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SELECTED VARIABLES RELATED TO MOVEMENT

TASK PERFORMANCE MEASURES OF

7-YEAR-OLD GIRLS

by

Joy C. Greenlee

A Dissertation Submitted to
the Faculty of the Graduate School at
The University of North Carolina at Greensboro
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of the Requirements for the Degree
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Approved by

Dissertation Adviser

APPROVAL PAGE

This dissertation has been approved by the following committee of the Faculty of the Graduate School at the University of North Carolina at Greensboro.

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GREENLEE, JOY C. Selected Variables Related to Movement Task Performance Measures of 7-Year-Old Girls. (1977) Directed by: Dr. Pearl Berlin. Pp. 136.

The present investigation examined the relationship of three developmental variables--skeletal maturity, visual-motor functioning, and mental ability--with the early- and late-trial performance scores on three motor control tasks. In addition, the degree to which early- and late-trial performance on each of the motor control tasks could be predicted by the developmental variables was investigated. The subjects for the study were 35 7-year-old girls.

The developmental variables were measured by the following instruments: (a) skeletal maturity was determined from a hand-wrist X-ray; (b) the average of the T-score conversions for the five subtests of the Frostig was the measure of visual-motor functioning; and (c) mental ability was assessed by the OLMAT, Primary I level.

The investigation utilized elements of computer-analogy models in establishing the criteria for the movement tasks. The motor control tasks developed for this investigation were designated as hopscotch, throw and catch, and stepping stones. Subjects in the study performed each of the motor control tasks for five trials per day on three consecutive days, resulting in a total of 15 trials. Early-trial performance was the sum of the time required to perform the task on Trials 1 and 2. The performance score for late trials was the result of summing the child's times for Trials 14 and 15.

Canonical correlation was utilized to examine relationships between the developmental variables and performance on the motor control tasks. The degree to which each of the performance measures could be predicted by skeletal maturity, visual-motor functioning, and mental ability was determined through the use of multiple regression analysis. A maximum R^2 improvement technique was used to enter variables in the prediction equation.

Results of the canonical correlation procedure revealed that no significant relationships existed between the developmental variables and performance on the motor control tasks. The first canonical correlation ($p > .742$) accounted for 22.28% of the variance between the two sets of variables. Multiple regression analysis revealed that mental ability was a satisfactory predictor ($p < .05$) of performance for the early- and late-trials of the throw-and-catch task. No combination of the developmental variables was found to have significant predictive power for early- and late-trial performance of the hopscotch or stepping-stones task. The proportion of variance accounted for when all developmental variables were entered in the prediction equation were the following: 7.99% for hopscotch--early trials, 11.43% for hopscotch--late trials; 15.[illegible]% for throw and catch--early trials. 16.12% for throw and catch--late trials; 9.63% for stepping stones--early trials, and 11.77% for stepping stones--late trials.

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CHAPTER I

INTRODUCTION

For decades, the study of motor development and motor learning followed separate and theoretically distinct research strategies. Recently, Connolly (1970b) called for a consolidation of research approaches in order to achieve more complete understanding of motor skill development in children. Keogh (1971b) proposed that control may be an important concept about which research in motor skill development might be based. In general, motor control implies the ability to plan and execute successive actions in accordance with the demands made by the environment and/or task. The child's ability to achieve motor control in a wide variety of situations appears to be an essential feature of motor skill development.

A potentially significant advance toward unifying different approaches to the study of motor skill development was marked by the appearance of computer-analogy models proposing hypothetical explanations of the processes operating in skill acquisition. A unique feature in applying these models to children is that many of the processes hypothesized to be related to skill development undergo concurrent change. Connolly (1973b) suggested that the following factors place constraints on the ability of children to learn motor skills: (a) the modularization and extent of the subroutines, (b) the ability to apply cognitive rules in combining subroutines into specific skills, and (c) the capability for sensory-motor functioning.

Most researchers emphasized a single factor in formulating explanations of the child's ability--or inability--to perform motor skills. Birch and Lefford (1967) and Williams (1973b) suggested that the child's level of intersensory integration may impose restrictions on the ability to deal with simultaneous information from different sense modalities during the movement performance. Similarly, Kay (1969) hypothesized that the limited information-processing capabilities of the child may account for inferior performance under certain conditions, especially those involving speed. Bruner (1970) emphasized the idea that the child's ability to select appropriate sequential actions and utilize feedback is essentially a problem-solving task and, therefore, related to cognitive functioning. In addition, Seefeldt (1973) identified biological age as an important variable related to motor development. In summarizing the complexity of motor skill development, Connolly (1970a) stated that "there is more than one kind of mechanism involved and many developmental processes are going on simultaneously" (p. 186).

Statement of the Problem

The purpose of this study was to investigate the relationship between selected developmental variables and the performance of tasks requiring motor control by seven-year-old girls.

This study sought to answer the following broad question: How are skeletal maturity, visual-motor functioning, and mental ability related to motor control task performance measures of seven-year-old girls? More specifically, the investigation attempted to answer these questions: (a) What is the nature of the relationship of skeletal maturity, visual-motor functioning, and mental ability with respect to early- and late-trial performance on three distinct motor control tasks? and (b) To what extent are skeletal maturity, visual-motor functioning, and mental ability predictors of early- and late-trial performance on each of the motor control tasks?

Hypotheses

The study tested the following null hypotheses:

1. No significant canonical correlations exist between skeletal maturity, visual-motor functioning, and mental ability and the early- and late-trial performance on three distinct motor control tasks by seven-year-old girls.

2. Skeletal maturity, visual-motor functioning, and mental ability, considered separately or in combinations, are not significant predictors of early- and late-trial performance of the hopscotch, throw-and-catch, and stepping-stones tasks.

Definition of Terms

Computer-analogy model--a schematic representation utilizing computer operations to formulate hypothetical explanations of processes operating in another system.

Early-trial performance--the sum of the scores for Trials 1 and 2 in a series of 15 trials.

Feedback--information from an action which can be utilized in subsequent actions.

Late-trial performance--the sum of the scores for Trials 14 and 15, the last two trials of a given series.

Mental ability--the raw score on the Elementary I level of the Otis-Lennon Mental Ability Test.

Motor control task--a task requiring the performer to plan and execute successive actions without specifying the form of the movement; not assumed to be representative of all movement tasks.

Motor plan--an integrated strategy for accomplishing an action (Miller, Galanter, and Pribram, 1960).

Motor skill--"the organization of actions into a purposeful plan which is executed with economy" (Elliott and Connolly, 1973, p. 135).

Motor skill development--intraindividual change in the ability to plan and execute goal-directed movements.

Seven-year-old girl--a female between the ages of 7 years, 0 months and 7 years, 11 months when calculated to the nearest month.

Skeletal maturity--the skeletal age equivalent as determined by selected bones of the hand and wrist using X-ray procedures and interpreted according to the Pyle-Waterhouse-Gruelich Atlases for females.

Visual-motor functioning--the score on the Marianne Frostig Developmental Test for Visual Perception.

Assumptions Underlying the Research

The following assumptions were made in regard to the study:

1. The hand-wrist X-ray is a valid and reliable measure of skeletal maturity when evaluated by a trained radiologist according to the Pyle-Waterhouse-Gruelich method.

2. When administered and scored by a school psychologist, the Otis-Lennon Mental Ability Test, Elementary I level, is a valid and reliable measure of mental ability for seven-year-old children.

3. The Marianne Frostig Developmental Test of Visual Perception is an accurate measure of visual-motor functioning for seven-year-old girls when administered and scored by a school psychologist.

4. The time necessary to complete execution offers a valid representation of a child's performance on the selected motor control tasks. The measurement of time to the nearest one-tenth of a second is a valid means of determining such performance.

5. The measures of skeletal maturity, sensory-motor functioning, and mental ability were not subject to change during the three-week testing period.

Scope of the Study

The data were collected between October 11 and October 29, 1976. Subjects for the study were 35 seven-year-old female students from Hamilton, Emerson, and State Road Elementary Schools in La Crosse, Wisconsin. The nature of the measures included in the experiment necessitated obtaining parental consent for participation in the study. Any child having a diagnosed visual or auditory learning problem was excluded from the investigation.

The predictor variables in the study included skeletal maturity, visual-motor functioning, and mental ability. The early- and late-trial performance scores on (a) hopscotch, (b) throw and catch, and (c) stepping stones were the criterion variables in the experiment. No attempt was made to control for motivation or prior experience of the subjects.

Significance of the Study

Researchers and teachers interested in primary-age children are quite aware of the wide variation in their ability to perform motor skills. Although the age-related changes occurring within separate developmental systems have been well documented, few studies have examined developmental processes which may be related to the child's motor skill performance (Roberton and Halverson, in press).

Almost without exception, the motor skill of primary-age children has been measured by the performance scores from a few early trials. While this information is valuable, it does not provide a basis for anticipating the ability to perform the task after extended practice. Christina (1975) stated that practice is one of the most important determinants of a child's motor skill development. Therefore, it is important that the child's performance be measured following the opportunity for practice.

By examining relationships between motor control task measures and selected developmental variables, the present study may add to current understanding of factors influencing motor skill development in seven-year-old girls. Furthermore, the research permits reasoned speculation about the ability of these developmental measures to predict specific task performance measures. Although limited in its applicability to all children, the results of the present study may provide research evidence regarding the motor control task performance of seven-year-old girls which, to date, has been unavailable.

Finally, this investigation represented an initial attempt to design movement tasks that were consistent with computer-analogy models while retaining a similarity to physical education experiences. Perhaps, with refinement, this has the potential to be a viable research strategy for further investigating the motor skill development of children.

CHAPTER II

REVIEW OF LITERATURE

The purpose of the study was to investigate the relationship between selected developmental variables and the performance of tasks requiring motor control by seven-year-old girls. Consequently the literature review was organized into the following major sections: (a) computer-analogy models of motor skill development, (b) the relationship of skeletal maturity and motor skill development, (c) the relationships of visual-motor functioning and motor skill development, and (d) the relationship of mental ability and motor skill development. The major portion of the developmental literature was applicable to the primary-age child.

Computer-Analogy Models of Motor Skill Development

Cybernetic Concepts and Computer Analogy Models

Hubbard (n.d.) stated that man has sought to explain behavior in terms of machine analogies. In recent years, the computer served as the model most often used to form hypothetical explanations of human behavior. As Hubbard noted, the use of machine models as analogies of behavioral systems served as an alternative to the "black box" approach adopted by stimulus-response learning theorists.

Higgins (1972) used a modification of Wiener's statement in defining cybernetics as "the study of self-regulating systems or servo-mechanisms, both biological, and physical" (p. 313). A system has been designated as retaining its identity despite changes within the system and interaction with its environment (Hubbard). Cybernetic models were distinguished by the assumption that the systems are capable of generating their own activity (Hubbard). In addition, Smith and Smith (1962), Higgins, and Hubbard emphasized that cybernetic models are concerned with the manner in which control and communication are established within the system. Inherent in the concept of control, according to Miller, Galanter, and Pribram (1960) was the existence of a goal, or plan, against which feedback from the movement may be compared.

The literature about motor skill acquisition has undergone marked changes as the result of efforts during the last two decades to develop computer-analogy models utilizing the principles of cybernetics (Smith, 1972). While a complete review of the available computer-analogy models of motor skill acquisition was beyond the scope of the present study, the differentiating features of such models were summarized.

Welford (1972) differentiated cybernetic views of human movement performance from previous behavioristic theories. Contrary to the assumption that behavior was based on previous associations, cybernetic models were based on the tenet that, since no two movements are exactly the same, previous experience did not account for subsequent performance. Instead, a strategy for the execution of each action appeared to be computed based on data immediately available to the performer as well as the intent of the movement and previous experience.

In addition, Welford explained that by viewing the system as a servo-mechanism, performance was no longer considered to be controlled exclusively by external events. Cybernetic theorists asserted that information from the performance, as well as from external sources, was utilized by the performer to compare the differences between current status and the intended goal of the movement.

Welford summarized the cybernetic components of human performance as "a machine receiving data from the environment, processing it, storing it, and producing action" (p. 295). Fitts (1964) delineated the three types of computer-analogy models as the following:

(a) communication models that emphasized the information processing necessary for the performance of a task, (b) control system models that examined the sources of feedback, and (c) adaptive system models that were based on the existence of hierarchical processes. Whiting (1975) noted that, although all three types of models have been used to characterize the skill learning process, the communication models have been the most useful due to their close association with information theory. Fitts, however, stated that adaptive system models had the greatest potential utility because of their dynamic nature.

Phases of Motor Skill Learning

Whiting (1975) noted that the impetus for the examination of skill learning resulted from the need to train personnel for specific tasks during World War II. Many of the psychologists continued their research efforts following the war. Fitts (1962) reported that instructors involved in teaching sport activities and persons involved in pilot training reported similar observations regarding the learning of skills. Both groups of instructors identified the following four aspects of skill learning: (a) cognitive, (b) perceptual, (c) coordination, and (d) tension--relaxation. Thereafter, theoretical models were developed that encompassed a wide range of motor skills.

Fitts (1962) suggested the following phases were evident during motor skill learning: (a) cognitive, (b) fixation, and (c) autonomous. During the cognitive phase, also termed "plan formation" by Robb (1972a), the learner was required to formulate a strategy or plan for carrying out the task as well as determining the sequential organization of the movements. Robb emphasized the role of perceptual mechanisms in the initial phase of skill learning in addition to the ability to intellectualize the task requirements. Gentile (1972) labeled the initial stage of skill acquisition as "Getting the Idea of the Movement" (p. 5).

The fixation phase (Fitts, 1962) was described by Robb (1972a) as the period during which practice was used to "fix" the skill, especially the temporal qualities. Gentile (1972) modified the phase to include fixation or diversification depending on the "closed" or "open" nature of the skill, as defined by Poulton (1957). Robb emphasized the importance of feedback in improving performance during this fixation phase.

Fitts (1962) stated that the autonomous phase of skill learning is "based on a shift from reliance on visual to reliance on proprioceptive feedback, a shift of control to lower brain centers" (p. 188). Robb noted that performance of the task during the autonomous phase was marked by the ability of the performer to attend to other aspects of the activity.

In proposing the phases of skill learning, Fitts (1962) explained that the length of time required for each phase increased in proportion to the complexity of the task. Robb included the capabilities and previous experiences of the performer as additional factors to be considered.

Fleishman and his associates (Fleishman, 1972; Fleishman and Hempel, 1954; and Fleishman and Rich, 1963) examined the change in the relationship of selected abilities with performance of a particular skill as a function of practice. Having investigated a variety of specific tasks, Fleishman (1972) reached the following conclusions:

> (a) As practice continues, changes occur in the particular combinations of abilities contributing to performance; (b) these changes are progressive and systematic and eventually become stabilized; (c) the contribution of "nonmotor" abilities (e.g., verbal, spatial), which may play a role in early learning, decreases systematically with practive relative to "motor abilities"; and (d) there is also an increase in a factor specific to the task itself. (p. 99)

In most instances, laboratory-type tasks and skills used in pilot training were investigated.

Boucher (1972) examined the proposals of Miller, Galanter, and Pribram (1960) and Adams (1971) suggesting that during the initial phase of learning a task, the performer utilized the period of time between trials to evaluate the previous response based on the knowledge of results (KR) and formulate new strategies for achieving the desired response. The findings of Boucher, using an interference task between trials, supported the hypothesis. Early-trial performance was significantly superior for those subjects who were not required to perform the verbal task between trials. Thus, additional support was given to the existence of an early phase of learning a motor skill in which cognitive planning played an important role.

Models of Motor Skill Development

Most of the existing computer-analogy models of skill acquisition were applied to the motor behavior of adults. Kay (1969) noted that examination of the skill acquisition of adults rarely involved learning a totally novel task; rather, it required combining previously acquired skills in new combinations. Therefore, different problems might be encountered by the child and adult in acquiring the same motor skill. In addition, Connolly (1973) stated that changes occurring in other developmental systems might limit the ability of the child to perform selected motor tasks.

Kay (1970), Connolly (1970a), and Salmela (1976) proposed that cybernetic concepts offered a means by which the fragmented literature about the motor development of children and skill acquisition might be considered. Kay suggested that important features of an information-processing model be adopted for the investigation of motor skill development. The child was viewed by Kay (1970) as requiring more information to perform a task because fewer features of the situation were redundant and predictable. Additionally, significant developmental changes in the perceptual systems have been documented by researchers such as Gibson (1969) and Birch and Lefford (1963, 1967). Bruner (1970) reiterated Bartlett's statement that skilled performance was constantly under receptor control since the performer gains information regarding movements as they are made from both environmental and internal cues.

Bruner (1970) formulated an explanation for the changes in motor skill development by noting the infant's increased purposeful behavior. From Bruner's frame of reference, goal-directed movement reflected increased experience and an intellectual understanding of the activity. Bruner emphasized that in purposeful movement, intention precedes action. Bruner's explanation of motor skill development was based on the earlier work of Bernstein which was translated into English in 1967. Bernstein (1967) differentiated between actions which had purpose and independent movements. In addition, motor actions were considered to be directed primarily toward meaningful problems usually originating from the external environment. Bernstein's delineation of actions was also reflected in the Test-Operate Test-Exit (TOTE) model developed by Miller, Galanter, and Pribram and later elaborated upon by Pribram (1971).

Bruner (1970) made limited modifications in the model for achieving control of voluntary actions proposed by Bernstein (1967). The elements of the model were described by Bernstein (1967) in the following manner:

> (1) effector (motor) activity, which is to be regulated along the given parameter;
>
> (2) a control element, which conveys to the system in one way or another the required value of the parameter which is to be regulated;
>
> (3) a receptor which perceives the factual course of the value of the parameter and signals it by some means to
>
> (4) a comparator device, which perceives the discrepancy between the factual and required values with its magnitude and sign;
>
> (5) an apparatus which encodes data provided by the comparator device into correctional impulses which are transmitted by feedback linkages to

(6) a regulator which controls the function of the effector along the given parameter. (p. 129)

As Bernstein explained, Δw represents the value of corrections initiated during the course of the movement. Bernstein asserted that practice should not involve repeating the means of solution; instead, it should require that the process of solving the problem be repeated using techniques that have been modified and improved with repetition.

Bruner (1970) proposed that the development of skill required the establishment of a program consisting of the objective to be achieved and the selection and serial ordering of subroutines to be utilized. While it was possible to order subroutines in different ways which were equivalent, Bruner noted that tasks that were constrained in real time (e.g., catching, batting, juggling) were limited in the number of different arrangements of subroutines meeting the demands of the activity. An important factor in the motor skill development of children, as stated by Bruner, was the problem-solving ability of the child in selecting movements which effectively met the demands of the task. Using the computer-analogy, Elliott and Connolly (1973) suggested that "if skill is modular, the distinction between problem solving and skilled performance might be the distinction between the organization and the execution of subroutines" (p. 136).

An additional feature of most cybernetic views of motor skill development was the hierarchical structure of the subroutines used to accomplish a task (Bruner, 1970; Bruner and Bruner, 1968; and Elliott and Connolly, 1973). Thus, after a subroutine has been established, it may be combined in different ways to achieve the goal of an action. Combining subroutines into a smooth sequence indicated that attention was no longer required for individual acts but was used to control the sequence as a unit. Miller, Galanter, and Pribram (1960) proposed that the practiced sequence becomes a modular unit of performance, or subroutine. Elliott and Connolly noted the difficulty of young children in sequencing activities. It was speculated that, since sequencing required the ability to anticipate, demands of such tasks might overload the attention mechanisms of the young child.

Connolly (1973) noted the importance of physiological and neurological changes in the development of motor skills but maintained that the differentiating factors in skill learning were cognitive, not physical components. In addition, considerable theoretical emphasis has been placed on the importance of physiological and neurological maturation by most researchers in motor development (Connolly, 1970b). Based on the computer-analogy models of motor skill development in children, Connolly (1973) suggested that the sources of limitation in learning motor skills were the following:

> Physical growth processes (neurological and mechanical), the establishment through experience of sensory-motor relationships, the assembly of the basic building blocks of skill (subroutines) and learning the transformation rules by which these units are governed and mobilized in executing action programmes. (p. 361)

Research on the Motor Skill Development of Children

Although there has been an observable increase in the references made to the work of authors suggesting the use of computer-analogy models for investigating motor skill development in children (Rarick, 1976; Roberton, 1975; and Roberton and Halverson, in press), relatively little research has been conducted under the assumptions of such models. Investigations of the development of prehension and manual skills were conducted by Bruner (1970), Connolly (1970b, 1973), and Elliott and Connolly (1973). These studies generally involved children of preschool age. Elliott and Connolly (1973) reported that asymmetrical actions were more difficult for children in the study and noted that these results argued against the assertion that task difficulty was determined entirely by experience. It was observed that younger children found tasks which required sequential movement of different hands and a change of direction to be most difficult. Thus, task difficulty appeared to be related to the compatibility of the movements in the sequence. Elliott and Connolly noted a regression to less controlled grips in certain situations and suggested that the change was necessitated by an increased burden on the child's information-processing capabilities in a difficult task.

Connolly (1970b) examined the temporal sequencing and information-processing capabilities of 6-, 8-, and 10-year-old subjects. Significant age differences were evident in the task performance when irrelevant stimuli were included in the task. Connolly interpreted the results as indicating that the inferior information-processing capabilities, especially the filtering mechanisms, of younger children offered a partial, though not complete, explanation for the poorer performance.

The speed, accuracy, and scatter of performance by children on a small target task was examined by Connolly, Brown, and Bassett (1968). Significant age differences were evident in the speed of performance, but not the accuracy component. Likewise, the speed of performance improved with practice--12 trials--while accuracy did not. Differences in the pattern of scatter were noted for the 6-, 8-, and 10-year-olds in the study. The significantly faster performance of girls at each age level was linked to advanced skeletal and neural maturation and increased cerebral inhibition.

Based on the analysis of movements by Bernstein (1967), Keogh (1971) proposed that motor control should be the focus of study in motor development. Keogh examined the control of limb movements by developing a series of tasks which systematically varied limb involvement. For the 5- to 7-year-old children in the study, use of the legs alone or with arm movements was found to be more difficult than when arm movements alone were required. Complex count patterns were also shown to increase the difficulty of the movement. Following investigation of variations for a 2-2 hopping pattern, Keogh suggested that the control of force might be of central importance in the establishment of motor control. Keogh speculated that:

> It seems more likely that the integrated and dynamic control of a series of movements is where increased control occurs even though separate component events do not show increased control. (p. 15)

Goulet (1970) observed that numerous investigations of child development have outlined changes in performance as a function of age. Instead of using age as an independent variable, Goulet suggested that developmental variables utilized in research should be those that have been found to co-vary with age. The literature within a computer-analogy framework on motor skill development in children suggested that progress in other developmental systems may be related to the physical skill performance of children. Specifically, developmental variables purported to be related to the motor skill performance of children were the following: (a) physiological maturity of the systems of the body involved in motor skill performance, (b) the level of perceptual functioning in extracting visual information relevant to the movement task from the environment, (c) the ability to apply cognitive rules in solving movement problems. The developmental trends for each of the factors identified from the literature were presented in summary form. Previous investigations of the relationship of each of the factors to the performance of physical skills by children were also reviewed.

The Relationship of Skeletal Maturity and Motor Skill Development

Concept of Physiological Maturity

Demirjian, Goldstein, and Tanner (1973) explained that the "concept of physiological age is based upon the degree of maturation of different tissue systems" (p. 211). Interest in the assessment of physiological or biological age resulted from the awareness that children of the same chronological age exhibited a wide variation on physiological age measures. Krogman (1972) stated that biological age was a better indicator than chronological age regarding the behavioral expectancy for children.

A biological age determination may be made by examining the progress toward maturity of any of the systems of the body. The most common measures of maturity, according to Demirjian, Goldstein, and Tanner, were the following: (a) skeletal age, (b) morphological age, (c) the appearance of secondary sex characteristics, and (d) dental age. Due to differing patterns of maturation within each system, the biological age assessments for a single child on different measures may show marked variation.

Skeletal Maturity

For primary-age children, skeletal maturity has been the most widely used indicator of physiological age. Acheson (1966) noted that Todd identified osteogenesis in cartilage as the maturational process in the skeletal system. Pyle, Stuart, Cornoni, and Reed (1961) documented wide variation in the onset, completion, and span for growth centers of various bones in the body. While the expected pattern of ossification for the growth centers of most bones has been well delineated, the hand-wrist area is most commonly used in making determinations of skeletal maturity (Roche and French, 1970). Skeletal maturity assessments are made by examining an X-ray of the hand-wrist area and assigning an age equivalent determined from a comparison with established standards or atlases (Acheson, 1966). The atlas method developed by Greulich-Pyle and the bone-specific approach of Tanner-Whitehouse-Healy have been the most widely used methods for making skeletal age determinations based on hand-wrist X-rays (Malina, 1971). However, the atlases prepared by Pyle, Waterhouse, and Greulich (1971a) for the National Health Survey serve as the current standard of reference for the assessment of skeletal maturation for research in the United States.

Sex differences in skeletal maturity have been evident at birth and continue until maturity, with girls having a skeletal age approximately two years in advance of the average for the boys of the same chronological age (Pyle, Waterhouse, and Greulich, 1971a). Acheson explained that because the female reaches maturity sooner, the concept of the skeletal age year is not the same for males and females.

Acheson and Krogman differentiated between measures of growth--size changes of the body--and maturity. As Acheson stated, growth and maturation processes are distinct and, therefore, should be measured by separate scales.

Maturity Measures and the Performance of Physical Skills

The literature about motor development of young children has been dominated by research and theories that considered maturational processes to be of primary importance in the appearance and acquisition of motor skills (Espenschade and Eckert, 1967; Glassow and Kruse, 1960; Ilg and Ames, 1972; and Wild, 1938). Considering the emphasis placed on maturation, relatively few studies examined the relationship between maturity measures and the performance of physical skills by children. The longitudinal studies conducted during the first half of the twentieth century often included maturity measures (Conrad, 1966; Ebert and Simmons, 1943; Jones and Bayley, 1941; Pyle, Stuart, Cornoni, and Reed, 1961; and Shuttleworth, 1938). However, the examination of relationships between the maturity measures and motor performance variables, when the latter measures were included in the study, was limited.

Clarke (1971) summarized the findings of the Medford Boy's Growth Study with the statement that skeletal age was generally not significantly related to the motor ability measures for males included in the study. Clarke and Petersen (1961) reported that athletes in the study were more mature than nonparticipants. Significant differences between athletes and nonparticipants in relative maturity (skeletal age/chronological age) were evident during the upper elementary grades but did not continue through junior high school. Hale (1956) and Krogman (1959) found that the maturity ratings of participants in the Little League World Series exceeded the average for boys 10 to 12 years of age. Differences in maturity were reflected in player position and batting order. During the upper elementary grades, the increased strength accompanying puberty in males may, in part, explain the advantage of early-maturing boys in sport skills.

The relationship between maturity measures and motor performance for children in the primary grades has received even less research attention. Thompson, Blanksby, and Doran (1973) compared selected maturity scores of swimmers with competitive events and time. Male and female swimmers between the ages of 7 and 15 were included in the study. Breaststrokers were found to have skeletal ages in advance of chronological age. Shorter and lighter girls were more successful in the younger age groups, while taller and heavier girls had better performance scores for the older age groups.

Seils (1951) examined the relationship between physical growth measures and the performance of primary grade children on selected gross motor tasks. X-rays of the carpal bones provided the measure of maturity. Seils reported correlations which ranged from moderately high to low between skeletal maturity and maximum performance on the movement tasks. Different patterns of relationship were evident for boys and girls. Seils found height, weight, and age had little relationship with the motor performance measures for children in the study and suggested that skeletal maturity might be a variable of somewhat more significance.

Rarick and Oyster (1964) examined maturity, strength, and motor performance data for primary-age boys. Height, weight, chronological age, and skeletal age (hand-wrist X-ray) were defined as maturity indicators. Rarick and Oyster reported that the skeletal age measure added little to the prediction equations for the strength and motor performance measures of males in the study. Oyster (1961) summarized the findings for the females in the study as being similar to that reported for the males. The height, weight, and age measures could adequately predict the strength measures but were not significant predictors of the motor performance scores (Oyster, and Rarick and Oyster).

Teeple (1973) investigated the influence of physical growth and maturational variables on the static force production of 6- to 12-year-old boys. Physical growth and maturation, as measured by body size, were significant predictors of maximum static force production. Maturation (hand-wrist X-ray), independent of measures of body size, was not significantly related to the force production ability of 6- to 12-year-old males.

Limitations in the number of motor performance variables and the manner in which certain of these variables were measured suggested that the relationship between skeletal maturity and performance of motor control tasks remained to be determined. The research was especially inadequate for females.

The Relationship of Visual-Motor Functioning and Motor Skill Development

The Development of Visual Perception in Children

The literature related to the developmental trends in perception, with special emphasis on visual perception, was reviewed. Due to the extensive material available, this report presents a summary of the research findings.

Gibson (1969) defined perception as "the process by which we obtain firsthand information about the world around us" (p. 3). Gibson examined the developmental literature in perception and identified the following general trends: (a) the increased specificity of discrimination, (b) optimized attention, and (c) increasingly economical search and acquisition of information. According to Gibson, discrimination becomes more specific due to a reduction in the number of stimuli eliciting the same response, an increase in the consistency of perceptual judgments, and a decrease in the time required to make distinctions among similar objects. The child's attention changes from a passive state of being captured to an active process of search for which strategies are developed (Gibson, 1969). In addition, the child develops the ability to selectively attend to perceptual information while ignoring irrelevant stimuli. With respect to greater economy in the acquisition of information, Gibson discussed the trend toward making discriminations based on the distinctive features of an object and seeking invariants in the properties of an object under conditions of stimulus change. Williams (1973a) suggested that, in addition to the improved intrasensory discrimination discussed by Gibson, the perceptual development of children is also marked by increased intersensory communication and a shift in the dominance of sensory modes from proximo-receptors to distance receptors, especially the eyes.

Rivoire and Kidd (1966) summarized the stages in perception of space delineated by Lowenfeld. Children between 7 and 9 years of age organized space based on an observable plan, while prior to the age of 7 no pattern was evident in the relationship of objects in space. Although certain aspects of distance perception are thought to be innate, Vernon (1970) observed that the ability to make distance judgments is facilitated by experience. Rivoire and Kidd reported that limited research attention has been directed to the development of movement perception.

Intersensory Integration

Although the focus of the present study was on visual perception, all sensory modes may be utilized in gaining information relevant to the movement performance. Intersensory integration was defined by Sullivan and Salmoni (1975) as "the ability to organize (integrate) input information from different modalities" (p. 491) and was suggested by Birch and Lefford (1967) to be a developmental process which markedly increases the information-processing capabilities of the child. Williams (1973b) stated the following:

> The move toward multisensory functioning is important because it is believed to be a reflection of the growing integrative powers of the brain--powers which allow the child to match-up or evaluate input from a variety of sources before a given movement or motor response is decided upon. (p. 56)

Thus, Williams (1973b) and Birch and Lefford (1967) hypothesized that increased intersensory integration is also reflected in the improved performance of motor skills.

The results of studies by Birch and Lefford (1963) indicated that intersensory integration, as measured by matching items using different sense modalities, increased with age. Children in the study exhibited rapid improvement in matching ability between the ages of 6 and 8 years. Birch and Lefford noted a wide range of individual differences in the performance of younger children; the individual differences were less evident in the performance of 10-year-olds.

Research of the Relationship of Visual Perception and Motor Skill Development

The literature available about the relationship of visual perception factors and movement performance of children was examined. Similarity of the visual perception measures was used as the basis for organizing the presentation of the research findings.

Visual, perceptual, and performance characteristics of catching for 6- and 7-year-old children designated as successful and nonsuccessful in catching were examined by Hellweg (1972). The perceptual measures employed in the study were intended to require the child to make the perceptual and anticipatory judgments while omitting the catching act. Hellweg stated that children who were successful and unsuccessful in catching a ball could not be differentiated based on their performance on the perceptual measures. While it was observed that successful performers tended to initiate movement toward the ball more quickly and appeared to track the ball until contact, Hellweg concluded that subjects developed consistent individual strategies in performing the catching task.

Williams (1973a) reported the results of a study in which 6- to 12-year-olds predicted the landing point of a ball but were not required to perform the catching task. Developmental trends in the speed and accuracy with which judgments were made were evident. The younger children tended to respond quickly but, based on their inaccurate judgments, were unable to utilize the visual information in making the response. Williams noted that

9-year-olds made very accurate estimations of the landing point but were quite slow in making the judgment. Twelve-year-olds in the study were observed to make judgments rapidly and accurately.

Torres (1966) examined the relationship between figure-ground perceptual ability and ball catching proficiency. For the 10- and 13-year-old boys and girls in the study, performance on the Witkin Revision of the Gottschaldt Embedded Figures Test was significantly related to catching proficiency for one of the three ball-projection angles. Significant age differences were noted on the performance of both measures, and boys were superior to girls in catching proficiency.

The relationship of two measures of field dependence--independence and performance measures on a walking beam of graduated width--was examined by Bundy (1974). No significant correlations were found to exist between the walking beam measures and the score on the Children's Embedded Figures Test or the Portable Rod and Frame Test for kindergarten children.

Gallahue (1968) required kindergarten children to perform a side-stepping task through a ladder arranged in four different embedding configurations. The time required to perform the task differed significantly as a function of the figure-ground pattern. Gallahue reported significant correlations between performance on three of the conditions and the score on the figure-ground subtest of the Marianne Frostig Developmental Test of Visual Perception.

Neiner (1971) investigated the relationship between performance of first- and third-grade children on pursuit tracking tasks and scores for three subtests of the Marianne Frostig Developmental Test of Visual Perception. No significant correlations were found between pursuit tracking performance and the visual perception measures.

Williams (1973b) tested two groups of 6- and 7-year-old children defined as normally developing (NDC) and slowly developing (SDC) based on the ratings of teachers. The Marianne Frostig Developmental Test of Visual Perception was selected as a measure of visual intrasensory differentiation. Intersensory functioning was determined by scores on three subtests of the Ayres Perceptual-Motor Test Battery and proficiency on selected movement tasks. Significant between-group differences were reported for the visual differentiation measures with all results favoring the normally developing children. These findings were also consistent with the results of the three items from the Ayres test. The performance of the two groups on the motor proficiency tasks was significantly different for some, but not all, of the movement skills. Williams stated that:

> There is the hint that when successful performance of a motor task involves highly controlled and/or precisely spatially regulated movement of the body, the NDC is likely to be superior to the SDC. (p. 67)

The results of the study were interpreted as giving tentative support to the hypothesis that differences between the two groups were attributable to differences in intra- and intersensory development (Williams, 1973b).

Herkowitz (1972) noted the discrepancy between the static nature of most tests of visual perception and the dynamic judgments required in movement skills. The Moving Embedded Figures Test was developed by Herkowitz for use in movement research involving children. Preliminary results from the test revealed a tendency toward field-independent judgments with older children, a trend reported in other developmental studies of visual perception. No research was found which examined the relationship between performance of the Moving Embedded Figures Test and measures of motor skill development.

Research evidence regarding the relationship between visual-motor functioning and motor skill development of children was inconclusive. It appeared that the variety of instruments used to assess visual perception and the diverse tasks employed in the measurement of movement performance contributed to the discrepant results. The suggestion by Williams (1973b) that movement tasks requiring more control and/or spatial regulation were more likely to result in differences in performance scores as a function of the developmental levels of the child appeared to be worthy of further investigation. In addition, the type of task recommended by Williams seemed to be consistent with the concept of motor control.

The Relationship of Mental Ability and Motor Skill Development

The cognitive development of children has received ample theoretical and research attention. The scope of the present literature review was limited to the summarization of developmental changes in cognitive development. Proposed relationships between perception and cognition were also examined. Finally, research investigations of the relationship between cognitive ability and the performance of movement skills by children were reviewed. Studies utilizing physical skill performance for the prediction of mental ability and academic achievement were excluded from the review.

Summary of Cognitive Development in Children

Cognitive development--the manner in which "human beings increase their mastery in achieving and using knowledge" (Bruner, 1966a, p. 1)--is one important dimension of human behavior. As Krogman (1972) and Bruner (1966a) noted, human beings have the longest period of development of all species. At birth, man is more helpless than other animals and is equipped with fewer predetermined patterns of behavior. Consequently, man has the benefit of biological and cultural influences as opposed to animals which possess only a biological inheritance (Krogman). Krogman summarized the importance of this feature of man's development by observing that human beings appear to be programmed for learning rather than reacting according to instinctive, or pre-existing, mechanisms.

Bruner (1966a) stated that the exposure to the culture in which the child operates creates a necessity for developing a means of representing that world and organizing previous experiences for future use. The following unique forms of representation were delineated: (a) enactive, or action; (b) iconic, or images; and (c) symbolic, or language. Changes occurring in the development of representation were summarized by Bruner in the following manner:

> At first the child's world is known to him principally by the habitual actions he uses for coping with it. In time there is added a technique of representation through imagery that is relatively free of action. Gradually there is added a new and powerful method of translating action and image into language, providing a third system of representation. (p. 1)

Although the three forms of representation are acquired by the child prior to entry into school, considerable change in cognitive functioning continues to occur as equivalencies are established between modes (Bruner, 1966b). As Bruner (1973a) suggested, between the ages of 4 and 12, the acquisition of language results in the use of remote reference, transformation and combination, thereby vastly increasing the possibilities for cognitive functioning. Olson (1966) stated that problem solving during childhood gradually changes from dealing with immediate stimuli to generating plans or hypotheses regarding the problem at hand. Symbolic representation was considered to be especially important in permitting inferential steps beyond the immediate data.

Luria and Yudovich (1971) emphasized the importance of speech as a regulatory function which allows the child to persist at a task by talking about what he/she plans to do. In addition, Luria (1961) suggested that "speech for self" plays an important role in the ability of the child to inhibit and control movement.

Piaget and Bruner, according to Ginsburg and Opper (1969) and Anglin (1973), held similar, though not identical, views regarding the course of cognitive development in children. One notable difference was that Piaget placed much less importance on the function of language, especially as a mediator in the increased problem-solving ability evident in 6- to 7-year-old children. Piaget (1952) described cognitive development from 2 to 7 years as the preoperational stage, a period characterized by an inability to use certain information logically. During the years from 7 to 11, the child's thinking is increasingly based on the use of principles and rules applied to the situation at hand and was labeled by Piaget as the concrete operational stage. While the stages delineated by Piaget may vary with regard to the age and length of time at a specific period, the sequence was considered fixed.

Interrelatedness of Visual Perception and Mental Ability

Vernon (1966) suggested that the infant makes judgments based on raw sense data, but as the child gets older, cognitive processes are increasingly used to evaluate a task. As postulated by Vernon:

> Percepts, after the first few months of life, do not exist in isolation, but are related across sensory modes; they are integrated with memories of previous similar perceptual experiences, and of reactions to these, into schematic categories of associated percepts. The categories are further refined and restructured through the development of relevant ideas by intelligent reasoning. (p. 404)

Similar developmental changes in the manner in which perceptual information influences behavior were suggested by Piaget (1952), Gibson (1969), and Bruner (1966b). Using an information-processing model, Farnham-Diggory (1972) identified perception as one of the processes involved in cognition. While visual perception and mental ability have been investigated separately, the two constructs appear to be interrelated by the time a child enters school.

Fretz's (1970) factor analyzed the scores of poorly coordinated boys on the subtests of the Wechsler Intelligence Scale for Children (WISC), the Marianne Frostig Developmental Test of Visual Perception (Frostig), and the score on the Bender Motor Gestalt Test (Bender-Gestalt). Five factors, accounting for 76% of the total variance, were identified. Performance on the three measures, including the Frostig and the Bender-Gestalt, tended to be associated with separate factors.

Birch and Belmont (1965) examined the relationships among auditory-visual integration, intelligence, and reading ability in 5- to 12-year-old children. Visual-auditory integration scores improved with age but reached a plateau by fifth grade; intelligence and auditory-visual integration were reported to be related, but did not comprise a single factor. The limited literature reviewed indicated that for primary-age children, measures of visual perception and mental ability appeared to be related, but were not identical.

Research Concerned with the Relationship of Mental Ability and Motor Skill Development

Fowler and Leithwood (1971) outlined the theoretical importance of cognitive processes in the motor skill development of children by stating that:

> As the number and type of components and sequences in a motor task increase, the cognitive analytic and integrative processes essential for skill acquisition increase proportionately. (p. 523)

While Fowler and Leithwood proposed a system for analyzing the task complexity of specific skills, the classification system has received limited use in research studies relating mental ability and the performance of physical skills.

Singer and Brunk (1967) found low positive relationships between perceptual-motor ability and measures of mental ability for third- and fourth-grade children. However, five of the 11 correlations between the two sets of variables were significant ($p<.05$). Perceptual-motor ability was measured by the score on the Figure Reproduction Test, while mental ability measures included were the subtest scores from the Pitner Test and the Stanford Achievement Test. The use of the particular instruments in measuring the variables under investigation appeared to be a questionable practice. Singer and Brunk noted that the greatest relationship between perceptual-motor ability and mental ability was evident during early childhood. The authors concluded that for the children in the study, the two abilities exhibited the trend toward greater specificity with increased age.

As part of a study on the relationship of visual-motor skills and reading achievement for superior students, Chang and Chang (1967) reported significant correlations between visual-motor performance (Bender-Gestalt) and intelligence for children in second grade, but not for third-grade children. The authors observed that the pattern of relationship for the intellectually superior child appeared to be similar to that reported for older children of average intelligence.

Singer (1968) examined relationships among physical, perceptual-motor, and academic variables for third- and sixth-grade children. The perceptual-motor measures consisted of seven laboratory-type motor performance tasks. The academic variables were composed of scores on the Metropolitan Achievement Test and the Lorge-Thorndike Intelligence Test. Low correlations were reported between the two sets of variables, and the pattern of relationship was similar for both grade levels. Singer concluded that by third grade the trend toward specificity of abilities was evident. The observations of Chang and Chang (1967) regarding children with superior intelligence may be relevant to the data from Singer's study since the mean intelligence test scores reported, 111.27, 116.67, and 115.03, were above average.

Thomas and Chissom (1972) examined academic ability and perceptual-motor performance variables using canonical correlation. Significant correlations were reported between the two sets of variables for kindergarten through second-grade children, but not for children in grade three. Academic variables in the study included the score on the Otis-Lennon Mental Ability Test and teachers' ratings in four ability areas. The perceptual-motor performance tasks included were basket toss, wall bounce, and a "Shape-O-Ball" test requiring the matching of geometric shapes. The greatest contribution to the perceptual-motor variate was made by scores on the "Shape-O-Ball" test. With one exception, teachers' ratings contributed more to the variate for academic ability than the intelligence test scores.

Cooke (1968) investigated the relationship between performance on static and dynamic balance tasks and selected cognitive measures. Children between the ages of 8 and 13 were included in the study. Comparisons between balance performance and intelligence test scores revealed significant correlations for the youngest males and for males with low scores on the balance tasks. No other relationships, including comparisons for females, were found to be significant.

Eleven perceptual-motor tasks were used by Skubic and Anderson (1970) to examine differences in perceptual-motor performance of high and low achievers in the fourth grade. Most of the perceptual-motor battery was comprised of activities requiring large movement, and specific criteria were employed in the selection of perceptual-motor tasks. Performance on the total perceptual-motor battery was significantly related to the intelligence test score (California Test of Mental Maturity). Comparisons of performance on individual items in the perceptual-motor battery with intelligence scores were not made. Skubic and Anderson noted that four of eight tasks which were designated as having high difficulty and/or motor control demands were significantly related to scores on the achievement test. Thus, partial support was received for the hypothesis that perceptual-motor tasks requiring greater motor control and difficulty would be related to achievement test performance.

In general, the literature supported Singer's (1968) conclusion that the specificity of abilities, as related to intelligence and movement performance, increases with age. For children age eight and older, significant correlations were generally reported only when composite scores were used in the calculation of the movement performance variable (Cooke, 1968, and Skubic and Anderson, 1970). There was limited support for the relationship between measures of mental ability and large movement task performance of kindergarten and primary age children when the activity was difficult and/or required considerable control.

Oxendine (1972) noted the relationship between movement performance and intelligence has been difficult to discern due to the variety of research designs and variables measured. The problem is also evident in the research reviewed in this section. In some instances, instruments used to assess movement performance (perceptual-motor skill) were identical, or similar, to those reviewed in the previous section as measures of visual perception. Thus, while cognitive processes have been hypothesized to be an important factor in motor skill development, especially during the initial phase of learning (Bruner, 1966b; Fitts, 1962; Fowler and

Leithwood, 1971), research evidence in support of these theories was not substantial.

CHAPTER III

PROCEDURES

The purpose of this study was to investigate the relationship between selected developmental variables and the performance of seven-year-old girls on tasks requiring motor control. The procedures for this investigation included the following processes: (a) preliminary preparation, (b) the collection of data, and (c) the treatment of data.

Preliminary Preparation

The preliminary preparation for the study involved the following general procedures: (a) development of the motor control tasks; (b) selection of measures of skeletal maturity, visual-motor functioning, and mental ability; and (c) selection of schools participating in the study.

Development and Description of the Motor Control Tasks

A major purpose of the research was to examine the performance of children on tasks that had been designed to be consistent with current computer-analogy models appearing in the motor skill development literature. The following theoretical criteria were used in the development of each motor control task: (a) First, the goal of the task, including the speed criterion, was specified; the movement pattern to be used was not dictated to the subject. (b) The task permitted the use of different actions to accomplish the specified goal. (c) The strategy and the actions employed by the subject to accomplish the task could be altered as practice progressed. (d) The task was serial in nature (Welford, 1972). (e) Information from the display--the immediate external environment relevant to the skill (Whiting, 1972b)--was necessary for the performance of the task. (f) The task required decision making in the formulation of the movement response based on the information acquired from the display (Whiting, 1972b). (g) Finally, the serial nature of the task required that ongoing feedback was monitored during the performance of the task (Whiting, 1972b).

In addition, the following criteria were established and effected in the development of the motor control tasks: (a) the task was appropriate for the abilities and interests of 7-year-old children; (b) the task involved large movement activities; (c) the safety of the child was not endangered while performing for speed; (d) the tasks required minimal equipment and space in order to assure the consistent arrangement of the testing situation in the three elementary schools used in the data collection process.

Three motor control tasks were developed to meet the above specified criteria. It was not assumed that the motor control tasks devised for the study were the only ones which might meet the established criteria, nor was it intended that the tasks were representative of motor control tasks generally. Rather, they were regarded as suitable for the purposes of the research as well as appropriate to the meanings inherent in motor control. The following motor control tasks were developed for purposes of this investigation:

Motor Control Task 1--Hopscotch. The hopscotch task required the child to hop or jump into each of the squares as she progressed through the course. Upon reaching the semi-circular area at the opposite end, the child immediately reversed her direction and continued in the same manner to the starting area. Each segment of the hopscotch course, illustrated in Appendix B, was 15 inches square and the diagram was placed on a large clear plastic sheet with one inch red marking tape. The child's score on a trial was the elapsed time between leaving the starting area and touching it with her foot after having moved through the course.

Motor Control Task 2--Throw and Catch. The throw and catch task required the child to throw a 6-inch red playground ball against a wall and gain control of it following each of four consecutive throws. The ball was thrown alternately at two adjacent walls which were joined at a 90-degree angle. Both walls were free of any obstructions. The child was required to throw from behind a restraining line which was 8 feet from one wall and 12 feet from the second wall. No restriction was placed on the child's movement to gain control of a ball rebounding from the wall. However, a barrier was erected behind the throwing area to limit the distance a child moved to retrieve a ball that was not caught. A diagram of the task is contained in Appendix B.

The score on a single trial was the time, to the nearest one-tenth second, required to complete the throw and catch sequence. The timing began when the child initiated the forward arm movement for the first throw and stopped when the ball was held in a stationary position touching the child's hands and/or arms following the fourth throw. Due to the complexity of the task, one practice trial was given to insure that the subject understood the task.

Motor Control Task 3--Stepping Stones. The child began the stepping-stones task by standing on a 12-inch indoor carpet square which had been placed behind the starting line. An identical carpet square was held by the child. The floor diagram for the stepping stones task consisted of two lines which were 8 feet apart. The lines were 4 feet in length and marked with 1-inch red tape on a large clear plastic sheet which was secured on all sides by 2-inch masking tape. The stepping stones diagram is presented in Appendix B.

The task required the child to traverse the 8-foot distance by alternately placing one square on the floor and standing on it while retrieving the other square. The child was not permitted to touch the floor to retain balance. The score on a trial was the time required to move a distance of 8 feet in the prescribed manner. Timing for each trial began when the child stepped on the first carpet square which she had placed on the floor and terminated when the child was standing beyond the second line with both feet on the carpet square.

Selection of a Measure of Skeletal Maturity

The hand-wrist X-ray was selected as the measure of skeletal maturity for the study. The atlases developed by Pyle, Waterhouse, and Gruelich (1971b) were chosen as the standard against which the hand-wrist X-rays were compared in assessing skeletal age. The nature of the skeletal maturity measure dictated that the administration and evaluation of all X-rays be performed by a radiologist.

Selection of the hand-wrist X-ray as the measure of skeletal maturity was based on the relative ease with which an X-ray of the hand-wrist area can be obtained. By virtue of the types of bones comprising the area, the use of the X-ray of the hand-wrist accurately represents varying rates of ossification occurring throughout the skeletal system. The reliability of the assessment has been found to be satisfactory when all X-rays are evaluated by the same radiologist. The Pyle, Waterhouse, and Gruelich Atlases (1971b) were developed after extensive standardization on American populations and are currently used by radiologists for the interpretation of skeletal age.

Selection of a Test of Visual-Motor Functioning

A review of the tests used to measure visual-motor functioning resulted in the selection of the Marianne Frostig Developmental Test of Visual Perception for use in this investigation. This test is comprised of five subtests which are intended to measure the following aspects of the child's ability to deal with visual perceptual information: (a) eye-motor coordination, (b) figure-ground perception, (c) form constancy,

(d) position in space, and (e) spatial relations. The reliability of the test is +.80 and adequate standardization has been achieved.

Selection of the test was based on the following attributes: (a) the evaluation of several areas of visual perception, (b) a sufficient number of items in each of the subtests, (c) appropriateness for group administration to the 7-year-olds being tested in this study, and (d) construction of the test for the purpose of assessing the child's developmental level and not solely as a means of determining perceptual deficiencies. While the Marianne Frostig Developmental Test of Visual Perception has certain acknowledged weaknesses, namely the low reliability of some of the subtests, for purposes of this study it appeared to be the most adequate test of visual-motor functioning currently available for use with young children.

Selection of a Test of Mental Ability

The Otis-Lennon Mental Ability Test (OLMAT), Elementary Level I, was selected as the measure of mental ability for the investigation. This level of the test was designed for children in grades 1.6 to 3.9, which suited the grade level of the subjects in the study. The purpose of the OLMAT is to measure verbal, numerical, and abstract reasoning ability (Robb, Bernardoni, & Johnson,

1972) although all items on Elementary Level I of the tests are presented in a pictorial manner. Approximately 50 minutes is required to administer the instrument to a group of children. The reliability, which was +.89 for the Elementary I level, validity, and normative data have been most adequately established by the authors of the test (Otis & Lennon, 1967).

Selection of Schools Participating in the Study

A letter was written to Ms. Kathryn Cappelen, Director of Curriculum and Instruction for the La Crosse Public Schools, La Crosse, Wisconsin, stating the nature of the study and requesting permission to conduct the study in selected elementary schools in the system. Ms. Cappelen consented and made all contacts with the principals of individual schools. The nature of the testing procedures required that a limited number of schools, rather than individual subjects, be selected from the school system. The cooperation of three schools in different areas of the city was secured by Ms. Cappelen.

Meetings were held with the principal and teachers of each of the schools by the investigator. The purpose of the study and the details of all testing procedures were thoroughly discussed. Every attempt was made to avoid disruption of the ongoing activities of each school.

Collection of Data

Selection of Subjects

The subjects for the study were 35 females attending Hamilton, Emerson, and State Road Elementary Schools in La Crosse, Wisconsin, during October, 1976. Sixty-eight students were initially contacted to serve as subjects. The following criteria were met in the selection of subjects:

(a) The girl was between the ages of 7 years, 0 months and 7 years, 11 months when age was calculated to the nearest month.

(b) The child's parent or legal guardian agreed to the child's participation and returned all required consent forms. All consent forms used in the study are presented in Appendix A.

(c) Children with diagnosed visual or auditory learning problems were excluded from participation. School records and conferences with the school principals were utilized to determine those children currently receiving or awaiting special education services.

Administration of Motor Control Tasks

The order of the three motor control tasks for each of three testing days was randomly determined prior to the initiation of testing. The motor control tasks were administered individually to each child with the investigator and an assistant present. All children received identical instructions. However, if a child was unable to understand the task requirements, further clarification was given by the experimenter. A comparable testing environment, in terms of the availability of space, walls, and floor surface, was utilized in the three schools and all children performed the motor control tasks prior to receiving all other measures in the study.

Each subject performed five trials per task on three consecutive days resulting in a total of 15 trials on each of the motor control tasks. A 30-second rest period followed each trial.

A stopwatch was used in timing all trials for each motor control task. The time, in tenths of a second, was recorded on the Subject Data Form presented in Appendix C and the same individual, the assistant, timed and recorded scores for all testing of motor control tasks. After the score had been recorded, it was reported to the subject in terms of the nearest second.

For purposes of the study, the early- and late-trial scores were utilized in examining relationships among the predictor variables. The early-trial score was the sum of the scores for Trials 1 and 2. The total of the time required to perform the task during Trials 14 and 15 comprised the late-trial score on all motor control tasks.

Administration and Evaluation of the Hand-Wrist X-ray

Each child received a hand-wrist X-ray of the right hand for use in the assessment of skeletal maturity. All X-ray procedures were performed by the Gundersen Clinic, La Crosse, Wisconsin, under the supervision of Dr. Renato Travelli, a radiologist. In addition, Dr. Travelli evaluated all X-rays for the study and assigned a skeletal age equivalent (in months) to each hand-wrist X-ray using the Pyle, Waterhouse, and Gruelich Atlases (1971). Comparisons with atlases for the entire hand and wrist as well as the average of individual bones, excluding the epiphysis of the distal ulna, were used to determine skeletal age.

Administration and Scoring of the Marianne Frostig Developmental Test of Visual Perception

The Marianne Frostig Developmental Test of Visual Perception was given to each subject during the week following the administration of the motor control tasks. The tests were administered and scored by a school psychologist who was familiar with the test. At each school, a room which was free from distraction was provided for all testing and the measure was administered to no more than five children at one time.

The score used for each subtest was the T-score conversion of the raw score (Barrow and McGee, 1971). The raw scores were converted to T-scores in order that the subtests, which contained varying numbers of items, could be given equal weighting. A subject's score on the visual-motor functioning measure was the average of the T-scores for the five subtests.

Administration and Scoring of the Otis-Lennon Mental Ability Test

Elementary Level I (Form J) of the Otis-Lennon Mental Ability Test (OLMAT) was administered to each of the subjects in the study during the third week of data collection. All tests were administered and scored by a school psychologist. Subjects at each school were tested at the same time in a classroom that had been assigned by the principal. As directed by the test manual, the OLMAT was administered in a morning and an afternoon session, each of which was approximately 30 minutes in length.

The score on the OLMAT was the total number of items answered correctly. No conversion to normative data was made since Deviation IQ and percentiles are computed separately for each three months of age.

Treatment of Data

A canonical correlation procedure provided by the Statistical Analysis System (SAS) Program CANCORR was utilized to analyze the data. Canonical correlation examines the number and nature of independent relationships between two sets of variables (Darlington, Weinberg, & Walberg, 1975). The predictor variables in the analysis were the skeletal maturity, visual-motor functioning, and mental ability scores. The early- and late-trial performance scores on the three motor control tasks--hopscotch, throw and catch, and stepping stones--were designated as the criterion variables in the analysis.

The significance of each of the canonical correlations was tested using the chi-square approximation on Wilk's lambda distribution. The correlation of each variable with the variate, calculated for each set of variables in computing the canonical correlations, was also examined.

Multiple regression analysis was employed to determine the extent to which performance on each of the criterion variables could be accounted for by the predictor variables operating separately and in combination. The Maximum R^2 Improvement technique developed by Goodnight (Service, 1972) was used in conjunction with the Statistical Analysis System Program for linear regression (REGR) in executing the multiple regression analysis.

For each of the criterion variables in the study, the Maximum R^2 Improvement technique selected the one-variable model producing the largest R^2 statistic. This statistic represents the percentage of the variance in the criterion variable accounted for by the predictor variable. In addition, the selection of the best two-variable combination was determined, as well as the regression equation and resulting R^2 statistic when all three predictor variables were entered. Partial sums of squares and regression coefficients for each model were also calculated.

An F test to ascertain the significance of the variance in the motor control task accounted for by the predictor variables in each equation was computed. In addition, the significance of the contribution of each of the regression coefficients in the equation was evaluated by the *t* statistic. A probability of .05 was accepted for all tests of significance. Options for the REGR program were utilized to compute the means, standard deviations, and correlation matrix for the variables in the study.

The reliability of each of the motor control tasks was determined by correlating the scores of subjects on adjacent trials for the five trials occurring on the same day. The Hewlett-Packard Time-Shared Basic Multiple Regression/Correlation Program (MULREG: 36178) was utilized to obtain the Pearson Product-Moment Correlation coefficients.

CHAPTER IV

ANALYSIS OF DATA

This study investigated the relationship of three developmental variables--skeletal maturity, visual-motor functioning, and mental ability--with the early- and late-trial performance scores on three motor control tasks by 7-year-old girls. The motor control tasks developed for this investigation were designated as hopscotch, throw and catch, and stepping stones. In addition, the degree to which early- and late-trial performance on each of the motor control tasks could be predicted by the developmental variables was exzmined.

Thirty-five 7-year-old girls who were enrolled in Hamilton, Emerson, and State Road Elementary Schools in La Crosse, Wisconsin, served as subjects for the study. Canonical correlation was utilized to examine relationships between the developmental variables and performance on the motor control tasks. The degree to which each of the performance measures could be predicted by skeletal maturity, visual-motor functioning, and mental ability was determined through the use of multiple regression analysis. The Pearson Product Moment

Correlation procedure was used to calculate the correlations between all pairs of variables included in the study.

The Data

The obtained scores which served as the raw data for all statistical analyses are presented in Appendix D. The skeletal maturity score represents the child's skeletal age assessed in months as determined by an X-ray of the hand and wrist. The average of the T-score conversions for the subtests of the Marianne Frostig Developmental Test of Visual Perception was used as the measure of visual-motor functioning. Mental ability was determined by the number of items answered correctly on the Otis-Lennon Mental Ability Test. The early- and late-trial performance scores for the three motor control tasks were computed in the following manner:
(a) early-trial performance was the sum of the time required to perform the task on Trials 1 and 2; and
(b) the performance score for late trials was the result of summing the child's times for Trials 14 and 15. The mean and standard deviation for each of the variables comprising the raw data are contained in Table 1.

The reliability coefficients for each of the motor control tasks are presented in Appendix E. Information

Table 1

Means and Standard Deviations for Predictor and Criterion Variables

Variable	Mean	SD
<u>Predictor Variables</u>:		
Visual-Motor Functioning (Frostig T-Score)	49.99	6.11
Mental Ability* (OLMAT Raw Score)	50.31	10.31
Skeletal Maturity** (Hand-Wrist X-ray)	85.23	9.66
<u>Criterion Variables</u>:		
Hopscotch Early Trials	19.89 sec.	4.21
Hopscotch Late Trials	16.34 sec.	2.63
Throw and Catch Early Trials	32.55 sec.	7.49
Throw and Catch Late Trials	28.20 sec.	6.81
Stepping Stones Early Trials	34.35 sec.	6.71
Stepping Stones Late Trials	21.23 sec.	4.30

Legend: N = 35

*OLMAT score reported in terms of number of item answered correctly.

**Skeletal maturity reported according to skeletal age in months.

regarding performance of individual trials for each of the motor control tasks and the subtests of the Marianne Frostig Developmental Test of Visual Perception is also reported in Appendix E.

Pearson Product-Moment Correlation

The correlation between all pairs of variables in the study is presented in Table 2. Although correlation coefficients between individual variables are not directly related to the problem under investigation, the information was included to aid in the understanding of subsequent statistical analyses.

Examination of relationships between developmental variables revealed that the measures of visual-motor functioning and mental ability were significantly related. The correlations of skeletal maturity with visual-motor functioning and mental ability were not significant. Correlation of each of the developmental variables with individual motor control tasks performance measures resulted in a significant relationship between mental ability and both the early- and late-trial performance on the throw-and-catch task. No other

Table 2

Correlations for Predictor and Criterion Variables

Variable		2	3	4	5	6	7	8	9
<u>Predictor Variables</u>:									
Visual-Motor Functioning	1	.412*	-.003	-.146	-.183	-.011	-.059	-.176	-.271
Mental Ability	2		.105	-.266	-.305	-.334*	-.380*	-.295	-.302
Skeletal Maturity	3			.061	.102	-.207	.024	.047	-.046
<u>Criterion Variables</u>:									
Hopscotch Early Trials	4				.788**	.480**	.511**	.380*	.281
Hopscotch Late Trials	5					.442**	.576**	.362*	.354*
Throw and Catch Early Trials	6						.686**	.200	.090
Throw and Catch Late Trials	7							.336*	.274
Stepping Stones Early Trials	8								.352*
Stepping Stones Late Trials	9								

*$p < .05$ $r = .333$ $N = 35$

**$p < .01$ $r = .430$

correlations between the developmental variables and the motor control tasks were significant.[1]

Intercorrelations among the motor control task variables yielded significant correlations for the early- and late-trial performance on each of the three motor control tasks. Performance on the hopscotch task, both early and late trials, was significantly related to performance on all other tasks with the exception of the correlation between the early-trial performance on hopscotch and the late-trial performance on the stepping-stones task. Of the remaining comparisons, only the late-trial performance on the throw-and-catch task was significantly related to performance of the stepping-stones task for early trials.

Canonical Correlation

Canonical correlation was used to determine the number of significant independent relationships between the developmental variables and the measures of motor control task performance which were examined in the study. The results of the canonical correlation procedure are presented in Table 3. No significant canonical correlations were found to exist between the

[1]The negative sign of the correlation coefficient was expected since time was used as the measure for the motor control tasks.

Table 3

Canonical Analysis of Developmental Variables and Motor Control Task Performance

	1	2	3
	$R_c = .472$	$R_c = .368$	$R_c = .246$
	$\chi^2_{18} = 13.81$	$\chi^2_{10} = 6.24$	$\chi^2_{4} = 1.88$
	$p > .742$	$p > .795$	$p > .760$
	$R^2 = .2228$	$R^2 = .1354$	$R^2 = .0605$
<u>Developmental Variables</u>:			
Visual-Motor Functioning (Frostig)	.384	-.354	.853
Mental Ability (OLMAT)	.991	-.130	-.017
Skeletal Maturity (Hand-Wrist X-ray)	.233	.932	.278
<u>Motor Control Tasks</u>:			
Hopscotch Early Trials	-.532	.351	-.018
Hopscotch Late Trials	-.601	.500	-.043
Throw and Catch Early Trials	-.755	-.427	.334
Throw and Catch Late Trials	-.786	.216	.533
Stepping Stones Early Trials	-.596	.348	-.106
Stepping Stones Late Trials	-.632	.192	-.623

two sets of variables when the chi-square approximation of Wilk's lambda distribution was applied.

The first canonical correlation extracted represents the maximum relationship between the two sets of variables. The obtained value for this canonical correlation was .472. The eigenvalue of .2228 indicated that 22.28% of the variance in the canonical variate for the motor control tasks could be accounted for by the canonical variate for the developmental variables.

Examination of the correlations for each set of variables with the variate extracted for the set indicated that mental ability was most highly correlated with its canonical variate. The correlations of individual motor control tasks with the variate for the set were similar for all criterion variables. The negative sign of the motor control task correlations was anticipated since the measurement was the time required to perform each task.

Subsequent canonical correlations were calculated to determine remaining relationships between the two sets of variables which were independent from those previously extracted. The second and third canonical correlations were .368 and .246, respectively. In general, the second canonical variate was primarily related to the skeletal maturity measure for the predictor variables, while the correlations of the criterion variables with the variate were low to moderate. All relationships except performance on the early trials of the throw-and-catch task were in a negative direction from that which might be anticipated.

The third canonical correlation accounted for variance which was related primarily to the visual-motor functioning measure in the predictor variable set and moderately related to performance on the throw-and-catch task for both early and late trials. However, the relationships of the throw-and-catch scores with the variate were in opposite directions. As previously stated, none of the canonical correlations was found to be significant.

Multiple Regression Analysis

Multiple regression was employed to determine the extent to which the variance of each of the motor control task measures could be predicted by the developmental variables, specifically skeletal maturity, visual-motor functioning, and mental ability. For each of the motor control tasks, the best one-, two-, and three-variable models were determined using the Maximum R^2 Improvement technique.

Multiple Regression for Hopscotch--Early Trial Scores

The results of the multiple regression on the early-trial scores of the hopscotch task are presented in Table 4. Mental ability was entered in the one-variable model with 7.07% of the variance in the early-trial performance on the hopscotch task accounted for by that measure. The value of R^2 was .0789 when mental ability and skeletal maturity were used to compute the two-variable model. The use of all three predictor variables resulted in an R^2 of .0799. Results of the *t* test of the regression coefficients (B values) indicated that none of the values in the three models was significantly different from zero. Based on the analysis of variance for each of the models, no combination of the predictor variables accounted for a significant portion of the variance in the performance on the early trials of the hopscotch task.

Multiple Regression for Hopscotch--Late Trial Scores

Table 5 indicates the results of the multiple regression for the late-trial scores of the hopscotch task. The values of R^2 for the one-, two-, and three-variable models were .0929, .1112, and .1143, respectively. Mental ability was determined to be the best single predictor, while the two-variable model was

Table 4

Multiple Regression Analysis for
Hopscotch--Early Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for H_0:B=0	Prob> |t|	Analysis of Variance	df	MS	F	Prob>F
1	.0707	MA	-.109	-1.585	.119	Regression	1	42.686	2.512	.119
			A=25.364			Error	33	16.992		
2	.0789	MA	-.113	-1.614	.113	Regression	2	23.742	1.367	.269
		SM	.039	.525	.608	Error	32	17.374		
			A=22.225							
3	.0799	MA	-.106	-1.361	.180	Regression	3	16.082	.897	.554
		SM	.038	.506	.622	Error	31	17.909		
		VM	-.027	-.206	.832					
			A=23.305							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

Table 5

Multiple Regression Analysis for
Hopscotch--Late Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for $H_0: B=0$	Prob> $\lvert t \rvert$	Analysis of Variance	df	MS	F	Prob>F
1	.0929	MA	-.078	-1.839	.072	Regression	1	21.885	3.381	.072
			A=20.257			Error	33	6.473		
2	.1112	MA	-.081	-1.904	.062	Regression	2	13.093	2.002	.150
		SM	.037	.811	.571	Error	32	6.540		
			A=17.284							
3	.1143	MA	-.074	-1.570	.123	Regression	3	8.977	1.334	.280
		SM	.036	.781	.554	Error	31	6.727		
		VM	-.027	-.333	.740					
			A=18.353							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

comprised of mental ability and skeletal maturity. The results of the analysis of variance for each of the models indicated that these combinations of the predictor variables were not satisfactory predictors of late-trial performance on the hopscotch task. In addition, regression coefficients for the three models were not significant.

Multiple Regression for Throw and Catch--Early Trial Scores

Mental ability accounted for 11.18% of the variance of the early-trial performance on the throw-and-catch task; this was considered to be a significant predictor. See Table 6. The addition of skeletal maturity in the two-variable model resulted in an R^2 value of .1415, which was not significant. The inclusion of all three predictor variables accounted for 15.86% of the variance in the performance on the throw-and-catch task for early trials. This value was not significant. Examination of the B values indicated that the regression coefficient associated with mental ability was significant for the one- and three-variable model.

Table 6

Multiple Regression Analysis for
Throw and Catch--Early Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for H_0:B=0	Prob>|t|	Analysis of Variance	df	MS	F	Prob>F
1	.1118	MA	-.243	-2.038*	.047	Regression	1	213.385	4.15	.047*
			A=44.781			Error	33	51.300		
2	.1415	MA	-.230	-1.920	.061	Regression	2	135.076	2.64	.085
		SM	-.134	-1.053	.301	Error	32	51.199		
			A=55.580							
3	.1586	MA	-.273	-2.060*	.045	Regression	3	100.872	1.95	.141
		SM	-.129	-1.000	.324	Error	31	51.803		
		VM	.176	.792	.559					
			A=48.529							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

Multiple Regression for Throw and Catch--Late Trial Scores

The results of the regression analysis for the late-trial performance in the throw-and-catch task are reported in Table 7. Mental ability was found to be a significant predictor of performance on the task; an R^2 value of .1447 was obtained. The addition of visual-motor functioning to the prediction equation increased the R^2 coefficient of determination to .1562, a value which was not significant. Likewise, the three variable model accounted for 16.12% of the variance for late-trial performance of the throw-and-catch task and was found not to be a satisfactory prediction equation. The B value for mental ability was determined to be significantly different from zero in all three models.

Multiple Regression for Stepping Stones--Early Trial Scores

In Table 8, the results of the regression analysis for performance on the stepping-stones task during the early trials are presented. Mental ability was determined to be the best single predictor and accounted for 8.71% of the variance in the criterion variable. The F value for the analysis of variance of the one-variable model was 3.151, which was not significant. Subsequent

Table 7

Multiple Regression Analysis for Throw and Catch--Late Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for H_0:B=0	Prob>|t|	Analysis of Variance	df	MS	F	Prob>F
1	.1447	MA	-.251	-2.362*	.023	Regression	1	227.984	5.582*	.023
			A=40.841			Error	33	40.843		
2	.1562	MA	-.283	-2.407*	.021	Regression	2	123.115	2.963	.064
		VM	.132	.662	.519	Error	32	41.549		
			A=35.878							
3	.1612	MA	-.289	-2.410*	.029	Regression	3	84.665	1.986	.135
		VM	.136	.675	.511	Error	31	42.639		
		SM	.050	.426	.676					
			A=31.712							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

Table 8

Multiple Regression Analysis for Stepping Stones--Early Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for H_0:B=0	Prob>$\lvert t \rvert$	Analysis of Variance	df	MS	F	Prob>F
1	.0871	MA	-.192	-1.775	.082	Regression	1	133.705	3.151	.082
			A=44.035			Error	33	42.437		
2	.0932	MA	-.198	-1.793	.079	Regression	2	71.522	1.645	.207
		SM	.054	.463	.651	Error	32	43.472		
			A=39.655							
3	.0963	MA	-.181	-1.474	.147	Regression	3	49.252	1.101	.364
		SM	.053	.440	.667	Error	31	44.722		
		VM	-.067	-.325	.746					
			A=42.341							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

two- and three-variable models resulted in nonsignificant F values. The regression coefficients in each of the models were not found to be significant.

Multiple Regression for Stepping Stones--Late Trial Scores

The results of the regression analysis for the late-trial performance on the stepping-stones task are presented in Table 9. Mental ability accounted for 9.14% of the variance in the criterion variable. The addition of visual-motor functioning increased the R^2 value to .1171. Change in the value of R^2 as a result of adding skeletal maturity to the model was negligible. None of the prediction models which were generated was found to be significant. Regression coefficients for the variables in each of the models were found to be equivalent to zero in their contribution to the prediction equation for late-trial performance on the stepping-stones task.

Table 9

Multiple Regression Analysis for
Stepping Stones--Late Trials

Model	R^2	Variables Entered	B Values	$\underline{t}$ for H_0:B=0	Prob>|t|	Analysis of Variance	df	MS	F	Prob>F
1	.0914	MA	-.126	-1.822	.074	Regression	1	57.420	3.319	.074
			A=27.570			Error	33	17.299		
2	.1171	MA	-.096	-1.260	.214	Regression	2	36.798	2.122	.134
		VM	-.124	-.996	.657	Error	32	17.334		
			A=32.243							
3	.1177	MA	-.095	-1.216	.230	Regression	3	24.644	1.378	.267
		VM	-.125	-.957	.652	Error	31	17.882		
		SM	-.101	-.137	.887					
			A=33.109							

Note: MA = Mental Ability
SM = Skeletal Maturity
VM = Visual-Motor Functioning

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

CHAPTER V

DISCUSSION

The findings and research strategies underlying this inquiry warrant further commentary. The following discussion was organized to permit elaboration of (a) the findings of the study with respect to the literature, and (b) methodological considerations in the examination of motor skill development.

Based on a computer-analogy model of motor skill development in children, Connolly (1973) specified factors which were related to the ability of children to perform physical skills. Of the factors listed by Connolly, the present investigation failed to support the relationship of visual-motor functioning and skeletal maturity with the early- and late-trial performance by 7-year-old girls on the tasks designed for the study. Mental ability, also hypothesized by Connolly (1973) and Bruner (1970) to be a factor in the skill acquisition of children, received limited support.

While research results supporting the relationship of visual-motor functioning and movement performance of children had been limited (Gallahue, 1968; Williams, 1973b), the results of the present study failed to support such a relationship. It appeared probable that the Frostig test did not provide adequate differentiation among the girls in the study. Additionally, the above average performance by most subjects on the mental ability and visual-motor functioning measures indicated that caution should be exercised in generalizing the results to 7-year-old girls.

Witkin et al. (1962), Frostig (1966), and Singer (1968) noted the trend toward greater specificity of abilities during the second and third grades. Chang and Chang (1967) reported that children of superior intellectual ability may evidence a pattern of differentiation similar to that of older children of normal intelligence. While children in the present study were not considered to have superior intellectual ability, the trend toward greater specificity may have been evident in the low interrelationships among variables.

The relationship of skeletal maturity with performance on the motor control tasks tended to support the findings of Teeple (1973) that the skeletal maturity measure, without accompanying indices of body size, was insufficient in predicting performance. The results of research by Rarick and Oyster (1964) and Oyster (1961) indicated that skeletal maturity was related to age, height, and weight of primary-age children.

It was speculated that, in the present study, when emphasis was placed on the speed of performance, the height and weight of the subject may have confounded the relationship of skeletal maturity and the performance scores on the motor control tasks. In addition, the two girls in the study who might have been considered overweight had the highest maturity rating on the skeletal X-ray. Due to the relatively small number of subjects in the study, the aforementioned factor may have affected the resulting correlations. Perhaps the relationship between skeletal maturity and performance on the motor control variables would have been more clearly understood if the data had been adjusted for height and weight effects prior to applying the remaining statistical procedures.

Skeletal maturity is but one of the indicators of physiological maturity. In addition, the variation in the pattern of ossification for the growth centers of different bones has been documented (Pyle et al., 1961). While the hand-wrist X-ray has been widely used as the measure of skeletal maturity, the results of the present study gave no indication of the influence of all facets of maturation.

As stated previously, mental ability was determined to be a significant predictor of early- and late-trial performance on the throw-and-catch task. Although the performance of the remaining four criterion variables could not be adequately predicted from the mental ability measure, R^2 values exhibited a slight increase from early-trial to late-trial scores for each of the three tasks. Based on the phases of motor skill learning proposed by Fitts (1962) and the research of Fleishman (Fleishman, 1972; Fleishman and Hempel, 1954; and Fleishman and Rich, 1963), a decline in the relationship between mental ability and the motor performance scores might be expected across early- and late-trials. While children in the study may have remained in the initial phase of skill learning throughout the three days of practice, the phases of learning large movement skills evidenced in the performance of children warrants further investigation. The conduct of such research has been limited by the absence of specific instruments for examining abilities related to task performance in children.

Examination of the data for the 15 trials on each of the motor control tasks, presented in Appendix E, revealed an interesting pattern of improvement with practice. A marked increase in the speed of performance was evident on the first trial for the second and third days of testing. Thus, the greatest gains were made between days, rather than during the five practice trials. This trend was evident on all three tasks. Similar improvement without practice, or "reminiscence" effect, was noted by Humphries and Shephard (1959) in the performance of children following 20-minute rest periods. The phenomenon was not evident in the performance of the same task by adults. It appeared that this factor in the performance warranted further investigation.

During the initial phase of skill learning, the period of time between trials was reported by Boucher (1972) to be used for the evaluation of KR and the formulation of new strategies for achieving the goal of the movement. Although the girls in the study adopted different strategies as practice progressed, it was observed that most subjects were eager to perform the next trial instead of waiting the required time of 30 seconds.

The three motor control tasks which were designed for the experiment appeared to adequately serve the purposes intended. Subjects were observed to alter the strategy used to perform the task. Upon selection of a different movement plan, the children continued with the strategy for more than one trial. The fact that adoption of a new strategy often resulted in initially slower performance times did not prompt a return to previous strategies.

The reliability data for the motor control tasks are presented in Appendix E. The correlation coefficients for adjacent trials on each of the motor control tasks indicated the performance consistency of the children differed for each task. Since the subjects were permitted to alter the strategy used to accomplish the tasks, the reliability data may also reflect the change in performance times resulting from the adoption of different means of achieving the goal. While the performance of children is generally more variable than that of adults, the nature of the motor control tasks developed for the study may have influenced the adjacent trial fluctuations in reliability coefficients. The range of reliability coefficients across tasks, .466 to .902, is acceptable in the computer-analogy frame of reference.

The limitations in the generalizability of the results of the study should be noted. The relatively small number of girls tested (N=35) resulted in the scores of individual children exerting a marked influence on the group data. The fact that subjects for the study were not randomly selected also limits the generalizations which are permissible. In addition, the number of trials, the distribution of practice schedule, and the specific research purposes for which the tasks were designed are a factor in the uniqueness of the present inquiry.

Certain ongoing concerns associated with the motor skill development of children warrant discussion. Although improvement in performance with age and observable individual differences have been documented, limited information exists regarding factors which are related to the ability of children to perform physical skills. Using computer-analogy models, theoreticians have suggested factors which place constraints on the skill performance of children. Certain considerations are necessary in adopting research strategies which may increase the understanding of motor skill development in children. Since many abilities which may explain the performance of young children are interrelated, multivariate research designs appear to be necessary to understand the phenomena. The increasing specificity of abilities and motor performance scores reported for older children appear to limit the use of correlational techniques when investigating the motor skill development of children of different ages. Additionally, the instruments currently available for measuring the status of various developmental systems were not specifically designed to assess the task demands of motor skill acquisition for children. While such measures may indicate general directions for further research, they do not appear to be adequate for explaining the factors which affect motor skill development.

Keogh (1973) emphasized that motor skill development research has generally provided more information regarding the nature of the task than the nature of the child. Research paradigms which extract intraindividual variability, as well as interindividual variation, appear to be necessary for examining both factors. Perhaps task difficulty should be determined relative to the individual child. The examination of the variation of each child's scores on a task, in addition to a measure of average performance, may be a useful research strategy. Likewise, the concept of motor control seems to imply that improved performance should be accompanied by a reduction in variability. The present inquiry was conceptualized with these methodological problems in mind. Its results seem to support the strategies proposed by Keogh.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The present investigation examined the relationship of three developmental variables--skeletal maturity, visual-motor functioning, and mental ability--with the early- and late-trial performance scores on three motor control tasks by 7-year-old girls. In addition, the degree to which early- and late-trial performance on each of the motor control tasks could be predicted by the developmental variables was investigated. The subjects for the study were 35 7-year-old girls who were enrolled in Emerson, Hamilton, and State Road Elementary Schools in La Crosse, Wisconsin.

The investigation utilized elements of computer-analogy models in establishing the criteria for the movement tasks. The motor control tasks developed for this investigation were designated as hopscotch, throw and catch, and stepping stones. Subjects in the study performed each of the motor control tasks for 5 trials per day on 3 consecutive days, resulting in a total of 15 trials. Early-trial performance was the sum of the time required to perform the task on Trials 1 and 2. The performance score for late trials was the result of summing the child's times for Trials 14 and 15.

The developmental variables were measured by the following instruments: (a) First, the skeletal maturity score represented the skeletal age assessed in months as determined by a hand-wrist X-ray. (b) The average of the T-score conversions for the five subtests of the Marianne Frostig Developmental Test of Visual Perception (Frostig) was used as the measure of visual-motor functioning. (c) Finally, mental ability was determined by the number of items answered correctly on the Otis-Lennon Mental Ability Test (OLMAT).

Canonical correlation was utilized to examine relationships between the developmental variables and performance on the motor control tasks. The degree to which each of the performance measures could be predicted by skeletal maturity, visual-motor functioning, and mental ability was determined through the use of multiple regression analysis. In addition, the means, standard deviations, and intercorrelations for all variables in the investigation were computed.

Results of the canonical correlation procedure revealed that no significant relationships existed between the developmental variables and performance on the motor control tasks. Mental ability was determined to be an adequate predictor of performance for the early- and late-trials of the throw-and-catch task. No single developmental variable was found to have substantial predictive power for the early- and late-trial performance of the hopscotch or stepping-stones tasks.

Conclusions

Based on the null hypotheses which were tested and within the limitations of the study, the following conclusions seem justified:

1. No significant canonical correlations exist between skeletal maturity, visual-motor functioning, and mental ability and the early- and late-trial performance on three distinct motor control tasks by 7-year-old girls.

No significant canonical correlations were found to exist between the two sets of variables and, therefore, this hypothesis was accepted based on the findings of the study.

2. Skeletal maturity, visual-motor functioning, and mental ability, considered separately or in combinations,

are not significant predictors of early- and late-trial performance for each of the motor control tasks.

Based on the findings of the study, the hypothesis was accepted for early- and late-trial performance of the hopscotch and stepping-stones tasks. The hypothesis was rejected for performance of the throw-and-catch task. Mental ability was found to be a significant predictor of early- and late-trial performance for the throw-and-catch task.

Although limited support was found for the adequacy of mental ability as a predictor of movement performance, skeletal maturity and visual-motor functioning appeared not to be related to the performance scores for children in the study. The effect of mental ability seemed to be somewhat task-specific and did not decline between the early and late measures of performance.

Recommendations

The present investigation led to the following recommendations for future study:

1. Instruments should be developed for the measurement of specified information-processing and motor-planning abilities in children.

2. When time required to perform a task is the criterion, performance scores should be adjusted for

height and weight before the effects of skeletal maturity are determined.

3. Examine the phases of skill acquisition for large movement tasks by children.

4. Determine the sources of inter- and intraindividual variability on the motor control tasks in relation to task difficulty and the concept of motor control.

5. Examine movement performance of children for evidence regarding improved scores following periods of rest.

6. Adopt a research paradigm which accounts for the increased specificity of abilities with age when examining factors related to the motor performance of primary-age children.

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APPENDIX A

LETTERS TO PARENTS AND CONSENT FORMS

First Letter to Parents

October 4, 1976

Dear Parent:

At the present time we have relatively little knowledge regarding the ability of young girls to perform physical skills. I am currently on leave from my position as an instructor of Physical Education at the University of Wisconsin-La Crosse attempting to gain additional information on this topic and need the cooperation of you and your daughter.

The La Crosse Public Schools have generously indicated their willingness to cooperate with the study, and your child's school has been chosen as one of the schools participating in this research.

Specifically, each child will be asked to perform three movement tasks on three consecutive days. These tasks, which will require only 15 minutes per day, have been designed to be enjoyable and appropriate for children of this age. In addition, your daughter will be asked to take a test of visual perception and a mental ability test. Although these tests could be given by a teacher, a school psychologist will administer the tests at your child's school during the school day.

Upon completion of the aforementioned activities, your daughter's skeletal age will be assessed by means of a hand-wrist X-ray. The X-ray procedure will be administered by a radiologist and will involve only one exposure to the radiograph procedure. None of these tests will require any expense on your part.

The results of these tests will provide insight into some of the developmental factors influencing the ability of girls to learn physical skills. Naturally, all records will be kept strictly confidential. However, following completion of the study, I will be most willing to share your child's test results with you.

In order for your child to participate in the study, it is necessary that you indicate your approval by signing the form attached to this letter and returning it to the school prior to October 8, 1976. Should this letter fail to answer all of your questions, I will be most willing to discuss any or all parts of the testing with you and may be reached at the numbers listed below. While I realize this is an unusual request, your child's participation is most important to the success of the study.

I sincerely appreciate your willingness to cooperate and look forward to working with your child.

Sincerely,

Joy C. Greenlee
Assistant Professor
Department of Physical Education

Phone: Home 783-3439
Office 784-6050, Ext. 222

Parental Consent Form

Child's Name ____________________ Date of Birth ________

Address __________________________ Phone Number ________

INFORMED CONSENT

I understand that the purpose of this study is to learn more about the developmental factors which affect the physical skill performance of young girls.

I confirm that my daughter's participation as a subject is entirely voluntary. No coercion of any kind has been used to obtain my cooperation.

I understand that I may withdraw my consent and terminate my daughter's participation at any time during the investigation.

I have been informed of the procedures that will be used in the study and understand what will be required of my daughter as a subject.

I understand that all of my daughter's responses, written or oral, will remain completely anonymous.

I wish to grant approval for my daughter's participation as a subject.*

Signed: ____________________
Parent or Guardian

Date: ____________________

Please return the signed form to your child's teacher before October 8, 1976. Thank you again for your cooperation.

---

*Adapted from L. F. Locke and W. W. Spirduso, Proposals that work (New York: Teachers College Press, 1976), p. 237.

Second Letter to Parents

October 19, 1976

Dear Parent:

Your daughter has been participating in the study on the movement performance of young girls. As you will recall, one of the measures included in the study was a hand-wrist X-ray to determine the child's skeletal age. While your permission for this procedure was included in the initial parental consent form, we need your approval on the enclosed forms to complete this procedure.

Arrangements have been made for Dr. Renato Travelli at Gundersen Clinic to supervise the hand-wrist X-ray procedure. A signed consent form is required for such procedures by Gundersen Clinic. In addition, since the girls from each school will be transported by bus to the clinic, it is necessary to have your signature on the Field Trip Permission form provided by the La Crosse Public Schools. The children are scheduled to receive the hand-wrist X-rays on Thursday and Friday, October 21 and 22, and it is necessary that the completed forms be returned prior to that time.

I want to thank you for the cooperation of you and your daughter in making this study possible.

Sincerely,

Joy Greenlee

Clinic Registration Information

Date ________________

________________ is to receive a right hand and
(Name of Student)

wrist X-ray for bone age to be performed under the direction of Dr. Renato Travelli.

Billing and results of the examination should be sent to the following address:

Joy Greenlee
1620 West Meadowview Road
Greensboro, North Carolina 27403

Consent to Operation, Anesthetics

and Other Medical Services

Date ________________

1. I authorize the performance upon

____________________ of the following operation, right
(Name of Patient)
hand and wrist X-ray for bone age, to be performed under the direction of Dr. Renato Travelli.

2. For the purpose of advancing medical education, I consent to the admittance of observers to the operating room.

Witness ____________________ Patient ____________________

Patient is unable to sign because she is a minor and the undersigned is authorized to and does hereby consent on behalf of the patient.

____

Witness ____________________ ____________________________
(Name and Relationship)

(PARAGRAPHS WHICH DO NOT APPLY HAVE BEEN OMITTED)

Form #3036
Gundersen Clinic, Ltd.

Field Trip Permission Slip C-2

La Crosse Area Public School

We, the undersigned parent(s) or guardian(s) of

____________________ do hereby give our permission and
(Pupil's Name)
consent of our child to go on a field trip to

____________________ on ____________________ at
(Name of Place) (Date or Dates)

____________________.
(Time of Day)

It is understood that the instructor in charge will take reasonable precautions to guard against any accident or injury occurring to the pupil. If you have any special request to make concerning your child's participation in this field trip, you should convey your request in writing to the instructor in charge. If possible, such special request will be honored. It is understood that the pupil must abide by the directions given by the instructor at all times.

We agree, as parent(s) or guardian(s) of the above-named pupil to hold the La Crosse City School District, its Board of Education, and its employees harmless from any loss, damage, injury, or harm to the above-named pupil and agree to indemnify and save harmless the said La Crosse City School District, its Board of Education, and its employees for any loss or damage to the pupil occurring as a result of the above field trip.

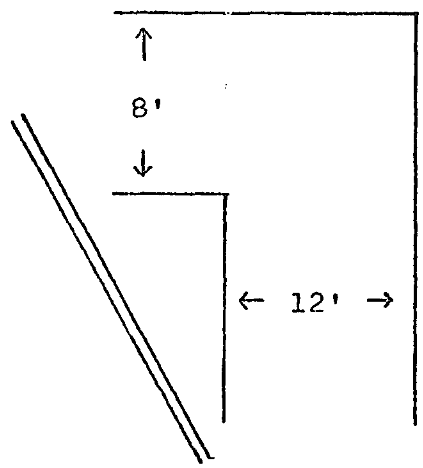
____
Parent(s)/Guardian(s)

THIS TRIP PERMISSION SLIP MUST BE SIGNED BY PARENT(S) OR GUARDIAN(S) AND BE ON FILE WITH THE INSTRUCTOR BEFORE THE PUPIL WILL BE TAKEN ON THE FIELD TRIP.

APPENDIX B

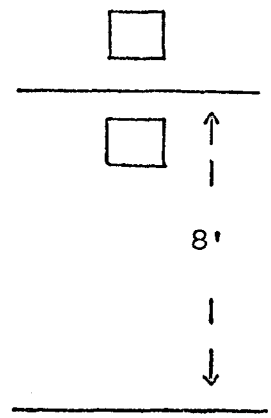
MOTOR CONTROL TASK DIAGRAMS

Motor Control Task Diagrams



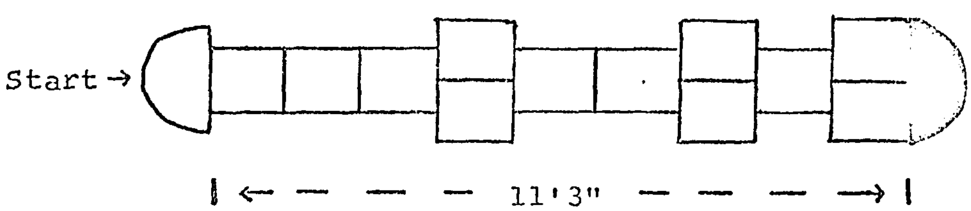
Task 1

Throw and Catch



Task 2

Stepping Stones



Task 3

Hopscotch

APPENDIX C

SUBJECT DATA FORM

Subject Data Form

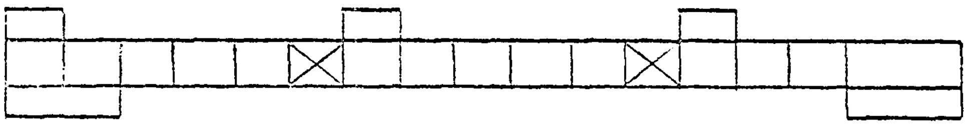
Name ______________________ Date of Birth ________

School: Emerson ___ Hamilton ___ State Road ___

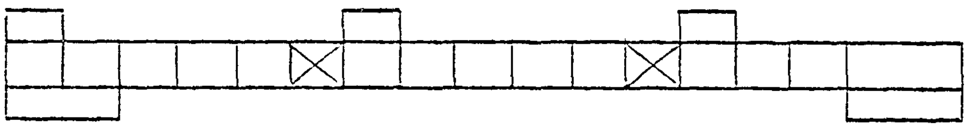
Address ______________________ Phone ________

Parent Name ______________________

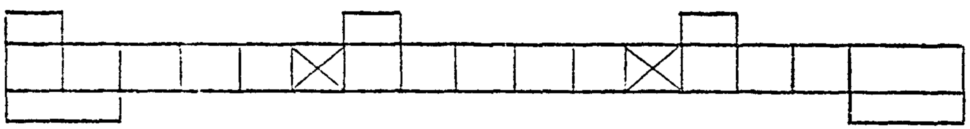
Hopscotch



Throw and Catch



Stepping Stones



Subject # ________

Frostig I ________

II ________

III ________

IV ________

V ________

Total ________

OLMAT ________

SKELAGE ________

HOPEARLY ________

HOPLATE ________

TACEARLY ________

TACLATE ________

STOEARLY ________

STOLATE ________

APPENDIX D

RAW DATA

Raw Data

Subject	FROSTIG	OLMAT	SKELAGE	HOPEARLY	HOPLATE	TACEARLY	TACLATE	STOEARLY	STOLATE
1	41.7	44	81	32.6	23.3	36.8	32.3	44.7	33.4
2	55.4	44	95	25.8	19.5	33.8	30.4	47.1	26.6
3	44.9	34	70	24.3	20.0	58.3	42.5	37.0	21.6
4	48.1	54	75	18.1	15.6	32.2	35.8	40.9	18.1
5	53.8	56	82	25.8	16.5	42.5	36.1	24.1	15.0
6	58.1	72	100	19.5	14.5	27.2	27.5	32.0	19.2
7	46.9	57	87	14.5	12.5	24.7	19.7	36.6	21.6
8	49.5	41	71	16.9	14.0	28.1	18.8	30.0	15.5
9	37.8	46	85	15.0	14.8	31.5	22.0	38.5	21.2
10	49.5	58	92	18.4	15.7	30.9	18.8	31.9	18.5
11	48.3	44	87	27.7	19.9	37.4	34.0	33.4	20.8
12	44.8	42	90	16.4	13.7	31.1	24.3	32.9	22.2
13	41.4	30	83	18.5	17.8	27.8	27.2	34.0	22.9
14	55.7	45	102	16.4	15.5	31.9	33.0	29.6	17.7
15	50.5	48	105	25.7	22.7	41.0	44.9	42.8	21.3
16	37.2	54	84	21.6	14.9	23.7	17.8	35.1	17.3
17	58.3	60	91	13.3	15.3	23.4	24.7	40.3	20.4
18	60.3	45	65	20.2	15.7	29.4	27.0	33.0	20.5
19	53.5	47	80	19.6	14.4	29.3	25.0	40.4	26.7
20	49.5	57	81	16.0	13.4	38.4	31.9	39.5	21.2
21	50.2	45	82	19.9	15.2	23.9	30.8	34.2	19.1
22	51.8	58	85	17.4	13.7	28.2	28.6	27.2	24.4
23	57.4	65	84	14.3	13.0	21.5	16.3	26.5	18.4
24	37.4	41	91	19.8	18.3	33.4	34.7	31.5	25.2
25	48.5	39	87	16.9	13.5	34.9	28.0	27.6	22.7
26	52.1	55	85	21.5	19.1	26.4	22.2	33.3	25.1
27	51.0	65	93	19.3	17.4	27.0	21.3	20.4	14.9
28	46.8	56	96	17.2	15.8	21.3	25.9	25.4	24.0
29	53.3	70	81	20.3	18.1	35.9	25.2	31.9	20.4
30	47.2	39	83	20.4	16.6	34.3	31.6	32.9	26.6

Raw Data (Continued)

Subject	FROSTIG	OLMAT	SKELAGE	HOPEARLY	HOPLATE	TACEARLY	TACLATE	STOEARLY	STOLATE
31	51.8	45	76	20.4	19.1	34.2	32.2	43.2	16.9
32	61.5	54	84	18.1	14.6	41.4	20.7	25.0	13.0
33	51.1	67	72	20.3	14.5	35.8	28.5	38.1	21.0
34	49.4	38	105	26.1	16.5	38.1	31.2	49.3	19.7
35	54.8	46	73	18.1	16.8	43.6	36.1	32.1	29.8

APPENDIX E

SUPPLEMENTARY DATA

Table A

Reliability of Motor Control Tasks

Correlation Coefficients for
Adjacent Trials
on Same Day

Task	Day 1				Day 2				Day 3			
	$r_{1,2}$	$r_{2,3}$	$r_{3,4}$	$r_{4,5}$	$r_{6,7}$	$r_{7,8}$	$r_{8,9}$	$r_{9,10}$	$r_{11,12}$	$r_{12,13}$	$r_{13,14}$	$r_{14,15}$
Hopscotch	.713	.902	.793	.880	.893	.874	.804	.652	.877	.819	.864	.853
Throw and Catch	.548	.585	.589	.466	.478	.531	.710	.733	.507	.650	.578	.612
Stepping Stones	.590	.607	.575	.657	.686	.668	.778	.831	.688	.488	.512	.738

N = 35

Table B

Means and Standard Deviations for Performance on All Trials of Hopscotch Task

Trial #	1	2	3	4	5
Day 1:					
$\bar{x}$	9.83*	10.07	9.53	9.71	9.19
SD	2.35	2.20	1.93	2.15	1.82
Trial #	6	7	8	9	10
Day 2:					
$\bar{x}$	8.59	8.67	8.71	8.81	8.60
SD	1.47	1.40	1.34	1.94	1.45
Trial #	11	12	13	14	15
Day 3:					
$\bar{x}$	8.22	8.53	8.29	8.18	8.17
SD	1.39	1.50	1.39	1.33	1.40

*Time in seconds.

Table C

Means and Standard Deviations for Performance on All Trials of Throw-and-Catch Task

Trial #	1	2	3	4	5
Day 1:					
$\bar{x}$	16.26*	16.29	16.46	15.31	15.66
SD	3.60	4.89	4.52	4.30	4.41
Trial #	**6**	**7**	**8**	**9**	**10**
Day 2:					
$\bar{x}$	14.75	14.43	15.35	14.39	14.89
SD	4.19	3.18	4.55	3.61	4.39
Trial #	**11**	**12**	**13**	**14**	**15**
Day 3:					
$\bar{x}$	13.55	14.22	14.33	14.95	13.25
SD	2.85	3.94	3.25	3.90	3.68

*Time in seconds.

Table D

Means and Standard Deviations for Performance on All Trials of Stepping-Stones Task

Trial #	1	2	3	4	5
Day 1:					
$\bar{x}$	18.38*	15.97	14.34	13.52	13.67
SD	4.55	2.94	2.51	3.26	3.30
Trial #	6	7	8	9	10
Day 2:					
$\bar{x}$	12.13	12.34	11.77	11.33	11.68
SD	2.15	2.94	2.55	2.35	2.67
Trial #	11	12	13	14	15
Day 3:					
$\bar{x}$	10.91	11.54	11.28	10.82	10.41
SD	1.98	2.76	2.11	2.44	2.16

*Time in seconds.

Table E

Means, Standard Deviations, and Correlation Coefficients for Subtests of Marianne Frostig Developmental Test of Visual Perception (Raw Scores)

Subtest		Mean	SD	2	3	4	5
Eye Motor	1	17.89	3.30	.057	.056	.122	.010
Figure Ground	2	19.34	1.16		.309	-.085	.365*
Form Constancy	3	13.69	2.42			.409*	.566**
Position in Space	4	7.54	.74				.350*
Spatial Relations	5	6.68	.68				

*p<.05 r = .333 N = 35

**p<.01 r = .430