The factor of age was perhaps restricted by the limited age range of subjects. As noted earlier (see Figure 2), 80.2 percent of subjects were in the range 6-6 to 7-6 years. It could be postulated that age might become a significant factor as the curriculum content becomes more sophisticated in higher grades. Subjects who are chronologically younger than their classmates might display cognitive differences which would affect mathematics achievement. However, in this study of grade one subjects, age was not a significant factor. (See Table 3).

The variable of sex has often been discussed in the literature (Atkinson, 1974; Cruickshank & Hallahan, 1975; and Lerner, 1976). It has been suggested that girls are encouraged by the female-oriented environment of the grade one classroom. Girls are observed to be more physically mature than boys when they enter school, and consequently learn more quickly (Atkinson, 1974). Boys more frequently display learning disabilities than do girls (Lerner, 1976). On the other hand, a perpetuating "myth" regarding education has been that boys do better in mathematics than do girls. It is interesting to note here that Piaget does not mention sex differences in his stages of learning. He has discussed and observed both boys and girls in his research and has not documented cognitive differences. In this study sex was not a significant factor. (See Table 3). This appears to support theories such as Piaget's which outline cognitive growth as general to all. Perhaps any observed differences in learning rates have been environmentally invoked. Some teachers might have expected "better" behavior from girls, and conversely, expected boys to be more interested in mathematics.

1. (ii) Will achievement in grade one mathematics correlate significantly with right-left orientation?

In this study right-left orientation was a significant factor in the correlational study (see Table 3). However, in the regression analysis, it was the "4th best" predictor in combination with three others. As noted earlier, scores on the right-left orientation test were interesting in their variations. Twenty-five percent of subjects were able to score the maximum, while 20.8 percent scored less than half the number of points. McCarthy included this test in her battery as a measure of perceptuo-motor performance. It also has conceptual overtones, as the subject has to "think" about body parts, and has to be able to reverse orientation when judging left and right on a body other than his own. It could be postulated that this sample population was too restricted to indicate a relationship between right-left orientation and mathematics achievement. Perhaps a larger "learning disabled" population might reveal a significant correlation between poor right-left orientation ability and poor performance in mathematics.

1. (iii) Will achievement in grade one mathematics correlate significantly with auditory sequential memory?

Results of this study do not show a significant correlation between auditory sequential memory as measured by the digit span subtest of the WISC-R, and achievement in grade one mathematics. (See Table 3) It is possible only to speculate on reasons for its relative insignificance: Perhaps this test does not effectively measure "re-auditorization" as described by Johnson & Myklebust. It is important however to note here that tests very similar in structure to the digit span test used here, have been included in other measures of children's abilities. (The Illinois Test of Psycholinguistic Abilities; The Detroit Test of Learning Aptitude; The McCarthy Scales of Children's Abilities). As in the WISC-R subtest, all similar digit span tests claim to reliably me[illegible]e auditory sequential memory. If this study has thus assumed to effectively measure auditory sequential memory, then the resulting conclusion is that it is not a factor significantly affecting grade one mathematics learning. Perhaps immediate recall of numbers is not important to an understanding of grade one mathematics concepts. In higher grades, where it is necessary to recall sequences of numbers given orally, strong auditory sequential memory would be an asset.

1. (iv) Will grade one mathematics achievement correlate

significantly with any of the five Piagetian tasks?

Piaget has outlined a theory of cognition which sees the development of number concept as being dependent upon operational thought in the areas of quantity, lasting equivalence, seriation, and ordination and cardination. Piaget has presented this as sequential, almost hierarchical development with each concept building on the foundation of the previous one. In this study subjects were observed to be at different stages in different tasks: Not one subject was at Stage 1 in all tasks, and not one was at Stage 3 in all tasks. (Outlined in Table 1.) Results here indicate variations both between subjects, and within subjects' scores. Research here indicates that operational thought in seriation, can appear before operational thought in conservation of discontinuous quantity.

Results of the Discontinuous Quantity tasks did not correlate significantly with grade one mathematics scores. Only 17.7 percent of subjects were not able to conserve quantity when the shape of containers was changed. These subjects were at Stage 2.

> Between the children who fail to grasp the notion of conservation of quantity, and those who assume it as a physical and logical entity, we find a group showing an intermediary behavior (Piaget, 1952:14).

Piaget has described such children as still being under the influence of perception. For him, true reversibility will occur only when the concept of quantity remains the same even if the appearance changes. In this study, some subjects were able to function effectively in grade one mathematics without being able to conserve discontinuous quantity.

Results of the Lasting Equivalence tasks did correlate significantly with grade one mathematics achievement. (See Table 3.) In fact, this test proved to be the "second best" predictor of the mathematics score, and in combination with the visual-motor score, accounted for 24 percent of the variance in mathematics scores. Piaget (1952) has placed great importance on the lasting equivalence concept:

> ...although one-to-one correspondence is obviously the tool used by the mind in comparing two sets, it is not adequate in its original form or forms, to give true equivalence to the corresponding sets.
>
> ...a set or collection is only conceivable if it remains unchanged irrespective of the changes occurring in the relationship between the elements (:41).

The concept of lasting equivalence is directly related to classification. The child who cannot group into sets, and then regroup according to some other principle, will find mathematics difficult. In this study, lasting equivalence of number did prove to be a significant factor in grade one mathematics achievement.

There was no significant correlational relationship between the Spontaneous Correspondence tasks and grade one mathematics achievement. (See Table 3.) Of interest in these results is the fact that no subject was found to be at Stage 1 which is described by Piaget as "glob l compar son":

> The characteristic ature of children at the first stage is that they not as yet feel the need for quantitative evaluation, since they have no precise notions of the cardinal number (1952:67).

Subjects in this study were able to complete simple designs to correspond with those of the examiner, thus displaying a notion of quantification and cardinal number: Consequently, 60.4 percent were found to be in the second stage:

> The second stage, that of intuitive qualitative correspondence, is merely a continuation of the first. As the copying of models becomes more exact, it leads to one-one correspondence susceptible to greater precision. But by the very fact that the correspondence is based on perceptual comparison, it is not numerical from the start, in spite of appearances, but remains qualitative and intuitive (Piaget, 1952:70).

Perhaps the large number of subjects at Stage II, has influenced the statistical results. That is, as all children were either at Stage 2 or Stage 3, then statistical comparison had only a narrow margin in which to operate. In this research, spontaneous correspondence was not a significant factor.

Results of the seriation task did not correlate significantly with mathematics scores (See Table 3.) Of subjects tested, 59.4 percent were able to complete all tasks successfully, thus establishing themselves at Stage 3. These results are interesting in view of the importance Piaget (1952) has placed on seriation. In this study, the majority of subjects were able to recognize the underlying principles of ordination and cardination. That is, they were able to correctly arrange (seriate) the dolls, walking sticks, and balls, and were able to match appropriate sizes, even when correspondence was not clearly recognizable. Thus, most subjects were operational in their understanding of the cardinal and ordinal properties of number.

Results of this study do not show a significant relationship between mathematics and results of the seriation task. (It must be noted here that the correlation coefficient for seriation was very close to being significant at the 0.01 level). Whyte (1977) observed operational thought in seriation to be an important ability in mathematics achievement in seven year olds, and to a lesser extent in nine year olds. Whyte's research involved a more complex evaluation of seriation-Stage 2 scoring was divided into three substages-and thus more specific abilities were tapped than in this study. Perhaps the lack of statistical significance reflects the general nature of this present study which could have missed some important variations, particularly at the Stage 2 level.

There was not significant correlation between scores on the ordination and cardination tasks and mathematics scores (see Table 3). Piaget's research on the study of numerical operations included investigation of the child's understanding of ordination, cardination and their interactions. For Piaget (1952) a true understanding of the ordinal and cardinal properties of numbers is a synthesis of logico-mathematical thought and fundamental to an understanding of the number system. The child must appreciate both the cardinal value of numbers-basic to enumeration, and the ordinal value-basic to sequencing and ordering, as well as additive and multiplicative properties. As in earlier findings, this study has found a majority of subjects in a similar stage. In this instance 72 of 96 subjects were at Stage 2 thus displaying intuitive appreciation of ordination and cardination. However, such appreciation did not prove significant in their mathematics achievement.

1. (v) Will achievement in mathematics correlate significantly with auditory memory

Auditory memory, as measured by the Betts Auditory Memory Span Test correlated significantly with achievement in grade one mathematics. In this study, auditory memory appeared as the "third best" predictor of the mathematics score. In the regression analysis it also emerged as the third most important factor in accounting for variance in mathematics scores. There are interesting variables at work here as auditory memory might reflect one of two aspects: Perhaps attentive behavior is being measured. Grade one pupils are often immature in attentive behavior-particularly where auditory stimuli are concerned. Inattentive behavior usually results in loss of information and consequently lack of understanding: Perhaps, however, th[illegible]s test is reliably measuring the subject's ability to recall meaningful material. This then is the second aspect. Research has shown that subjects differ in their ability to recall auditory material. The Betts test may measure one or the other, or both of these aspects. The fact remains though, that auditory memory as measured here is a significant factor in grade one mathematics achievement.

1. (vi) Will achievement in grade one mathematics correlate significantly with visual-motor integration?

In this study visual-motor integration, as measured by the Beery test, did show significant correlation with the grade one mathematics scores (see Table 3). It was the best predictor of mathematics achievement and alone accounted for 17 percent of the variance in the regression analysis. These results are interesting in light of the emphasis traditionally placed on concrete methods of teaching, particularly in grade one. This study indicates that children who have problems in visual-motor areas, could experience difficulties in learning mathematics concepts. Thus, if the teacher emphasizes the concrete mode such children might suffer if they cannot coordinate the visual and motor aspects of the learning process. In this study, those subjects who were more adept in the visual-motor processes were generally able to achieve better results on the mathematics test.

Question 2. Will combinations of the chosen factors outlined above account for significant variance in grade one mathematics scores?

In the regression analysis, four factors in combination accounted for 34 percent of the variance (see Table 7). Those factors which proved significant were visual-motor integration; lasting equivalence; auditory memory span and right-left orientation ability. The significance of the first three is not surprising as they were significant independent predictors. Of interest here is the inclusion of right-left orientation as the fourth most influential variable in the variance analysis although it did not prove significant as an independent variable.

Summary of Conclusions

In this study, the following factors were observed to demonstrate a significant relationship to grade one mathematics achievement: visual-motor integration, lasting equivalence of number, and auditory memory span. In combination, visual-motor integration, lasting equivalence of number, auditory memory span and right-left orientation accounted for significant variance in mathematics scores. Factors which did not display a significant relationship to grade one mathematics scores were: age and sex; auditory sequential memory; conservation of discontinuous quantity; spontaneous correspondence; and seriation.

Recommendations For Further Research

This study has been limited in the number of factors observed and in the type of instruments used. As already observed, the literature is sparse in studies evaluating the influence of such factors as "teacher effectiveness", and "children's attitudes towards mathematics". Further research into factors significant in mathematics success should include these topics.

Specifically, research which has been suggested by results of this study is as follows:

1. A diagnostic instrument such as the Key Math Diagnostic Arithmetic Test (Connelly, Nachtman & Pritchett, 1976) would be a more thorough assessment of mathematics knowledge than the test used in this study. A diagnostic analysis of strengths and weaknesses might reveal a more specific relationship with predictor variables such as auditory memory, etc.

2. This study has suggested a link between auditory memory and mathematics achievement. A more specific analysis here could involve use of such instruments as the Wepman Auditory Discrimination Test (1958) to examine the true nature of the process under investigation. That is, perhaps poor discrimination is affecting recall, rather than attention or memory facts.

3. An instrument such as the Purdue Perceptual-Motor Survey (Roach and Kephart, 1966) could be used in further assessment of the visual-motor/perceptual processes. In light of the findings of this research, it would be feasible to further investigate these areas. The Purdue Survey, and the Bender Visual-Motor Gestalt Test have the advantage of being individually administered, thus allowing for closer examination of the subject. They would refine the more

eneral results of the Beery Test.

4. The sample population used in this study was general in nature. Useful research could involve a pre-screening of subjects for mathematics achievement and a specific analysis of the performance of underachievers on Piagetian tasks.

Recommendations For Grade One
Mathematics Teaching

To conclude this research it is appropriate to make some recommendations for the teaching and learning of grade one mathematics based on the results of the study. The literature (Riesman, 1977; Kramer, 1978), has pointed to the need f[illegible]ivid-ualized instructional approaches, and to the employment of a variety of instructional methods.

It would appear that the popular emphasis on teaching through concrete methods in the primary grades is not a successful approach with all children. Wedell (1973) has noted:

> Modern mathematics teaching has emphasized the importance of the understanding of the concept of quantity. This has led to an increased use of concrete materials with which the child is required to carry out operations involving sensory and motor organization...The child without specific disabilities is able to manipulate these materials with sufficient competence, so that he can begin to build up his concepts of quantity from experience. The teacher may, however, find that the child with poor sensory and motor organization is having to spend most of his effort in the spatial arrangement of material (:105).

Results of this study have supported the notion that some children who experience difficulty with visual motor integration, display weaknesses in mathematics achievement. These children may have problems in setting out sums. They will possibly have difficulty when setting out tens, units, etc., and will end up with the incorrect answer because of organizational difficulties.

Teachers must also be aware of the importance of auditory memory span. This research has underscored its importance as a factor in grade one mathematics achievement. The grade one teacher should minimize the length of auditory cues and attempt to ensure that each child is attending when important auditory cues are given. The Distar reading method has a useful tip as it employs a hand signal and an auditory cue such as "ready", when information is about to be given. If the grade one mathematics teacher were to use cues such as a hand signal and an established short auditory cue, this might help to gain the pupils' attention.

The above concerns are related to the child's sensory-perceptual abilities. Of equal importance is an awareness of cognitive developmental levels as described by Piaget. Teachers who appreciate the role played by operational thought will be aware of the importance of one-to-one concepts and the lasting equivalence of numbers. Student teachers should be exposed to Piaget's theory in that it stresses the importance of operational thought as well as the uniqueness of each child. Teachers must recognize that [illegible] child must be capable of reversibility of thought before he can really know the nature of addition and subtraction. Piagetians (Isaacs, 1964; Furth, 1970; Elkind, 1976) have suggested practical outcomes of Piaget's theory:

1. The curriculum should be sequenced to allow for developmental levels.

2. The classroom environment should emphasize "thinking" skills. Children should be given the chance to explore and discover concepts for themselves.

3. The school day should allow for many types of learning: concrete, iconic, abstract; visual and auditory; teacher directed, pupil directed.

4. Teachers should be trained in observational skills.

This last point is interesting and brings this discussion to the teacher's need to look at individual pupil requirements. To determine the child's "readiness" the grade one teacher could develop her own checklist of skills. This could include a survey of the auditory, visual-motor and conservational skills of each pupil. The learning disabilities literature has proposed a "Diagnostic Teaching Model" which would seem appropriate for regular classroom use. The model follows the following stages:

1. Identify the child's strengths and weaknesses.
2. Hypothesize on the causes of weaknesses and plan strategies for meeting the child's needs.

3. Instruct according to strengths and remediate weak areas.

4. Evaluate regularly. Evaluation is a continuous function of diagnostic teaching and has relevance for the classroom. Regular assessment and re-alignment of strategies should maximize instruction.

Results of this study may suggest a need for employment of a variety of instructional methods. Crawley, (in Hammill & Bartel, 1978), has outlined an "interactive unit model of mathematics teaching." This model employs a multitude of pupil-teacher interaction techniques. The teacher may construct something, present something, say or write something. The child, in turn, can construct, identify, say or write. Crawley has conceived of 16 combinations of possible interactions. This allows the teacher to be flexible in her approach. This method would suit the recommendations of this study as it would allow the child with deficiencies in one area, to learn effectively through other mediums.

Finally, this study will conclude by reaffirming certain ideas which were basic to its inception. In the teaching of grade one mathematics "readiness" should be considered. Effective primary teaching can provide for evaluation of pupils' individual strengths and weaknesses. The teacher can remain cognizant of these and so vary instructional approaches to meet individual needs. Effective primary teaching might also see a variation in instructional methods such as those described by Crawley. Such methods provide for a multi-sensory approach and in this regard could instill knowledge in a number of ways. Also, it allows the child with a weakness in one dimension to possibly learn through another. Such approaches consider the unique cognitive and perceptual levels of each child.

It has been the purpose of this study to isolate certain factors influencing grade one mathematics achievement. In this respect modest success has occurred. The data of the research is factual and objective; but the underlying concern has always been the individual child in the school setting.

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APPENDIX A

Grade I Mathematics Program

Taken From The

Program of Studies For

Elementary Schools, 1978,

Alberta Education

LEVEL A (Grade 1)

Number

1. Matches members of two sets and determines equivalent and non-equivalent sets.

2. Describes relationships such as more, fewer, greater than, less than, equal to. (no symbols)

3. Associates a numeral with equivalent sets. (0-9) Cardinality.

4. Demonstrates knowledge of the order property of numbers by ordering sets by relative size, by counting, and by arranging digits in order. (Ordinality)

5. Reads and writes numerals. (0-99)

6. Identifies and renames the number of 10's and the number of 1's in any two-digit number.

Operations and Properties

1. Understands the processes of addition and subtraction.

2. Symbolizes addition and subtraction situations.

3. Demonstrates mastery of the basic facts involving sums and minuends through 9.

Measurement

1. Tells time to the hour.

2. Recites the days of the week in order.

3. Compares two or more objects as shorter than, longer than, thinner than, thicker than, heavier than, lighter than, etc.

4. Estimates and measures using non-standard units of capacity, mass, and linear measures.

5. Identifies instruments for measuring time, mass, length, capacity and temperature.

6. Recognizes pennies, nickles, dimes and quarters, and the value of each.

Geometry

1. Classifies, by manipulation, 3-dimensional objects according to various attributes.

2. Recognizes and names circle, square, triangle, rectangle.

Graphing

1. Collects data from immediate environment and constructs graphs using pictures or objects.

APPENDIX B

AUDITORY MEMORY TEST

BETTS AUDITORY MEMORY SPAN TEST

DIRECTIONS: "I am going to tell you something. After I have finished, you say it."

Do not phrase or repeat. Continue until one or more mistakes have been made in each of five sentences.

EXAMPLE: I have a puppy. Our puppy ran away.

1. My kitten likes milk.
2. Mother will be here soon.
3. Jack Frost comes when I am fast asleep.
4. I rode the pony far into the woods.
5. The hen opened the bag and ran away.
6. My brother did not know which way to go.
7. When my rabbit gets loose he is hard to catch.
8. A rabbit chased the puppies all the way home.
9. We like to wade in the water when it is not too cold.
10. The small white chick had no mother.
11. When the kite was high in the sky the string broke.
12. The little pine has long green needles.
13. The sun was shining but the rain kept falling.
14. The big brown bear ate honey three times that day.
15. The sly fox had a large bushy tail.
16. We had dogs, kittens and rabbits in our circus.

17. The little children saw the pretty rainbow in the sky.

18. In winter we slide down the hill on our sleds.

19. The big eyes of the owl were bright and shiny.

20. The postman brings us letters or packages almost every day.

21. A goat ate all the fresh green leaves on the tree.

22. He was a tall, lean man with a long gray beard.

23. When winter comes the animals grow heavy coats of fur to keep them warm.

24. The nice little puppy played with the white furry kitten all day long.

25. The carpenter had a heavy hammer, a sharp saw and a long ladder.

SCORING: One mark for each sentence correctly repeated.

21 - 25	Superior
17 - 20	Good
13 - 16	Mediocre
8 - 12	Poor
1 - 7	Failure

Name ____________________________

C.A. __________ Grade ______ I.Q. ____

Score /25 Rating ____________

Date ____________________________

Examiner ________________________

APPENDIX C

PIAGETIAN TASKS

Piagetian Tasks

Adapted From Marks, (1972:94-96)

Task 1-Conservation of Discontinuous Quantities.

Materials: beads (same number of blue and yellow beads)

The child was shown two cups of beads (blue, yellow). He was told that there were the same number of beads in both. He was then asked if a necklace made from the yellow beads would be as long as a necklace from the blue beads. If the answer was affirmative the examiner then poured the blue beads into a narrow container and asked the child if there were more now, or the same. If the child answered the same, he was judged to be conserving.

Task II-Lasting Equivalence

Materials: pennies and lollipops

The examiner placed six lollipops on the table. The child was asked to estimate the number of pennies needed if each lollipop were worth one penny. If the child answered correctly, the examiner then bunched the lollipops on the table and spread ten pennies out in a row. The child was asked if there were more, less, or the same number of pennies as lollipops. If the child answered affirmatively, the child was asked if there were more, less, or the same. The last procedure was to have the child exchange lollipops for pennies with the examiner. Depending on how high the child counted, the examiner covered the pennies exchanged with his hand at that counting point, but always under nine. The child was then asked to tell the examiner how many pennies were under his hand. A child at Stage III can deduct from the lollipops exchanged, the number of pennies under the examiner's hand.

Task III-Spontaneous Correspondence

Materials: black and red counters, 2 inches in length.

The child was asked to copy exactly what the examiner did. If the child asked about colour, the examiner responded by saying, "Do exactly what I've done."

Series 1 - open series - 2 parallel rows of counters.

Series 2 - closed figures, shape depended on number of elements: square- 4 counters and 8 counters, triangle-3 counters, circle-10 counters.

Series 3 - closed figures - rhombus, parallelogram. When the child was able to complete all figures satisfactorily, even if he disregarded color, he was considered at Stage III.

(some alterations were made here: The number of series was reduced from 5 to 3)

Task IV-Quantitative Similarity-Seriation

Materials: 10 paper dolls, 10 sticks, and 10 wax balls all equally proportioned from small to large.

The examiner placed the dolls on the table and asked the child to arrange them by size. If the child had trouble the examiner helped him. The examiner then placed the sticks on the table and asked the child to place the correct sticks with the dolls according to size. If the child still seemed in difficulty the examiner again assisted, explaining that the big stick went with the biggest doll and the smallest stick with the smallest doll. The balls were then brought out and the procedure was repeated. The examiner then took the balls and placed them above the dolls but moved them closer together. The child was asked which ball doll number seven would have (pointing to the doll), then doll number eight, and doll number four. The balls were reversed and the child was asked which ball would doll number ten have. If the child was able to satisfactorily complete all tasks, he was deemed to be at Stage III. (The seriation tasks were condensed slightly from the originals outlined by Marks).

Task V-Ordination and Cardination

Materials: Cards representing units: A-1, B-2a, C-3a, D-4a, E-5a, F-6a, G-7a, H-8a, I-9a, J-10a.

The child was asked to arrange the cards by size, thus making a ladder. If he had difficulty the examiner helped him. He was then asked to count the cards as far as he could without hesitating. He was then asked how many A's could fit into B.

If he was unable to answer, the examiner demonstrated that 2 A's could fit into B. He was then asked about C, E, and I. G was then pulled out and the child was asked to give the answer. If the child answered all the questions correctly, he was at Stage III.

Piagetian Stages in Conservation

As Outlined By Marks (1972:94-96)

Stage I (Pre-operational)-In conservation of discontinuous quantities, the child believes that when the quantity changes shape, the quantity changes. He cannot estimate how many elements are necessary to exchange sets, although he is able to handle one-to-one correspondence. The child gives a global comparison in spontaneous correspondence. He is unable to seriate, nor does he understand ordination and cardination beyond the numbers three or four.

Stage II (Intuitive)-The child is capable of intuitive understanding and can account for conservation when there is slight change in pattern, but not when the change is significant. In lasting equivalence, the child is capable of making correct estimates through visual correspondence, but still does not believe the sets are equivalent. The child operates intuitively in spontaneous correspondence, obtaining the qualities of the object with the quantity. In seriation, there is an intuitive effort to solve the problem, but it is without system. The child is capable of handling ordination or cardination through trial an[illegible], but not when the order is changed.

Stage III (Operational)-The child is able to coordinate differences in height and cross-section in a multiplication of relations. Lasting equivalence becomes obvious. In spontaneous correspondence, the [illegible] is able to use both numerative or qualitative correspondence. With seriation and ordination and cardination, the child understands the problem even if the elements are out of order.

QUESTION AND ANSWER SHEETS FOR PIAGETIAN TASKS

NAME OF SUBJECT ____________________

SCHOOL ____________________

TASK I CONSERVATION OF DISCONTINUOUS QUANTITIES

(Materials: 3 beakers: 2 approximately 4" x 2", 1 approximately 6" x 1")

Subject is shown two beakers; one containing 40 blue beads, and the other containing 40 yellow beads.

Examiner: These two containers have the same number of beads. Would a necklace made from the blue beads be as long as one made from the yellow beads?

Response:

		Stage
No	_____	I
Yes	_____	II

The blue beads are then poured into a long narrow container while the child watches.

Examiner: Are there the same number of blue beads as yellow beads; or are there more or less blue beads than yellow beads?

Response:

More or Less	_____	I
Same	_____	III

TASK II LASTING EQUIVALENCE OF NUMBER

(Materials: 6 lollipops, 10 pennies)

The examiner places 6 lollipops on table.

Examiner: How many pennies would I need to buy these lollipops if they cost 1 penny each?

Response:

		Stage
Other	_____	I
Six	_____	II

The lollipops are bunched and 10 pennies spread out in a row.

Examiner: Are there the same number of pennies as lollipops, or are there more or less pennies than lollipops?

Response:

Less, Same	_____	II
More	_____	II+

Examiner: I want you to give me one penny for each lollipop on the table.

Response:

Other	_____	II
Six	_____	III

Examiner: How many pennies are left? (covers remainder)

Response:

Other	_____	III
Four	_____	III

TASK III SPONTANEOUS CORRESPONDENCE

(Materials: 20 black, 20 red counters 1" x 2")

Examiner: I want you to copy the things that I do.

Series I: Examiner makes 2 parallel rows of 3 counters each.

Response:

		Stage
Different	_____	I
Same	_____	II

Comments ______________________________

Series 2: Examiner makes a square using 8 counters.

Response:

Different	_____	II
Same	_____	II+

Comments ______________________________

Series 3: Examiner makes a circle using 10 counters

Response:

Different	_____	II
Same (Shape and Number)	_____	III

Comments ______________________________

TASK IV QUANTITATIVE SIMILARITY: SERIATION

(Materials: 10 paper dolls, 10 walking sticks, 10 clay balls all equally proportioned from small to large.)

Examiner: Places dolls on the table: I want you to arrange them in order of size.

Response:			Stage
	Help required	_____	I
	Correct	_____	II

Comments ____

Examiner: Now I want you to place the correct stick with each doll, according to size.

Response:			
	Help required	_____	I
	Correct	_____	II+

Comments ____

(If help required in both-then at Stage I.)

Examiner: Now place the balls with the dolls according to size.

Response:			
	Help required	_____	II
	Correct	_____	II+

Comments ____

Examiner: Bunches balls above the dolls: Which ball would this doll have?

Response:			
	No. 7	_____	II
	No. 8	_____	or
	No. 4	_____	III

TASK V ORDINATION AND CARDINATION

(Materials: Cards representing units A-1, B-2a, C-3a, D-4a, E-5a, F-6a, G-7a, H-8a, I-9a, J-10a.)

Examiner: I want you to arrange these cards according to size. This will make a ladder.

Response: Stage

	Help required	_____	I
	Correct	_____	II

Examiner: Please count these cards for me.

Response:

	Incorrect	_____	II
	Correct (10)	_____	II+

Comments ______________________________________

Examiner: How many A's could fit into B?

Response:

	Incorrect	_____	II
	Correct (2)	_____	III

Help required? ______________________________

Examiner: How many A's could fit into C? _____

into E? _____

into I? _____

into G? _____

If all correct Stage III

APPENDIX D

TABLES OF RESULTS

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age in Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
01	1	78	12	10	11	09	1	1	2	1	1	22
02	2	88	12	06	13	10	2	3	2	3	3	44
03	1	80	12	09	21	11	2	3	2	2	1	50
04	2	79	07	09	15	13	3	3	2	3	2	50
05	1	83	00	14	12	13	1	2	2	3	3	48
06	2	78	11	10	08	14	2	2	2	3	2	43
07	1	81	10	10	17	15	1	3	2	3	3	49
08	2	78	00	10	12	10	1	3	3	2	2	30
09	2	86	09	08	17	15	3	3	2	3	2	43
10	1	82	06	10	10	14	2	3	3	3	3	44
11	1	82	08	06	14	14	1	3	3	3	2	47
12	1	83	08	05	15	11	1	1	3	3	2	47
13	2	88	12	12	16	11	2	2	2	1	2	44
14	1	84	03	06	04	10	2	2	2	1	1	37
15	1	87	10	15	14	15	2	2	2	2	3	44
16	2	88	12	15	15	12	2	1	3	2	2	50

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age in Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
17	1	85	10	03	02	08	1	2	3	1	1	44
18	2	91	12	08	10	12	2	3	3	3	2	40
19	2	87	10	04	06	15	2	3	3	1	2	40
20	2	83	08	07	05	17	2	1	2	2	2	43
21	2	77	12	10	08	12	2	2	2	1	2	36
22	1	80	12	07	10	13	2	3	2	2	2	39
23	1	85	10	06	08	09	2	3	2	1	2	42
24	1	78	12	08	11	11	2	2		1	2	43
25	2	78	08	07	12	15	2	2	2	1	2	36
26	2	75	11	10	14	10	1	2	2	3	2	32
27	1	88	07	07	10	16	2	3	3	3	3	48
28	2	86	07	10	18	13	3	2	2	3	2	49
29	1	84	09	08	06	15	2	3	2	3	2	40
30	1	78	11	08	08	10	2	2	2	3	2	25
31	2	80	08	07	20	13	3	3	3	2	2	37
32	2	89	12	10	10	15	2	2	3	3	2	29

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age In Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
33	1	80	08	11	17	14	1	1	3	3	2	37
34	2	83	12	11	20	13	2	2	3	3	3	44
35	2	84	05	04	05	13	2	3	2	3	2	42
36	1	91	055	08	21	12	3	1	2	3	2	33
37	2	77	02	13	19	11	2	2	2	1	3	15
38	1	88	10	09	07	17	2	2	2	3	2	41
39	2	86	09	09	16	16	1	2	3	3	3	38
40	2	79	06	04	03	07	2	1	2	1	1	14
41	1	86	08	08	11	14	1	2	2	1	2	37
42	1	88	06	07	17	10	2	2	3	3	2	33
43	2	84	12	12	21	13	2	3	2	2	2	31
44	1	97	06	07	13	14	3	2	3	3	2	37
45	2	92	09	08	10	14	2	3	3	3	2	41
46	2	80	02	12	13	09	2	2	2	1	2	28
47	2	77	01	05	08	14	2	2	2	3	2	32
48	2	81	07	04	06	12		3	3	3	2	27

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age In Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
49	1	87	09	07	15	11	2	3	2	2	2	27
50	2	85	12	12	11	13	2	2	3	3	2	40
51	1	74	06	10	16	15	2	2	3	3	2	40
52	2	83	08	11	13	15	2	3	3	3	3	52
53	2	76	09	06	11	09	2	3	3	1	3	38
54	2	79	00	09	11	09	2	3	2	1	2	35
55	1	86	09	07	08	12	1	3	2	1	2	34
56	2	80	12	09	11	15	1	3	2	3	2	36
57	2	85	12	08	09	14	3	2	3	3	2	43
58	1	78	08	08	10	16	3	3	3	3	2	52
59	2	76	06	04	02	07	1	1	2	3	2	28
60	2	81	12	09	14	10	2	3	2	3	2	42
61	1	81	04	12	12	10	3	3	2	2	2	41
62	2	88	00	08	15	14	2	2	3	3	2	43
63	1	93	04	06	14	14	3	2	2	3	2	48
64	1	78	09	11	19	11	2	2	2	2	2	47

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age In Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
65	2	89	11	07	16	14	2	2	3	3	2	56
66	1	85	02	07	16	16	3	3	3	3	2	56
67	2	86	08	11	09	11	2	1	3	2	2	35
68	2	79	12	13	11	17	2	2	3	3	2	56
69	2	81	10	10	10	11	1	3	3	1	2	50
70	1	96	09	07	11	13	2	3	2	3	2	51
71	1	85	08	07	14	13	2	3	3	3	2	53
72	2	77	12	06	10	16	2	2	2	3	2	49
73	2	83	12	08	17	11	2	3	2	3	2	50
74	1	80	07	09	04	11	2	3	3	1	2	40
75	1	80	12	12	21	10	3	1	3	3	2	55
76	1	84	12	11	16	15	3	3	2	1	2	55
77	1	75	03	13	16	14	3	3	2	3	2	48
78	2	85	06	05	13	16	3	3	3	3	3	39
79	2	86	12	07	09	12	2	1	2	3	1	22
80	1	91	06	04	00	12	2	1	2	2	1	20

GENERAL RESULTS

Subject I. D.	Sex (1-Male) (2-Female)	Age In Months	Right-Left Orientation	Digit Span	Auditory Memory Span	Visual-Motor Integration	Discontinuous Quantity	Lasting Equivalence	Spontaneous Correspondence	Seriation	Ordination & Cardination	Mathematics Score
81	2	82	10	11	18	11	2	1	2	2	1	34
82	1	80	11	10	09	10	2	1	2	3	2	33
83	1	80	02	05	09	11	2	1	2	3	2	16
84	1	80	022	09	11	12	2	3	2	3	2	34
85	2	83	12	07	14	[illegible]	1	3	2	3	2	36
86	1	86	12	08	12	13	1	3	2	2	2	49
87	2	78	04	04	08	11	2	1	2	3	2	38
88	2	95	12	06	09	10	2	1	3	1	1	44
89	2	84	00	11	16	11	2	3	2	3	3	51
90	1	80	05	08	11	12	2	3	3	3	2	51
91	1	90	07	09	11	12	2	3	3	2	2	36
92	2	89	11	07	12	13	1	3	3	3	3	49
93	2	96	03	09	04	11	1	2	2	2	2	32
94	2	78	09	05	12	09	2	3	2	2	2	37
95	1	81	10	05	09	14	3	3	2	2	3	42
96	1	85	05	03	03	10	2	2	3	1	2	25

MEANS AND VARIANCES FROM STATISTICAL ANALYSIS OF VARIABLES

Column Variable	1 Sex	2 Age	3 Left-Right Orientation	4 Auditory Sequential Memory	5 Auditory Memory Span	6 Visual-Motor Integration
Mean	1.531	83.343	8.083	8.260	11.781	12.437
Variance	0.249	25.309	12.972	6.972	21.879	5.267
Column Variable	**7 Discontinuous Quantity**	**8 Lasting Equivalence**	**9 Spontaneous Correspondence**	**10 Seriation**	**11 Ordination Cardination**	**12 Math Score**
Mean	1.979	2.302	2.396	2.375	2.062	39.937
Variance	0.375	0.565	0.239	0.672	0.246	85.140

REGRESSION ANALYSIS

Source	Sum of Squares	D of F	Mean Square	F obs.	Probability
Regression	2892.955	5	578.591	9.861	0.00000
Residual	5280.512	90	58.672		
Total	8173.469	95			
Variable(s) Entered		6 8 5 3 9			
r-squared		0.354			

REGRESSION ANALYSIS

(continued)

Source	Sum of Squares	of F	Mean Square	F obs.	Probability
Regression	2994.714	6	499.119	8.578	0.00000
Residual	5178.754	89	58.188		
Total	8173.469	95			
Variable(s) Entered	6 8 5 3 9 1				
r-squared	.366				

REGRESSION ANALYSIS

(continued)

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	3050.005	7	435.715	7.484	0.00000
Residual	5123.461	88	58.221		
Total	8173.469	95			
Variable(s) Entered		6 8 5 3 9 1 4			
r-squared		0.375			

REGRESSION ANALYSIS

(continued)

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	3114.685	8	389.335	6.696	0.00000
Residual	5058.781	87	58.147		
Total	8173.469	95			
Variable(s) Entered		6 8 5 3 9 1 4 10			
r-squared		0.381			

REGRESSION ANALYSIS
(continued)

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	3142.454	9	349.161	5.969	0.00000
Residual	5031.012	86	58.500		
Total	8173.469	95			
Variable(s) Entered		6 8 5 3 9 1 4 10 7			
r-squared		.384			

REGRESSION ANALYSIS

(continued)

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	5161.019	10	316.102	5.360	0.00000
Residual	5012.449	85	58.970		
Total	8173.469	95			

Variable(s) Entered	6 8 5 3 9 1 4 10 7 2
r-squared	0.387

REGRESSION ANALYSIS

(continued)

Source	Sum of Squares	D of F	Mean Square	F. obs.	Probability
Regression	3161.814	11	287.438	4.813	0.00000
Residual	5011.652	84	59.663		
Total	8173.469	95			

Variable(s) Entered	6 8 5 3 9 1 4 10 7 2 11
r-squared	0.387