1976

# A comparison of foot-eye coordination of boys and girls 7, 9, and 11 years of age on a tracking task

Lucille A. Straub

# A COMPARISON OF FOOT-EYE COORDINATION OF BOYS AND GIRLS 7, 9, AND 11 YEARS OF AGE ON A TRACKING TASK

by

Lucille A. Straub

An Abstract

of a project submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the School

of Health, Physical Education

and Recreation at

Ithaca College

June 1976

Project Advisor: Dr. Harold H. Morris

The motor development of young children is an important concern of physical education teachers. It is during the elementary school years that boys and girls refine such fundamental movements of locomotion as walking, running, jumping, skipping, and galloping. In addition, the hand-eye coordination skills of throwing and catching become an important part of their repertoire of movement experiences. Although considerable attention has been given to the development of hand-eye coordination skills, little research has been done on the development of foot-eye coordination mechanisms. The purpose of this study was to determine the foot-eye coordination of boys and girls at 7, 9, and 11 years of age.

The subjects of the investigation were 42 elementary school age boys and girls who attended the Enfield Elementary School, Ithaca, New York during the 1975-76 school year. They ranged in age from seven to 11 years. Subjects were selected randomly from each of the 7, 9, and 11 year old age groups. There were seven boys and seven girls in each group.

Foot-eye coordination was measured by a ski simulator (Ski 'N Skore, Dukane Model #14A635, Games Division of Dukane Corporation, St. Charles, Illinois). Each subject was tested for 10 trials a day on each of two consecutive days. A trial consisted of the manipulation of a miniature skier through a series of 80 gates that were located on a motor driven belt that revolved at a speed of 17.23 inches per second. Each time a subject missed a gate a red light flashed and an error was counted by the investigator on a hand calculator. The subject's score was the total number of gates missed.

Results were analyzed by means of a 3x2x2x10 (age x sex x days x trials) ANOVA with repeated measures on two of the factors. Day 1 scores were eliminated because of a significant across trials learning effect. The final analysis involved only Day 2 scores. The Neuman-Keuls procedures were used to locate between groups differences when significant differences were found.

Foot-eye coordination differences were found for the age factor. Post-hoc comparisons, however, produced significant differences only between children seven and 11 years of age. There were no significant differences in foot-eye coordination among children 7 and 9, or 9 and 11 years of age. Sex differences in foot-eye coordination were not found between boys and girls 7, 9, and 11 years of age. It was concluded that foot-eye coordination of young children improves with advancing age.

# A COMPARISON OF FOOT-EYE COORDINATION OF BOYS AND GIRLS 7, 9, AND 11 YEARS OF AGE ON A TRACKING TASK

---

A Research Project Presented to the Faculty

of the School of Health, Physical

Education and Recreation

Ithaca College

---

In Partial Fulfillment of the

Requirements for the Degree

Master of Science

---

by

Lucille A. Straub

June 1976

Ithaca College
School of Health, Physical Education and Recreation
Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE RESEARCH PROJECT

This is to certify that the Research Project of

Lucille A. Straub

submitted in partial fulfillment of the requirements for the degree of Master of Science in the School of Health, Physical Education and Recreation at Ithaca College has been approved.

Research Project
Advisor:

Candidate:

Chairman, Graduate
Program in Physical
Education:

Director of Graduate
Studies:

Date: August 31, 1976

# ACKNOWLEDGEMENTS

The investigator wishes to express appreciation to Dr. Harold H. Morris for serving as my advisor and for his suggestions and guidance in conducting this study. Also, I wish to thank the pupils of the Enfield Elementary School, Ithaca, New York who served as subjects and to Mr. John Wertis, Principal, for permitting the use of space in school to collect data.

TABLE OF CONTENTS

| CHAPTER | | Page |
|---|---|---|

## LIST OF TABLES

LIST OF FIGURES

## Chapter 1

## INTRODUCTION

The motor development associated with the learning of basic skills is a major objective of the elementary school physical education program. During a child's first five years of life, fundamental motor patterns are developed as problems of locomotion are overcome and he learns to manipulate various objects in his environment. By elementary school age most basic movement patterns have been established so that during these early school years the focus is upon the improvement of the basic movements and developing variations of them (25). This period of childhood is described by Goodenough (13) as one of slow developmental change yet one of rapid learning. Rarick (26:73) sees the fifth through eleventh or twelfth years as "characterized more by the perfection and stabilization of skills than by the emergence of new ones." It is during these years that a child develops a more mature form in the performance of basic skills and readies himself for the learning of more advanced sports skills.

A large amount of literature exists describing physical growth in early childhood and the maturation that takes place through various stages of development. There is, however, little information about the development of foot-eye coordination in children. Since most of the fundamental locomotor movements (e.g., walking, running, and jumping) normally require a process of matching foot movements with what is perceived visually, it is unfortunate that more studies have not focused on this important aspect of motor learning.

The objective of this study was to compare the foot-eye coordination of elementary school boys and girls, ages 7, 9, and 11 years. This information may be of value to elementary school physical education teachers and other specialists who desire to improve the motor performances of children. Since there was a dearth of information on foot-eye coordination, a central purpose of this study was to provide some information on this topic.

## Statement of Problem

The purpose of this study was to determine the foot-eye coordination of elementary school children. Specifically, this investigation sought to determine if boys and girls at 7, 9, and 11 years of age differed in ability in foot-eye coordination as assessed by a paced contour tracking task.

## Significance of Study

There is growing interest in the study of the motor development of young children. All too often the emphasis in motor learning has been placed on analyzing the performance of secondary school students or highly skilled athletes, little information, however, is available about where the initial responses of skilled performance were learned. In addition, many children experience movement problems that are thought to be linked to reading, writing, speech and/or hearing difficulties, making this area an important part of what is currently referred to as 'learning disabilities.'

As previously mentioned, studies about the development of foot-eye coordination were not found in the research and conceptual literature. Various well-known motor learning texts (2, 5, 21, 22, 23) do not include the terms eye-foot or foot-eye coordination in their reference sections. Apparently, the absence of information about this topic is partially due to the lack of valid instrumentation. Eye-hand or hand-eye coordination, on the other hand, was covered in nearly all motor learning books and there has been a great deal of research done in this area.

Foot-eye coordination is an important factor in the motor behavior of children. Without the adequate coordination of these mechanisms the child's repertoire of motor responses is severely restricted. Kicking, dribbling, or pedaling, for example, are limited. A child's ability to move well in the play and game culture of the early school years may lead to social approval and peer recognition. The importance of motor skill development is often overlooked by educators who would focus exclusively on the cognitive development of children. Movement, however, plays a vital role in almost all aspects of life during the primary and intermediate school years. Self-concept and body-image are developed as children interact through the medium of play, games, and sports. Some aspect of foot-eye coordination is nearly always involved since a child's ability to move from place to place is dependent upon some form of locomation.

## Scope of Study

The subjects of this study were 42 boys and girls who ranged in age from seven to 11 years. They were selected randomly from a list of children attending the Enfield Elementary School, Ithaca, New York during the 1975-76 school year. There were seven boys and seven girls in each of the 7, 9, and 11 year old age groups.

## Definition of Terms

The following terms were defined operationally for this study so that agreement may be reached regarding their precise meanings:

### Coordination

Coordination is the ability to perform a series of movements of varying speeds and forces that combine into a motor act of a more complex nature (5).

### Foot-eye Coordination

Foot-eye coordination is the ability to combine in harmonious relation movements of the feet with vision.

### Visual Tracking

Visual tracking is the total ability to move the eyes in the proper direction and at the proper speed to glean as quickly, correctly, and effectively as possible the needed information (12).

### Paced Contour Tracking

Paced contour tracking is following a line on a tape or track that approaches at a fixed speed by controlling a marker or stylus that is to be kept on target (the line) as it passes (20).

### Ski Simulator

A Ski simulator is a machine designed to allow an individual to imitate the foot-eye coordination movements in slalom skiing by steering a miniature figure of a skier with the movements of foot pedals, and directing the figure through gates or openings along a moving ramp or track.

### Error Score

An error score is the total number of gates missed by the subject out of a possible total of 72 gates on any one trial run on the ski simulator.

### Vigilance

Vigilance is the subjects' ability to watch for gates that appeared on a motor driven belt.

## Hypothesis

### Major Null Hypothesis

There will be no statistically significant differences in the foot-eye coordination of boys and girls at 7, 9, and 11 years of age.

## Assumptions of Study

This study is based upon the following assumptions:

1. Each child performed to the best of their ability while taking the test on the ski simulator.

2. The error scores recorded on the ski simulator represent a relevant measure of foot-eye coordination for elementary school children.

## Limitations of Study

When interpreting the results of this investigation, the following limitations should be considered:

1. The validity of the ski simulator as a measure of foot-eye

coordination has not been determined for the age group for which it was utilized.

## Chapter 2

## REVIEW OF RELATED LITERATURE

This chapter's contents will be subdivided into three parts. The first section will focus on the research and conceptual literature pertaining to the development of foot-eye coordination. Second, the findings of studies relating to the role of vigilance in motor performance will be covered. Third, since performance on the ski simulator was classified as a tracking task, the tracking literature will be presented. The intent of the researcher is to inform the reader of the findings of other investigators who have examined the same or similar areas of motor performance. These data will form the basis for the discussion of the results of this study which will be presented in Chapter 5.

### The Development of Foot-eye Coordination

Studies of the development of foot-eye coordination of young children are conspicuously absent in the developmental literature. This dearth of information is surprising since success in basic locomotor tasks (e.g., walking, running, and jumping) requires a delicate balance between perceptual and motor mechanisms. Increasing age and maturation enable the young child to make greater use of his motor mechanism to explore and master his environment. Creeping, standing with support, and walking develop sequentially to permit the infant to gain greater control of his skills of locomotion.

Although research studies are lacking, a number of contemporary authorities, such as Rarick (26), Espenschade and Eckert (8), and Cratty (6), write in general terms about the motor development of children at various age levels. In 1961 Rarick (26) wrote that the most remarkable aspect of early development was the rapidity with which the child gains control and use of the large muscles of the trunk and extremities. Espenschade and Eckert (8) discuss the role of hereditary, prenatal maternal influences, and differentiation and integration of the sensory-motor system. They postulate that the infant progresses through five separate stages in the development of bipedal locomotion. Citing Shirley's (27) classical study, Espenschade and Eckert suggest that postural control of the upper body occurs before 20 weeks of age. At the second stage (25 to 31 weeks), the infant gains control of the entire trunk, followed by stage three, which involves active efforts at locomotion that results in some progress moving on the stomach. Between 42 and 47 weeks, the infant can usually stand holding to furniture. He can also walk when led and can pull himself to the standing position. Usually by age 62 to 64 weeks postural control and walking alone without support are well developed.

Cratty (6), in contrast to Rarick and Espenschade and Eckert, places greater emphasis on the role of reflexes in the development of of various motor responses. By the second week of life, Cratty claims that the walking reflex is developed in about 58 percent of the infants he studied. That is, if infants are held in an upright position, permitting their feet to touch a level, horizontal surface, they will move their legs as if to walk. Cratty (6) is of the opinion these early motor behaviors are controlled at the spinal cord level and do not involve, at this time, higher cortical centers. Cratty places considerable emphasis on the role of reflexes as the forerunners of what are later to become sophisticated motor responses. His emphasis on the role of reflexes is supported by Piaget's (19) belief that reflexes form the building blocks for the development of more mature types of behavior.

In a more recent publication, Malina and Rarick (16) discuss the role that physique plays in the early motor development of infants. Although Sheldon's somatotyping is not widely used in physical education today, Malina and Rarick suggest that motor development early in life is related to a variety of morphological features. Citing the work of Shirley (27) and Norval (39), Malina and Rarick state that small boned infants and those of linear frames tend to walk at an earlier age than the heavier boned child. Garn (11) found that muscle mass at six months of age was predictive of walking at one year.

Both boys and girls who possess mesomorphic body physiques tend to become involved in gross motor tasks at an early age. Apparently, a high energy level coupled with a mesomorphic physique make it possible for such children to withstand the stresses of active play soon after walking, running, and other fundamental movement patterns are well developed (16). Due to the lack of research, however, Malina and Rarick state that only tentative conclusions may be drawn at this time concerning the role of physique in the motor development of children.

Although reflexes, physique, muscle mass, and other factors play important roles in the development of the motor behavior of young children, Rarick (26) has repeatedly stressed the importance of providing favorable opportunities for motor development during early years. Early motor responses form the foundation for the development of more intricate coordinations that are needed during adolescence and adulthood. Play is the vehicle which enables children to exercise their motor mechanisms in response to a wide variety of internal and external stimuli. Children in all cultures play, and it is logical to assume that innate processes as well as environmental stimuli help to shape the child's behavior in play. It has been found that active parents tend to produce active children (47). Therefore, it appears that the role of parental influence in the establishment of early motor responses should not be negated.

The development of motor control during early childhood is made possible by rapid physical growth. At birth only 25 percent of an infant's weight is muscle tissue with this proportion remaining almost constant until about the fifth year when 75 percent of the weight gain is attributed to muscle tissue (39). Big muscle activity stimulates this growth and, in addition, helps the child to integrate his neuromuscular responses. By the time a child enters school he has developed a repertoire of fundamental movement patterns and an increasing interest in the exploration of his environment. He can walk, run, jump, throw, hit and catch various objects as well as perform other gross motor skills. The refinement of these tasks continues during the early years as well as the development of more intricate movement patterns.

In summary, the motor development of young children is the result of the integration of maturational and environmental forces. Foot-eye coordination in walking is the start of the development of a wide variety of foot-eye motor patterns. Although motor development authorities such as, Rarick, Espenschade, Eckert, Cratty, and others, do not focus attention specifically on the development of foot-eye coordination, they all seem to agree that it is one of the most important developmental tasks that the young child has to learn. Walking, for example, enables the child to explore and expand his environment. Much later other foot-eye coordination tasks such as bicycle riding and driving a car will become important to him. Foot-eye along with hand-eye coordination are possibly two of the most important and widely used behaviors in man's repertoire of movement responses.

## Vigilance

Vigilance refers to "the study of alertness for the detection of critical signals when they occur " (1:187-188). In this study, vigilance was defined as the subjects' ability to watch for gates that appeared on a motor driven belt. This definition, although in agreement with Adam's, is not in keeping with Broadbent (3:18), who defined vigilance as "the study of men keeping watch for inconspicuous signals during fairly long periods of time." Vigilance, as it took place during ski similuation, did not require subjects to watch for inconspicuous signals. In contrast, the gates were very visual but the subjects were required to maintain their attention in order to perform efficiently. In this sense, ski simulation may be categorized as a vigilance task.

Theories of vigilance may be grouped into four separate but overlapping areas. Broadbent (3) and Welford (24) provided a framework for doing so. The oldest approach to the study of vigilance decrement was Mackworth's (48) inhibition theory. Proponents of this view believe that a lack of reinforcement during a vigilance task is responsible for the decrement in performance that occurs. In brief, responses that are not rewarded are soon extinguished. Furthermore, lack of reinforcement leads to a decrease in motivation. That is, the subjects' arousal level may be too low for him to respond efficiently. In this sense, some authorities (e.g. Broadbent) stipulate that the inhibition theory may be categorized as a sub-class of the activation theory.

Application of the inhibition theory to explain performance decrement over time in ski simulation suggests that toward the end of the task subjects do not find movements of the model skier through the gates rewarding. Possibly the novelty of the task wears off and subjects do not feel rewarded for good performance. Providing extrinsic rewards such as praise would help to prevent performance decrement according to this view. This generalization is supported by Mackworth's (48) original findings that stimulant drugs, rest pause, and knowledge of results increased the efficiency of detection. Broadbent (3) reported that some tasks show no decrement during the run but these were tasks where the signal remained available over a prolonged period of time.

On the basis of Deese's (32) finding, that performance in a vigilance task improves if the rate at which the signal occurs is increased, the inhibition theory was revised in 1955. Straub (43) found that expert women skiers of college age performed better when the ski simulator was run at faster speeds. Apparently, at slower simulation speeds, the subjects became bored with the task and as a result their performances were not as good as at high speed.

A second theory of vigilance closely allied to Mackworth's inhibition theory is Deese's (32) expectancy view. This position specifies that response to a signal will become more likely if the signal is more probable. In other words, the likelihood of signals being missed depends on the predictability of the moment at which they will arrive (37). Welford (24) cites as evidence in support of this theory what is commonly called the "end spurt" phenomenon. In "end spurt" subjects tend to improve their performances as the end of a task occurs (30). What is not known, however, is how expectancy exerts its effect on performance. Perhaps expectancy causes a raising or lowering of activation levels. It is possible that an optimum level of arousal exists for ski simulation. Knowing that the gates will appear at established intervals may enable the subject to adjust his activation level so that he is near the optimum amount of excitation for this task. Since expectancy was constant in ski simulation (the gates appeared at regular intervals), it probably prevented performance decrement.

A third explanation or theoretical position is the activation or arousal theory (32). Supporters of this position contend that the nervous system requires a constant barrage of stimulation in order to maintain itself at a reasonable level of general efficiency (3). Physiological psychologists (7) postulate that the reticular formation, located at the base of the brain stem, plays a vital role in sensitizing the cerebral cortex to receive stimuli. Alertness depends on the creation of an optimum level of arousal for a given task. For gross skills, high levels of arousal may produce optimum performances; fine motor skills require lower levels of arousal. Oxendine's (17) model suggests that ski simulation would be located in the middle of the arousal continuum.

There is little doubt that activation or arousal plays some role in vigilance. Sensory deprivation studies (45) show that the deliberate withholding of stimulation over long periods of time results in a reduction in performance. Studies by Harlow (14) with monkeys indicate that long-term sensory deprivation leads to adjustment problems during the adult years. According to Broadbent (3), Mackworth's (48) finding that performance decrement could be avoided by the administration of 10 mg. of benzedrine shortly before the experimental session began, is the most strikingly direct evidence in support of the activation theory. Benzedrine speeds up body processes so the subjects are more highly activated, apparently to a level appropriate for the given task, preventing performance decrement.

It is possible to apply the activation theory to ski simulation. As mentioned above, an optimum level of arousal is needed for subjects to perform this skill. Too much activation or too little arousal will lead to performance decrement. When activation levels are inappropriate for the ski simulation task, more gates will be missed. Support for this statement would be evident if the subjects in this study missed more gates during the first few trials than during subsequent trials. Activation theorists might explain this fact by suggesting that levels of arousal were too high at the beginning of the task and high activation prevented the subjects from performing the skill correctly.

The fourth theoretical position advanced by Broadbent (3) and Welford (24) is called the filter theory. According to this view, signals are missed because they are only partially received by the subject. The organism tends to sort out or filter certain information that reaches the senses. Novel stimuli, as Broadbent (3) suggests, tend to get through the filtering mechanism. Welford (24) refers to this phenomenon as "blocking." In other words, from time to time during vigilance tasks performance decrement takes place because of what Welford calls perceptual selectivity. There is a brief loss of attention during which time less relevant or even competing stimuli "filter" through the sensory mechanism.

This theory may be applied to ski simulation as an explanation of performance decrement. Perhaps perceptual fatigue led to a blocking of sensory pathways, preventing subjects from receiving stimuli relevant to this task. As the rate of work increased over time, irregularities in performance would begin to occur. Fatigue appears to be one of the most important factors influencing performance in tasks such as ski simulation. Fatigue also leads to a 'filtering' of stimuli so that the organism's system does not become overloaded. Filtering or blocking may be thought of as a protective mechanism which enables the subject to maintain equilibrium.

## Tracking

A thorough review of the research and conceptual literature produced a few investigations in which foot-eye coordination had been specifically studied. In contrast, this review produced an abundance of information on hand-eye tracking skills. Ammons and Ammons (46), for example, have spent more than 20 years investigating various aspects of hand-eye coordination using the pursuit rotor. After 23 years of work, they reported that they were far from their original goal of constructing a comprehensive theory of motor learning. After more than 100 studies, Ammons and Ammons (46) reported a notable absence of comprehensive laws which govern skilled motor behavior. The failure of the Ammonses to uncover the underlying basis of motor skill acquisition attests to the complexity of human behavior and the need for long term research in this area.

One of the most complete descriptions of the various types of tracking was presented by Poulton (20). He classified tracking into five different categories. They were: 1) pursuit, 2) compensatory, 3) acquisition or discontinuous step-function, 4) unpaced contour, and 5) paced contour tracking.

In pursuit tracking the subject is required to keep a marker in line with a moving target. Ammons (29) claims the pursuit rotor is an example of this type of tracking task since the subject is required to keep a stylus in contact with a small circular disk set into a rotating platform or turntable.

A task that requires subjects to hold a moving element, such as a model car, over a fixed target (road) is classified by Poulton as compensatory tracking. The subject must make adjustments as the moving object (car) tends to deviate from the target.

Acquisition or discontinuous step-function tracking is similar to compensatory tracking. However, in acquisition tracking both the target and response marker start superimposed but one of them jumps to a new position. When this happens the subject must superimpose the marker on the target again. Poulton (20) stated that step function tracking may also be classified as a special case of pursuit or compensatory tracking.

Stylus maze and star tracing in mirror drawing experiments are classified by Poulton as unpaced contour tracking. Paced contour tracking, in contrast to unpaced, requires the subject to control a marker superimposed upon a wiggly line as it passes at a predetermined speed. In both paced and unpaced tracking the subject can normally see the wiggly line some distance ahead. If vision of the line ahead is impaired the task becomes much like pursuit tracking, according to Poulton.

A careful review of the literature on tracking produced only two studies that dealt specifically with tracking as it relates to ski simulation. Both investigators, Straub (43) and Klingman (50), used the same ski simulation device that was used in this study. Straub (43) established the validity of the ski simulator as a test of skiing performance. He hypothesized that the ski simulation performance of college age women (N=80) would vary depending on their levels of skiing proficiency. That is, skiers classified as expert would score significantly better (miss fewer gates) than skiers classified as intermediates, beginners or non-skiers. Utilizing a deliberate sampling procedure, he selected 20 women from each of the previously mentioned categories and measured their ski simulation performance. As expected, the hypothesis was found to be tenable except at the low simulation speeds. The expert skiers made fewer errors than the intermediate. beginner or non-skiers. Beginning level skiers, however, did not score significantly better than non-skiers. Straub attributed this finding to the fact that some of the subjects in the beginners category were not beginners in the strict interpretation of the term; they had only been skiing a couple of times.

In contrast to Straub, Klingman (50) used the ski simulator to measure the foot-eye coordination of college age (17-25 years) male skiers and non-skiers. He hypothesized that the skiers (N=30) would score significantly better than the non-skiers (N=30) in foot-eye coordination. As expected, the skiers out performed the non-skiers at slow, medium and fast simulation speeds. Within the limits of the study, Klingman (46) concluded that college age skiers possess significantly better foot-eye coordination than college age non-skiers. Furthermore, Klingman found that the ski simulator was a very reliable instrument, particularly at medium (20.96 inches per second) and fast (24.60 inches per second) speeds, as evidenced by Pearson product-moment correlation coefficients of .79 and .83 for test-retest scores.

During World War II a number of psychologists studied a variety of parameters of psychomotor abilities for the armed forces. Among this group was Edwin A. Fleishman who was given the task of developing a battery of psychomotor tests to select pilots, navigators, bombardiers and other members of a flight crew. Included in this battery were several tests of different types of hand-eye and foot-eye coordination (34). After more than 18 years of work, Fleishman (9) and his associates have identified, largely through factor analysis, 11 psychomotor abilities and nine abilities in the area of physical proficiency. According to Fleishman (9:81) these components "consistently appear to account for the common variance in psychomotor tasks." The psychomotor abilities are: 1) control precision, 2) multilimb coordination, 3) response orientation, 4) speed of arm movement, 5) rate control, 6) manual dexterity, 7) arm-hand steadiness, 8) finger dexterity, 9) wrist-finger speed, 10) aiming, and 11) reaction time.

Of these 11 abilities, many of them are utilized in paced contour tracking as performed on the ski simulator. Control precision, defined by Fleishman (9) as the ability to make fine, highly controlled muscular adjustments, was required to manipulate the skier so that he would pass through the gates on the moving belt. Multilimb coordination, or what Fleishman called the ability to coordinate the movements of a number of limbs simultaneously, is also needed to keep the skier on the track. Both feet must work together to perform this task. Likewise, rate control, or the ability to make continuous anticipatory motor adjustments to a constantly moving target is required. In ski simulation the subject must position the skier prior to going through a gate so that he will be facing the next approaching gate. Reaction time, or the speed with which one is able to respond to a stimulus, appears to be vital to successful performance on the ski simulator. The approaching gate is the stimulus to which the subject must react so that he can maneuver the skier into the appropriate position for the next gate.

The other previously listed factors, all of which involve the use of hands or arms do not seem to be related to success in ski simulation. Fleishman (34:438) summarized the underlying dimensions of movement reactions, such as those performed on the ski simulator when he stated:

In movement reactions one is interested in the ability to make smooth or coordinated control movements, to move a body member or control at a given rate, in a rhythmical fashion, in a certain sequence, or along specified pathways. The distinguishing feature is that skill during the movement is of primary interest, as contrasted with position movements, when terminal accuracy is the primary feature, and static reactions, where maintenance of a certain limb position is the central task.

Studies involving the foot-eye coordination of college age males were conducted by Smith (51) and by Whitley (44). The purpose of Smith's study was to determine the reliability of an adapted tracing board test, previously used in testing hand ability, to measure both hand-eye and foot-eye coordination. The test consisted of six sine-curve mazes of various widths, with subjects testing both their feet and hands. The results showed that three of the 10 correlations were significant in the hand-eye task while only two of the 10 correlations were significant in the foot-eye coordination tests. Smith reported that none of the correlations met the .75 minimum correlation level for retention of the test for use in testing physical skills.

Whitley's study was conducted to determine the amount of learning on a task he referred to as the "foot twist tracking task." Thirty-five trials were given to 60 subjects, each trial consisting of 30 seconds of work and a 30-second rest period. The subject was seated with a stylus attached to a foot piece. During the test the subject attempted to keep the stylus in contact with the target, which was an irregular smooth curve drawn on a rotating drum. The results showed that the amount of learning on the task was significant but less than that on pursuit rotor tasks or large muscle coordination tests.

Since Fleishman's work in the early 40's and 50's, progress in the development of a more functional interpretation of skill acquisition as it relates to tracking, has not been forthcoming. Theoretical formulations by Adams (1), and more recently by Schmidt (42), do not deal with tracking tasks. The learning of tracking tasks is not explained by theoretical position statements in any of the recognized theories of motor learning (42).

Despite the absence of theories that apply to the learning of tracking skills, Pew and Rupp's (40) work provides some insight into the learning of tracking tasks. Pew (18:10) emphasized the point that "it is the process-delay rather than any intrinsic discontinuities imposed by the subjects that produces many of the qualities of human tracking performance." Poulton's (20) work supports the importance of predictability in enhancing tracking performance. Simply providing the subject with a pursuit display produces better tracking performance. According to Poulton (20:369) this increment in performance is apparently the result of the subject's ability to "see the movement of the track directly, unconfounded by his own response function."

Other than these generalizations, little is known about tracking skill acquisition at this time. Schmidt (42) writes that he is hopeful that his schema theory of discrete motor learning may, at a later date, be applied to the learning of tracking skills.

## Summary

It was the purpose of this chapter to provide an overview of the research and conceptual literature in the development of foot-eye coordination, vigilance, and tracking. The coverage of the literature was not all-inclusive but selective of the vast amount of attention that has been given to each of these topics.

There was a dearth of information on the development of foot-eye coordination in young children. In sharp contrast, much has been written about hand-eye coordination tasks. Contemporary authorities such as Rarick (26), Espenschade and Eckert (8), and Cratty (5, 6), however, write in general terms about the maturational processes involved in learning fundamental movements of locomotion such as walking, running, jumping, etc. Espenschade and Eckert (8) discuss the role of heredity, prenatal maternal influences and differentiation and integration of the sensory-motor system. They contend that the infant proceeds systematically through five separate stages in the development of bipedal locomotion. Cratty (6), in contrast to Rarick, Espenschade and Eckert, emphasized the role of reflexes in the development of various motor responses. Piaget's (19) work supports Cratty's beliefs. Reflexes, Piaget stated, form the building blocks for the development of more mature types of behavior. In brief, the motor development of young children is the result of the integration of maturational and environmental forces.

Four major theories of vigilance were presented. They were the: 1) inhibition, 2) expectancy, 3) activation or arousal, and 4) filter theories. Inhibition theorists, such as Mackworth, contend that performance decrement takes place because the subject fails to receive reinforcement throughout the vigilance task. Expectancy theorists suggest that responses to a signal are more likely if the signal is more predictable. If the subject knows when to expect the signal he will be more likely to respond to it when it does occur. Activation or arousal theorists postulate that performance decrement is due to too high or too low an activation level. In brief, they suggest that there is an optimum level of arousal for each task. Filter theorists, such as Broadbent (3) contend that signals are missed because they are only partially received by the subject. In other words, the subject "blocks" or filters out certain stimuli. Some authorities such as Welford, refer to this process as selective attention.

Poulton (20) classified tracking into five separate categories. They were: 1) pursuit, 2) compensatory 3) acquisition or discontinuous step-function, 4) unpaced contour, and 5) paced contour tracking. In pursuit tracking the subject is required to keep a stylus or marker in line or in contact with a moving target. The pursuit rotor is the most frequently cited pursuit tracking task. Compensatory tracking requires subjects to hold a moving element over a fixed target. Acquisition or discontinuous tracking is similar to compensatory tracking. In acquisition tracking, however, both the target and response marker begin superimposed but one of them jumps to a new position. When this happens the subject is required to superimpose the marker on the target once more. Paced contour tracking requires the subject to control a marker superimposed upon a wiggly line as it passes at a predetermined speed. Unpaced contour tracking, as in star tracing, requires the subject to trace a star while looking in a mirror. Only two studies, Straub (43) and Klingman (50), were found in the literature that had used the same ski simulator. Straub (43) established the validity of the simulator as a test of skiing performance using college age women skiers and non-skiers of different levels of ability. Klingman (50) used the ski simulator to measure the foot-eye coordination of college age males, 17 to 25 years of age.

Much of the pioneer work in motor performance was done by Fleishman (9, 10) and his associates. Through factor analysis they identified 11 psychomotor abilities. Of these 11 abilities many of them are used in paced contour tracking as required in ski simulation. Control precision or the ability to make fine highly controlled muscular adjustments appeared to be one of the most important abilities required in ski simulation.

The contents of this chapter clearly show the need for studies which attempt to assess the foot-eye coordination of young children. At the present time there is a dearth of reliable and valid information about the development, maintenance and decline of foot-eye coordination. It is particularly important during the early years of life as children attempt to gain control of their motor mechanisms. Use of the feet plays a vital role in enabling the child to master skills such as walking, running, jumping, and swimming. These fundamental movements of locomotion enable the child to explore and control his new environment.

During the elementary school years children use their motor apparatus, particularly the hands and feet, to play various individual and group games. Children who perform well in games and sports usually become accepted by their peers. Poor neuromuscular skill has been said to be the cause of adjustment problems. Self concept and acceptance of one's body and the way in which it functions should be major objectives of contemporary physical education programs, particularly during the elementary school years. Providing teachers with foot-eye coordination data should enable them to individualize their programs. With remediation many common foot-eye coordination problems may be alleviated or at least lessened. It is during the early years that children are most in need of special kinds of education. Once poor motor habits become established it is most difficult, if not impossible, to eliminate them.

Motor coordination problems have also been associated with learning disability problems. Decrements in reading skill, for example, are thought to be linked to a failure to master such basic coordinations as crawling, creeping, walking, etc. In brief, these skills depend, in part, on the development of the central nervous system. It is not surprising that foot-eye and hand-eye coordinations play an important role in enabling the child to become competent in what have previously been thought to be cognitive skills.

## Chapter 3

## PROCEDURES

This chapter contains the procedures that were used in the selection of subjects, the collection of data, and the organization of the data for statistical analysis. The design of the study is also included along with the procedures used to establish the reliability of the ski simulator.

### Selection of Subjects

The subjects (N=42) were selected randomly from the roll list of boys and girls, ages 7, 9, and 11 years, who were pupils at the Enfield Elementary School, Ithaca, New York. Pupils were listed alphabetically by age and sex and then numbered consecutively. A table of random numbers was used to select seven boys and seven girls from each of the 7, 9, and 11 year old age groups. Thus, the total sample consisted of 42 subjects, 21 boys and 21 girls.

### Source of Data

The only source of data was the error scores that each subject obtained on the 10 ski simulation trials during the second of two consecutive days of testing. These scores were the dependent variable of this study. Ten test trials were also given during the first day of testing in an attempt to eliminate the possibility of learning effects found during a pilot study. They were not, however, used in the final statistical analyses.

## Design of Study

The investigation was classified as ex post facto, that is, the factors that had produced foot-eye coordination, for example, maturational processes, had already operated. A 3x2x2x10 (age x sex x days x trials) factorial analysis of variance design, with repeated measures on two factors, enabled the investigator to test for foot-eye coordination changes across trials and between days for the children of each sex at each age level. The .05 level of significance was selected for rejection of the statistical hypothesis posed in Chapter 1.

## Instruments

The foot-eye coordination of subjects was determined by a ski simulator (Ski 'N Skore, Dukane Model #14A635, Games Division of Dukane Corporation, St. Charles, Illinois). Figure 1 shows the device was 64 inches long, 37.25 inches in width and 57 inches high. The standing subject was positioned on ski pedals while grasping the two handles located directly in front of him. Movement of the pedals produced a change in the position of the simulated skier while a belt equipped with gates revolved toward the subject. This was similar to paced contour tracking, as described by Poulton (41). Each time the subject missed a gate an error score was recorded by the investigator, using a hand calculator. A speed control knob located on top of the simulator, near the handles, enabled the investigator to regulate the belt speed for each trial. One trial consisted of 20 revolutions of the belt, or 80 gates, at a speed of 17.23 inches per second.

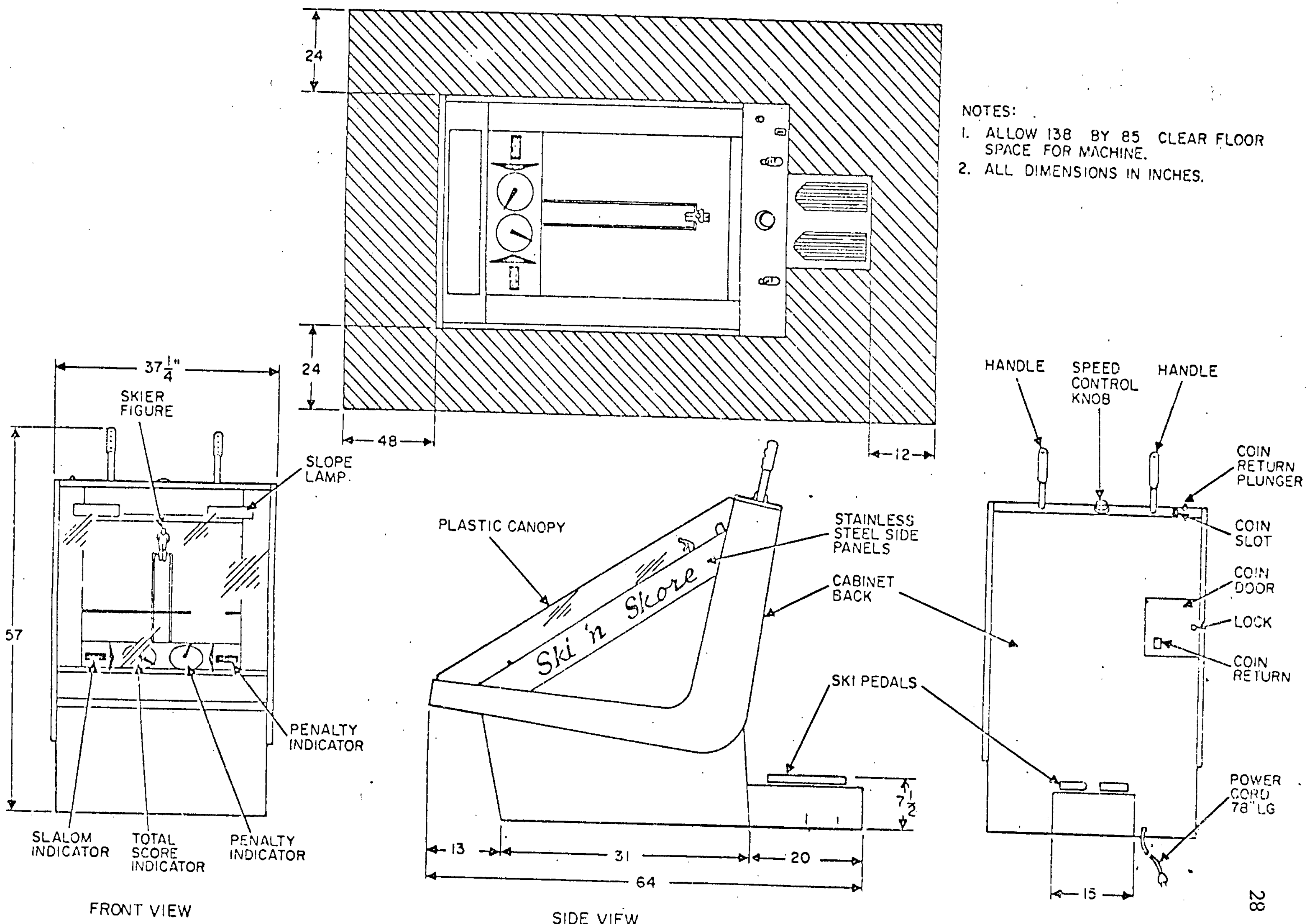

Figure 1 Schematic Drawing of the Ski Simulator

The validity of the instrument had been established in an earlier study by Straub (43). However, since his subjects were college age females, the validity of the instrument for boys and girls, ages 7, 9, and 11 years, was not established. Thus, the validity of the instrument was established on the basis of face or logical validity for this study.

The reliability of the ski simulator was established by an analysis of variance for repeated measures. This method is appropriate for the establishment of reliability over a series of trials during one test administration.

## Methods of Data Collection

As mentioned previously, data were collected on two consecutive days of testing, upon each of which the subjects received 10 consecutive trials on the simulator. A three minute rest period, during which time the subject was seated, was positioned between each of the 10 trials. The belt speed was maintained at 17.23 inches per second for each trial.

Two subjects entered the testing area at the same time. To enable the subjects to complete the task in the appropriate manner, the specific instructions that follow were read by the investigator prior to the initial testing session:

> This machine is called a ski simulator. I am going to use it to see how well you can move the little skier through the openings on the belt as it turns.
>
> One person stands on the pedals and holds the handles. The little figure can be turned from side to side by turning the pedals with your feet. When the machine is turned on the belt will revolve and you should turn the figure so it passes through the openings. They are called gates. After the first eight gates

a green light goes on and then if you make a mistake a red light will flash. After 80 gates the machine will stop.

You will each get one turn to practice and then you will have 10 turns with a rest in between. Your practice turn will be at a slightly slower speed than the 10 test trials. You will not be able to watch each other and you should not tell your scores to the other person. I will not talk to you during the test. You may talk if you wish but I will not answer you until the test is over.

Do you have any questions?

Just before the first three trials each day the following statement was read to each subject:

Remember, the first eight gates will not count, they are just practice. I will not keep score until the green light goes on. Don't worry about mistakes, just do the best you can; try to get through as many gates as possible. Ready?

Each subject received one practice trial at 10.2 inches per second at the beginning of each of the two days of trials. Test trials were given to one subject while the other was seated outside of the testing area. A screen separated the resting subject from the subject being tested. Thus, testing was individualized with only the investigator present.

## Organization of Data

After each trial the investigator recorded the subject's error score on the data cards which had been prepared for each subject. Figure 2. shows the record for one subject during the second day of testing.

Following the completion of testing, data were placed on data sheets and then key punched on data cards. To eliminate key punching errors cards were verified before statistical analyses began.

J. Smith
name

F
sex

1/76
date

9-25-66
birth

9
age

ERROR SCORE

| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Day 1 | | | | | | | | | | | |
| Day 2 | 14 | 10 | 11 | 18 | 19 | 6 | 12 | 6 | 7 | 7 | |

Figure 2. Sample Data Card

## Data Analysis

Mean error scores and standard deviations for each age group (ages 7, 9 and 11 years) by sex were calculated. An ANOVA of a factorial design with repeated measures for two of the four factors was used to determine if there were statistically significant differences in foot-eye coordination across trials, by age and by sex. When significant differences were found, the Newman-Keuls procedure was used to determine between group differences in mean error scores.

# Chapter 4

## RESULTS

It was the purpose of this study to measure the foot-eye coordination of elementary school age children. The investigator sought to determine if boys and girls, ages 7, 9, and 11 years, differed in foot-eye coordination. Foot-eye coordination was measured by a paced contour tracking task. The results of this investigation will be presented in this chapter.

The contents of this chapter will be structured according to the major null hypothesis of this study. First, the investigator will discuss the reliability of the data, i.e., the day-to-day variation in scores. Second, descriptive statistics will be covered, and third, inferential statistics will be presented.

### Descriptive Analysis

Table 1 shows the mean ski simulation error scores and their standard deviations for boys and girls 7, 9, and 11 years of age during Day 1 and Day 2 of testing. These data show that the mean error scores for both boys and girls decrease from Day 1 to Day 2 and that the standard deviations also were smaller, i.e., there was less variation in scores during Day 2.

As expected, the mean error scores for both boys and girls tended to be a function of age, with older subjects recording fewer error scores. The totals column of Table 1 shows that a mean of

Table 1

Means and Standard Deviations of Ski Simulation
Error Scores for Subjects
X Age X Sex X Days

| Age | 7 | | | | 9 | | | | 11 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sex | M | | F | | M | | F | | M | | F | | Totals | |
| | X | SD | X | SD | X | SD | X | SD | X | SD | X | SD | X | SD |
| Day 1 | 32.80 | 12.30 | 32.31 | 11.48 | 21.91 | 11.18 | 23.47 | 8.77 | 10.13 | 5.73 | 11.86 | 6.13 | 22.08 | 12.85 |
| Day 2 | 22.87 | 9.34 | 19.81 | 6.08 | 11.68 | 6.63 | 12.78 | 4.79 | 4.43 | 3.55 | 5.74 | 4.30 | 12.89 | 9.06 |
| Means for Days | 27.83 | | 26.06 | | 16.79 | | 18.12 | | 7.28 | | 8.80 | | | |
| Means for Each Age | | 26.95 | | | | | 17.47 | | | | 8.04 | | | |
| Means for All Males | | | | | | | 17.30 | | | | | | | |
| Means for All Females | | | | | | | 17.66 | | | | | | | |

26.95 errors was made by subjects who were seven years of age, while mean error scores of 17.46 and 8.04 were made by subjects nine and 11 years of age, respectively. However, the hypothesized differences between boys and girls at each age level tended to be slight. Apparently, as far as foot-eye coordination is concerned, boys and girls perform equally well at each age level.

Although the differences in mean error score between boys and girls was not great, the range of scores for boys at each age level was substantially larger than for girls. The range of scores for males at ages 7, 9, and 11 years was 35, 27, and 18 errors, respectively. For girls, the range at 7, 9, and 11 years was 26, 19, and 15 errors, respectively. Girls seem to be less variable in their foot-eye coordination performance than boys of similar age. And, as mentioned previously, with increasing age both males and females show less variability in foot-eye coordination.

## Reliability of Data

As mentioned in Chapter 3, the reliability of data were determined by the ANOVA technique. Day 1 and Day 2 error scores were analyzed together and then separately to determine if a trend effect was present across the 10 trials. Analysis of Day 1 and Day 2 scores showed that there was a substantial learning effect. The mean error score for Day 1 was 21.60 whereas for Day 2 it was only 12.75. All groups of subjects, regardless of age; significantly decreased their mean error scores on Day 2. However, the younger the subject, the more variation was shown in day-to-day error scores.

Since the ANOVA analysis for days reached statistical significance (.05 level), it was decided to drop Day 1 scores from the

Table 2

Factorial Analysis of Variance of Ski Simulation Error Scores on Days 1 and 2 for Boys and Girls 7, 9, and 11 Years of Age

| Sources of Variation | df | SS | MS | F |
|---|---|---|---|---|
| **Between Subjects** | | | | |
| Ages | 2 | 51,642.47 | 25,821.23 | 44.61[a] |
| Sex | 1 | 76.60 | 75.60 | <1 |
| Age x Sex | 2 | 688.39 | 344.19 | <1 |
| Subjects Within Groups | 36 | 20,839.82 | 578.88 | |
| **Within Subjects** | | | | |
| Days | 1 | 16,473.94 | 16,473.93 | 132.00[a] |
| Age x Days | 2 | 1,352.06 | 676.03 | 5.42[b] |
| Sex x Days | 1 | 58.67 | 58.67 | 1 |
| Age x Sex x Days | 2 | 97.62 | 48.81 | 1 |
| Days x Subjects Within Groups | 36 | 4,492.63 | 124.08 | |
| Trials | 9 | 8,534.00 | 948.22 | 48.48[a] |
| Age x Trials | 18 | 802.73 | 44.60 | 2.28[b] |
| Sex x Trials | 9 | 264.45 | 29.38 | 1.50 |
| Age x Sex x Trials | 18 | 392.62 | 21.82 | 1.12 |
| Trial x Subject Within Groups | 324 | 6,336.21 | 19.56 | |
| Day x Trials | 9 | 5,133.57 | 570.40 | 24.71[a] |
| Age x Days x Trials | 18 | 460.98 | 25.61 | 1.11 |
| Sex x Days x Trials | 9 | 315.79 | 35.09 | 1.52 |
| Age x Sex x Days x Trials | 18 | 239.97 | 13.33 | 1 |
| Days x Trials x Sex Within Groups | 324 | 7,478.27 | 23.08 | |
| Total | 839 | 125,625.79 | | |

[a]Significant beyond .001 level
[b]Significant beyond .01 level

final analysis. There simply was too much learning taking place during Day 1 to obtain a true picture of the subjects' foot-eye coordination. Support for this decision was forthcoming from the analysis of Day 2 scores. Analysis of variance of Day 2 scores across the 10 trials did not produce a significant F value. It was concluded that a significant learning effect was not present during Day 2 and that these scores were the base performance level of students.

## Inferential Analysis

Inferential statistical procedures were utilized to determine if differences in descriptive statistics were due to chance or whether significant differences (.05 level) existed among the groups at each age level. Two factorial analyses of variance programs were computed to answer these questions.

Table 2 shows the results of ANOVA when Day 1 and Day 2 scores were pooled for all subjects. The results of the 3x2x2x10 (age x sex x days x trials) ANOVA showed that statistically significant differences existed for the age, days, and trials components. That is, as expected, on the average, older subjects made fewer errors. The significant F value for days indicates that subjects, at all age levels, made fewer errors on Day 2. And, finally, there existed a significant difference in error scores from trial to trial.

Interaction effects (Table 2) were also found for age x days, age x trials, and days x trials. Subjects at different ages made significantly different mean error scores from Day 1 to Day 2. The age x trials interaction indicates that subjects of different ages made significantly different mean error scores from trial one through trial 10. The days x trials interaction effect shows that there was a significant difference in scores across trials during Day 1 and Day 2. No other interaction effects were present.

As indicated above, because of the significant learning effect present on Day 1, only Day 2 scores were used for analysis purposes. Table 3 shows the 3x2x10 (age x sex x trials) ANOVA for Day 2 error scores. As shown, only the main effect for age reached statistical significance at the required .05 level. As expected, subjects decreased their error scores significantly as they became older. Table 3 also shows that there were no differences between boys and girls in their mean error scores at each of the three age levels. The sex component and age x sex interaction failed to reach statistical significance.

The Newman-Keuls procedures were used to locate between groups differences for the significant F value found for the main effect for age. Table 4 shows that significant differences (.05 level) were found only between the mean error scores for seven and 11 year old boys and girls. It was concluded that subjects differed only in foot-eye coordination at seven and 11 years of age. There were no differences in foot-eye coordination between subjects ages 7 to 9, and 9 to 11 years.

On the basis of these analyses the major null hypothesis of this study was rejected. There existed statistically significant differences in foot-eye coordination among elementary school age children at 7, 9 and 11 years of age.

Table 3

Factorial Analysis of Variance of Ski Simulation Error Scores on Day 2 for Boys and Girls 7, 9, and 11 Years of Age

| Sources of Variation | df | SS | MS | F |
|---|---|---|---|---|
| Between Subjects | | | | |
| Age | 2 | 18,684.98 | 9,342.49 | 39.50[a] |
| Sex | 1 | 0.54 | 0.54 | <1 |
| Age x Sex | 2 | 521.25 | 260.62 | 1.10 |
| Between Subjects Within Groups | 36 | 8,514.25 | 236.51 | |
| Within Subjects | | | | |
| Trials | 9 | 330.81 | 36.76 | 1.95 |
| Trials x Age | 18 | 167.42 | 9.30 | <1 |
| Trials x Sex | 9 | 125.25 | 13.92 | <1 |
| Trials x Age x Sex | 18 | 398.33 | 22.13 | 1.17 |
| Trials x Subject Within Groups | 324 | 6,122.13 | 18.90 | |
| Total | 419 | 34,864.96 | | |

[a]Significant beyond .001 Level.

## Summary

It was the purpose of this chapter to present the results of this study. Descriptive and inferential statistical procedures were utilized along with tabular analyses. As expected, the major null hypothesis of no significant difference among elementary school age children in foot-eye coordination at 7, 9, and 11 years was rejected. With increasing age, foot-eye coordination improved significantly. Differences in foot-eye coordination among boys and girls were not found. There existed, however, a trend toward less variability in the foot-eye coordination among girls than boys at each age level.

Because of significant learning effects during the first day of testing, these data were not used in the final analysis. Day 2 scores were by far more reliable. Support for making this decision was provided within the contents of this chapter.

Table 4

Newman-Keuls Comparison Among Ski Simulator
Error Scores for Boys and Girls
7, 9, and 11 Years of Age

| Years | | | 7<br>$\bar{X}_3$ | 9<br>$\bar{X}_2$ | 11<br>$\bar{X}_1$ |
|---|---|---|---|---|---|
| 7 | $\bar{X}_3$ | 8.04 | -- | 9.42 | 18.91* |
| 9 | $\bar{X}_2$ | 17.46 | | ---- | 9.49 |
| 11 | $\bar{X}_1$ | 26.95 | | | ----- |

*$p < .05$

Chapter 5

# DISCUSSION OF RESULTS

In this chapter the investigator will compare the results of the present investigation with those of other researchers who have studied the same or similar phenomena. Since comparative research data regarding foot-eye coordination were not available, this discussion will focus largely on the conceptual literature pertaining to the development of foot-eye coordination among boys and girls 7 to 11 years of age. More specifically, the contents of this chapter will include sections on (1) the development of foot-eye coordination, (2) tracking, (3) vigilance, and (4) implications for elementary school physical education teachers.

## The Development of Foot-eye Coordination

The most obvious finding of this study was that there was a steady improvement in foot-eye coordination with advancing age. These data show that 11 year old boys and girls had superior foot-eye coordination to seven year olds. This finding was not unexpected since Rarick (26), Espenschade and Eckert (8), and Cratty (5,6) all agreed that there is a rapid increase in motor ability as children gain control and use of the large muscles of the trunk and extremities.

Perhaps the most unexpected finding of this study was that there were no significant differences in the foot-eye coordination of boys and girls at 7, 9, and 11 years of age, as measured by the ski simulator. Although comparative foot-eye coordination data were not available, boys are usually thought to be superior to girls in motor ability during middle childhood. For example, boys seven to 11 years of age nearly always exceed girls of the same age in overarm throwing for distance. This difference in throwing performance, which continues to increase as children mature, may be a result of the influence of our culture. Boys are encouraged from an early age to be more active and athletic; girls are taught to be more passive, to be "ladylike." Ammons, Alprin and Ammons (29) investigated the relationship of age and sex to pursuit rotor performance in children in grades 3, 6, 9, 11, and 12. They found a marked overall improvement in proficiency accompanying each age period, with boys showing an increasing superiority over girls. The performance of girls declined from grade 9 to grade 12. Changing cultural values may, however, alter the above findings as participation in sports for girls becomes more socially acceptable.

A possible explanation for the failure of this study to find sex differences in foot-eye coordination is that boys and girls utilize similar leg movements during the early years. They run, jump, gallop, and ride bicycles. Cultural factors seem to be more specific between the sexes regarding the use of the arms. For example, until recently, most girls were not involved in male dominated sports such as baseball, track, and crew. It has been considered ladylike to use a racket to play tennis but not the hand to play handball. Both sexes use the legs in similar tasks during the formative years, however. Since ski simulation requires basically the use of the feet and legs, this may explain why sex differences were not found.

## Tracking

Comparative data were not found in which boys and girls 7, 9, and 11 years of age were used as subjects in tracking studies. As mentioned in Chapter 2, there was a dearth of information on the development of foot-eye coordination among young children. Studies by Straub (43) and Klingman (50), using college age subjects, may not be used for comparative purposes. Both investigations, however, established the ski simulator as a valid device for measuring the skiing performance of male and female skiers of college age.

As mentioned in Chapter 2, ski simulation may be classified as a paced contour tracking task. Subjects were required to move a miniature skier through a series of 80 gates on a motor driven belt that moved 17.23 inches per second. It is possible that this task required considerable anticipation since the miniature skier must be maneuvered into a position which will make it possible for it to be directed through a second oncoming gate while being steered through the immediately approaching gate. If the subject does not anticipate correctly and adjust the skier's position, many errors (missed gates) are made. Perhaps learning to anticipate was the reason why a significant learning effect was found over trials one through 10 during the first day of testing. It is hypothesized that once anticipation was mastered there was significantly better performance. The results of this study support the above statement. During the second day of testing fewer errors were made and there was not a significant learning effect over trials.

In sum, ski simulation is a paced contour tracking task that requires what Fleishman (34) calls control precision or the ability to coordinate the movements of a number of limbs simultaneously. In this study, the subject was required to coordinate his feet so that he could keep the miniature skier on the track.

Anticipation, referred to above, is called rate control by Fleishman (34). He defined the term as the ability to make continuous anticipatory motor adjustments to a constantly moving target. Of Fleishman's 11 psychomotor abilities, control precision, multilimb coordination and rate control were the only components which seemed to be utilized in ski simulation. Perhaps there are other components, yet to be identified, that play an important part in success in ski simulation. However, Fleishman's (34) summary of the underlying dimensions of movement reactions seems to apply to this skill. "The ability to make smooth coordinated movements, at a given rate, in a rhythmical fashion, in a particular sequence, and along a specified track" (34:438) is the essence of the underlying dimension of ski simulation. The complexity of tracking is perhaps the reason why contemporary theorists such as Adams (1), and Schmidt (42) have not included it in their theories of motor learning. In support of this generalization, Schmidt (42) writes that he is hopeful that his schema theory of discrete motor learning may, at a later date, be applied to the learning of tracking skills.

## Vigilance

The results of this study do not confirm or negate any of the theories of vigilance posed in Chapter 2. It is, however, clearly evident that alertness for the detection of critical signals when they occur played an important part in ski simulation performance. Straub (43) reported that at very slow simulation speeds (10.2 inches per second), for example, subjects appeared to become bored with the task and performance decrements occurred. This observation is supported by Adams' (1) contention that the human operator's capacity for detecting critical events decreases over time. Deese (32), a prominent theorist, believes that this decline in vigilance over time is caused by a fall in the arousal or activation. Since physiological data were not obtained from the subjects in this investigation, Deese's premise can not be accepted or rejected. Neither can Mackworth's (48) belief that vigilance decline is caused by a lack of reinforcement be substantiated. However, if manipulation of the miniature skier through the gates served as reinforcement for the subject, it is possible that reinforcements do not occur fast enough at slow simulation speeds. Obviously, motivation of the subject is an important variable that can influence performance.

The results of this study do not provide supporting evidence for an expectancy theory of vigilance. Since subjects did not know when the task would end, the 'end spurt' phenomenon was not present. That is, the subjects' performances did not improve as they neared the end of the task. However, providing subjects with knowledge of results may uncover evidence for the expectancy view posed by Broadbent (3). Confirmation of this belief awaits further research.

In brief, since this investigation was not designed to test theories of vigilance, it is not surprising that support for or against theories were not found. Intuitively, one can say that vigilance is an important variable underlying ski simulation perfromance.

The extent of the contribution of vigilance, however, can not be determined from the results of this investigation.

## Implications for Elementary School Physical Education

Traditionally, in the United States, emphasis has been placed on the development of hand-eye rather than foot-eye coordination skills. In this society children are involved in a game culture that requires such skills as catching, batting, and throwing, all hand-eye coordination tasks. Only recently have lead-up games such as line and circle soccer been used to develop foot-eye coordination. Perhaps this lack of emphasis on the development of foot-eye coordination in our schools is the reason why the United States does not usually excel in international competition in such sports as soccer. More importantly, however, the failure to develop foot-eye coordination skills may be associated with a number of learning disabilities, including a child's perception of his body image. Although definitive data are lacking, there seems to be a relationship between academic performance during the primary years and the child's ability to use his body in the gross motor skills of walking, jumping, running or skipping, all foot-eye coordination tasks.

Data were not available so that the foot-eye performances of the children used as subjects in this study could be compared with subjects of similar ages in other parts of the United States. Therefore, generalizations may not be made about their proficiency or lack of it. All that may be said is that children 7, 9, and 11 years of age improve in foot-eye coordination with advancing age and that sex differences were not found at each of the three age levels.

The results of this study suggest that physical education programs for boys and girls 7, 9, and 11 years of age may be coeducational in nature. This generalization does not imply that children should not be separated by sex for some activities, e.g., football type games. The results, however, do suggest that girls 7, 9, and 11 years of age are as capable as boys of performing foot-eye coordination skills. And, as mentioned above, our culture should perhaps place greater emphasis on the development of motor skills which require coordination of the feet and eyes since many skills, e.g., driving a car, in adult life require these motor components.

## Summary

It was the purpose of this chapter to discuss the findings of this study. Attention was focused on the development of foot-eye coordination, tracking, vigilance, and implications for elementary school physical education programs. Since comparative data were not available, the investigator was unable to draw definitive conclusions about the foot-eye coordination of the children who served as subjects for this study. However, these results clearly show that there was a gradual improvement in foot-eye coordination with advancing age and that sex differences among boys and girls 7, 9, and 11 years of age were not found. Additionally, these data suggest that elementary physical education programs that involve foot-eye coordination skills may be coeducational in nature.

Support was not provided for theoretical positions found in the tracking or vigilance literature. Since this study was not designed to test theories of tracking or vigilance, lack of support should not be viewed as a weakness of this investigation. Confirmation or negation of these theories awaits further research.

Chapter 6

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The contents of this chapter will include an overview or summary of this study, conclusions, and recommendations for further research.

## Summary

It was the purpose of this investigation to determine the foot-eye coordination of children 7, 9, and 11 years of age. Since there was a dearth of information on this topic, the results of the study contributed to the child growth and development literature. No other studies were found in which researchers had measured the foot-eye coordination of young children of elementary school age.

Subjects (N=42) were selected randomly from boys and girls 7, 9, and 11 years of age who were attending the Enfield Elementary School, Ithaca, New York. There were boys and girls assigned to each age group. Foot-eye coordination was assessed by a ski simulator (Ski 'N Skore, Dukane Model 14A635, Games Division of Dukane Corporation, St. Charles, Illinois). Each subject was tested on two consecutive days during which time he received 10 trials on each day. A trial consisted of the manipulation of a miniature skier through 80 gates which revolved on a motor driven belt at a speed of 17.23 inches per second. Each time a subject missed a gate a red light flashed and the error was counted on a hand calculator. The subject's score was the total number of gates missed, after the first eight practice gates, on each of the 10 trials. Subjects were tested individually under controlled conditions by the investigator. Between trials subjects were seated away from the testing area. The format for the second day of testing was the same as Day 1. One practice trial was given at a belt speed of 10.2 inches per second each day. After each trial the subject was informed of his error score (gates missed).

Results were analyzed by means of a 3x2x2x10 (age x sex x days x trials) ANOVA with repeated measures on two of the factors. Day 1 scores were eliminated because of a significant (.05 level) across trials learning effect. Thus, final analyses involved only Day 2 scores. When significant differences were found, the Neuman-Kuels procedures were used to locate between groups differences.

Statistically significant foot-eye coordination differences (.05 level) were found for the factor of ages. Post-hoc comparisons, however, produced significant differences only between the ages of seven and 11 years. Differences in foot-eye coordination were not found between seven and nine year old children nor between nine and 11 year old children. Sex differences in foot-eye coordination were not found between boys and girls at 7, 9, and 11 years of age. The investigator concluded that foot-eye coordination improves with advancing age and that there were no significant differences in foot-eye coordination among boys and girls at 7, 9, and 11 years of age.

## Conclusions

Within the limitations of this study, the following conclusions were made:

1) With advancing age, there was a steady improvement in foot-eye coordination of boys and girls 7, 9, and 11 years of age.

2) At each age level, boys and girls 7, 9, and 11 years of age possessed similar foot-eye coordination.

## Recommendations

The ski simulator used in this study was found to be a useful tool for assessing the foot-eye coordination of young children. Subjects enjoyed performing the task of manipulating a miniature skier through gates (openings) that appeared on a motor driven belt that may be run at various speeds. And, since there is a dearth of information on foot-eye coordination, other investigations should be undertaken. These studies are as follows:

1) The development of foot-eye coordination should be assessed at other age levels, especially at age 13 when important physiological changes take place in females.

2) The ski simulator may be used to determine the effectiveness of various experimental treatments, e.g., perceptual motor programs, designed to improve foot-eye coordination.

3) As a training device, the ski simulator may be used to improve foot-eye coordination.

4) The "end spurt" phenomenon may be investigated by means of the ski simulator. Subjects may be provided with the information that they are nearing the completion of the task to determine if their performances improve.

5) Cross cultural studies should be made of the development of foot-eye coordination among boys and girls at various age levels in

the United States and abroad.

6) The foot-eye coordination of normal children should be compared to those children who are having various learning problems.

APPENDICES

# APPENDIX A

## RAW SKI SIMULATION ERROR SCORES FOR BOYS AGE 7 YEARS

| Boys Age 7 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 44 | 36 | 32 | 30 | 21 | 21 | 13 | 13 | 12 | 10 | 12 | 16 | 17 | 14 | 14 | 11 | 13 | 10 | 12 | 9 |
| 2 | 46 | 44 | 45 | 41 | 38 | 43 | 28 | 27 | 34 | 24 | 20 | 19 | 27 | 27 | 21 | 24 | 28 | 32 | 33 | 30 |
| 3 | 55 | 48 | 40 | 38 | 38 | 24 | 33 | 28 | 41 | 29 | 28 | 24 | 21 | 25 | 31 | 25 | 14 | 17 | 17 | 14 |
| 4 | 59 | 55 | 46 | 43 | 47 | 42 | 47 | 33 | 42 | 41 | 42 | 41 | 30 | 30 | 24 | 27 | 19 | 22 | 20 | 34 |
| 5 | 54 | 46 | 43 | 45 | 36 | 32 | 27 | 24 | 20 | 45 | 28 | 34 | 32 | 41 | 35 | 37 | 37 | 37 | 36 | 29 |
| 6 | 23 | 18 | 17 | 18 | 17 | 22 | 22 | 12 | 19 | 11 | 16 | 13 | 12 | 15 | 13 | 17 | 14 | 7 | 11 | 11 |
| 7 | 53 | 35 | 35 | 33 | 22 | 27 | 26 | 28 | 24 | 31 | 21 | 22 | 30 | 30 | 42 | 22 | 22 | 15 | 19 | 9 |

APPENDIX B

RAW SKI SIMULATION ERROR SCORES
FOR GIRLS AGE 7 YEARS

| Girls Age 7 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 8 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 54 | 45 | 40 | 37 | 34 | 28 | 22 | 32 | 28 | 20 | 13 | 17 | 11 | 11 | 12 | 15 | 18 | 13 | 12 | 18 |
| 2 | 47 | 43 | 30 | 24 | 24 | 20 | 23 | 17 | 16 | 13 | 18 | 17 | 13 | 14 | 9 | 10 | 29 | 25 | 16 | 15 |
| 3 | 25 | 26 | 23 | 22 | 20 | 13 | 15 | 19 | 15 | 18 | 27 | 16 | 18 | 13 | 14 | 22 | 20 | 21 | 20 | 26 |
| 4 | 52 | 34 | 35 | 37 | 30 | 24 | 35 | 30 | 29 | 35 | 28 | 12 | 28 | 27 | 24 | 27 | 23 | 16 | 27 | 20 |
| 5 | 50 | 50 | 44 | 49 | 46 | 42 | 34 | 38 | 41 | 29 | 31 | 23 | 35 | 11 | 19 | 28 | 20 | 26 | 27 | 23 |
| 6 | 57 | 47 | 53 | 33 | 31 | 36 | 34 | 32 | 42 | 21 | 24 | 31 | 31 | 25 | 19 | 20 | 17 | 16 | 14 | 19 |
| 7 | 59 | 42 | 39 | 29 | 26 | 31 | 25 | 22 | 26 | 20 | 21 | 15 | 13 | 19 | 22 | 18 | 15 | 23 | 23 | 24 |

APPENDIX C

RAW SKI SIMULATION ERROR SCORES
FOR BOYS AGE 9 YEARS

| Boys Age 9 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 25 | 12 | 13 | 15 | 13 | 8 | 7 | 9 | 3 | 14 | 5 | 6 | 7 | 2 | 14 | 8 | 3 | 9 | 3 | 0 |
| 2 | 27 | 22 | 13 | 10 | 13 | 12 | 9 | 12 | 15 | 6 | 3 | 2 | 4 | 13 | 2 | 5 | 6 | 0 | 1 | 2 |
| 3 | 8 | 10 | 7 | 9 | 10 | 18 | 10 | 6 | 16 | 23 | 7 | 8 | 13 | 9 | 10 | 10 | 17 | 8 | 12 | 16 |
| 4 | 48 | 47 | 46 | 46 | 48 | 28 | 31 | 18 | 30 | 20 | 25 | 15 | 15 | 12 | 11 | 8 | 3 | 13 | 15 | 6 |
| 5 | 28 | 34 | 36 | 20 | 22 | 26 | 23 | 27 | 19 | 11 | 21 | 21 | 20 | 14 | 27 | 14 | 15 | 16 | 16 | 9 |
| 6 | 33 | 29 | 17 | 18 | 12 | 12 | 6 | 8 | 4 | 11 | 4 | 4 | 2 | 8 | 4 | 2 | 11 | 10 | 5 | 12 |
| 7 | 35 | 36 | 31 | 29 | 31 | 27 | 25 | 23 | 18 | 25 | 17 | 22 | 25 | 17 | 16 | 15 | 25 | 22 | 20 | 16 |

# APPENDIX D

## RAW SKI SIMULATION ERROR SCORES FOR GIRLS AGE 9 YEARS

| Girls Age 9 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 34 | 29 | 31 | 24 | 25 | 25 | 17 | 23 | 22 | 10 | 11 | 13 | 19 | 12 | 17 | 8 | 12 | 9 | 7 | 9 |
| 2 | 30 | 25 | 24 | 19 | 18 | 14 | 17 | 18 | 12 | 22 | 9 | 10 | 14 | 8 | 10 | 13 | 6 | 11 | 15 | 9 |
| 3 | 37 | 28 | 25 | 22 | 21 | 15 | 17 | 15 | 20 | 7 | 6 | 10 | 10 | 8 | 12 | 9 | 11 | 12 | 7 | 15 |
| 4 | 42 | 37 | 32 | 22 | 17 | 9 | 22 | 14 | 18 | 17 | 14 | 10 | 11 | 18 | 19 | 6 | 12 | 6 | 7 | 7 |
| 5 | 38 | 33 | 37 | 26 | 26 | 20 | 18 | 18 | 21 | 13 | 18 | 15 | 17 | 13 | 7 | 13 | 13 | 13 | 16 | 7 |
| 6 | 41 | 44 | 33 | 38 | 31 | 18 | 21 | 19 | 14 | 11 | 9 | 19 | 19 | 11 | 7 | 8 | 16 | 11 | 16 | 16 |
| 7 | 39 | 33 | 36 | 26 | 26 | 14 | 21 | 19 | 16 | 17 | 23 | 18 | 25 | 20 | 24 | 15 | 16 | 17 | 18 | 23 |

## APPENDIX E

### RAW SKI SIMULATION ERROR SCORES FOR BOYS AGE 11 YEARS

| Boys Age 11 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 19 | 18 | 16 | 14 | 15 | 7 | 7 | 5 | 9 | 6 | 3 | 11 | 2 | 3 | 5 | 4 | 4 | 1 | 1 | 2 |
| 2 | 23 | 10 | 17 | 19 | 6 | 10 | 10 | 13 | 9 | 10 | 7 | 5 | 6 | 3 | 5 | 2 | 1 | 5 | 2 | 4 |
| 3 | 15 | 11 | 8 | 9 | 3 | 3 | 2 | 4 | 1 | 9 | 2 | 1 | 0 | 3 | 4 | 0 | 4 | 3 | 3 | 0 |
| 4 | 28 | 22 | 18 | 15 | 20 | 20 | 11 | 13 | 11 | 9 | 8 | 7 | 8 | 10 | 10 | 12 | 9 | 6 | 10 | 18 |
| 5 | 12 | 13 | 9 | 7 | 5 | 9 | 5 | 4 | 7 | 10 | 5 | 8 | 10 | 3 | 3 | 1 | 5 | 3 | 4 | 2 |
| 6 | 19 | 15 | 11 | 6 | 11 | 5 | 8 | 6 | 6 | 9 | 1 | 2 | 7 | 3 | 5 | 5 | 4 | 6 | 6 | 2 |
| 7 | 11 | 4 | 7 | 5 | 9 | 8 | 5 | 5 | 2 | 1 | 4 | 14 | 4 | 0 | 2 | 1 | 3 | 1 | 2 | 0 |

APPENDIX F

RAW SKI SIMULATION ERROR SCORES
FOR GIRLS AGE 11 YEARS

| Girls Age 11 Years | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Day 1 | | | | | | | | | | Day 2 | | | | | | | | | |
| Trials: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Subject | | | | | | | | | | | | | | | | | | | | |
| 1 | 26 | 21 | 13 | 10 | 9 | 5 | 8 | 5 | 13 | 3 | 1 | 4 | 7 | 2 | 3 | 2 | 14 | 4 | 3 | 0 |
| 2 | 18 | 10 | 9 | 11 | 13 | 7 | 10 | 6 | 11 | 1 | 8 | 4 | 7 | 13 | 3 | 0 | 7 | 0 | 4 | 2 |
| 3 | 17 | 23 | 10 | 19 | 10 | 14 | 8 | 12 | 13 | 12 | 10 | 14 | 11 | 13 | 12 | 8 | 9 | 12 | 10 | 5 |
| 4 | 9 | 9 | 11 | 9 | 4 | 10 | 4 | 4 | 4 | 3 | 0 | 1 | 1 | 1 | 0 | 2 | 2 | 4 | 0 | 0 |
| 5 | 33 | 21 | 23 | 23 | 19 | 14 | 13 | 12 | 17 | 11 | 15 | 12 | 11 | 8 | 10 | 11 | 7 | 8 | 4 | 7 |
| 6 | 24 | 15 | 10 | 14 | 7 | 17 | 18 | 11 | 4 | 9 | 7 | 2 | 3 | 11 | 7 | 13 | 9 | 3 | 4 | 6 |
| 7 | 11 | 12 | 13 | 10 | 9 | 7 | 10 | 11 | 14 | 4 | 2 | 9 | 3 | 2 | 3 | 5 | 9 | 4 | 1 | 3 |

# BIBLIOGRAPHY

## BIBLIOGRAPHY

### Single Volume Works


1. Adams, J. A. "Some Mechanisms of Motor Responding: An Examination of Attention." In E. A. Bilodeau, ed., Acquisition of Skill. New York: Academic Press, 1966.

2. Bilodeau, E. A., ed., Principles of Skill Acquisition. New York: Academic Press, 1969.

3. Broadbent, D. E. Decision and Stress. New York: Academic Press, 1971.

4. ________. Perception and Communication. London: Pergamon Press, 1958.

5. Cratty, B. J. Movement Behavior and Motor Learning. Philadelphia: Lea and Febiger, 1964.

6. ________. Perceptual and Motor Development in Infants and Children. New York: Macmillan Co., 1970.

7. Deutsch, J. A., and D. Deutsch. Physiological Psychology. Homewood, Ill.: Dorsey Press, 1973.

8. Espenschade, A. S., and H. M. Eckert. Motor Development. Columbus: Charles E. Merrill Books, Inc., 1967.

9. Fleishman, E. A. "Structure and Measurement of Psychomotor Abilities," In R. N. Singer, ed., The Psychomotor Domain: Movement Behavior. Philadelphia: Lea and Febiger, 1972.

10. ________. The Structure and Measurement of Physical Fitness. Englewood Cliffs: Prentice Hall, Inc., 1964.

11. Garn, S. M. "Body Size and Its Implications." In L. W. Hoffman and M. L. Hoffman, eds., Review of Child Development Research, Vol. 2. New York: Russell Sage Foundation, 1966.

12. Getman, G. N. "Concerns of the Optometrist for Motor Development." In Foundations and Practices in Perceptual Motor Learning: A Quest for Understanding. Washington D. C., AAHPER, 1971.

13. Goodenough, F. L. Developmental Psychology: An Introduction to the Study of Human Behavior. New York: Appleton-Century and Co., 1945.

14. Harlow, H. F. "The Development of Affectional Patterns in Infant Monkeys." In B. M. Foss, ed., Determinants of Infant Behavior. London: Methuen, 1961.

15. Lindsley, D. B. "Emotion." In S. S. Stevens, ed., Handbook of of Experimental Psychology. New York: John Wiley and Sons, 1951.

16. Malina, R. N., and G. L. Rarick. "Growth, Physique, and Motor Performance." In G. L. Rarick, ed., Physical Activity: Human Growth and Development. New York: Academic Press, 1973.

17. Oxendine, J. B. Psychology of Motor Learning. New York: Appleton-Century-Crofts, 1968.

18. Pew, R. W. "Human Perceptual-Motor Performance." In B. H. Dankowitz, ed., Human Information Processing: Tutorial in Performance and Cognition. Hillsdale: Lawrence Erlbaum Assoc., Publishers, 1974.

19. Piaget, J. The Psychology of Intelligence. London: Routledge and Kegan Paul, 1950.

20. Poulton, E. C. "The Tracking Behavior." In E. A. Bilodeau, ed., Acquisition of Skill. New York: Academic Press, 1966.

21. Robb, M. D. The Dynamics of Motor Skill Acquisition. Englewood Cliffs: Prentice Hall, Inc., 1968.

22. Singer, R. N. Motor Learning and Human Performance. New York: Macmillan Co., 1968.

23. Stallings, L. M. Motor Skills: Development and Learning. Dubuque: William C. Brown Co., 1973.

24. Welford, A. T. Fundamentals of Skill. London: Methuen and Co., Ltd., 1968.

25. Wickstrom, R. L. Fundamental Motor Patterns. Philadelphia: Lea and Febiger, 1970.

Monographs

26. Rarick, G. L. Motor Development During Infancy and Childhood. Madison: College Printing and Typing Co., Inc., 1961.

27. Shirley, M. M. The First Two Years: A Study of Twenty-Five Babies. Vol. 1. Postural and Locomotor Development. Minneapolis: University of Minnesota Press, 1931.

Periodicals

28. Adams, J. A. "A Closed-Loop Theory of Motor Learning," Journal of Motor Behavior, 3:111-150, 1955.

29. Ammons, R. B., S. I. Alprin, and C. H. Ammons, "Rotary Pursuit Performance as Related to Sex and Age of Pre-Adult Subjects." Journal of Experimental Psychology, 49:127-133, 1955.

30. Bergum, B. O., and D. J. Lehr. "End-Spurt in Vigilance," Journal of Experimental Psychology, 66:383-385, 1963.

31. Crossman, E. R. G. W. "The Information-Capacity of the Human Motor System in Pursuit Tracking," Quarterly Journal of Experimental Psychology, 12:1-16, 1960.

32. Deese, J. "Some Problems in the Theory of Vigilance," Psychological Review, 62:359-368, 1955.

33. Duffy, E. "The Psychological Significance of the Concept of 'Arousal' or 'Activation'," Psychological Review, 64:265-275, 1957.

34. Fleishman, E. A. "Dimensional Analysis of Movement Reactions," Journal of Experimental Psychology, 55:438-453, 1958.

35. Hebb, D. O. "Drives and the C. N. S. (Conceptual Nervous System)," Psychological Review, 62:243-254, 1955.

36. Helmstadter, G. C., and D. S. Ellis, "Rate of Manipulative Learning as a Function of Goal-Setting Techniques," Journal of Experimental Psychology, 43:125-129, 1952.

37. Kapphauf, W. E., and W. E. Powe, "Performance Decrement at an Audio-Visual Checking Task," Journal of Experimental Psychology, 57:49-56, 1959.

38. Malmo, R. B. "Activation: A Neuropsychological Dimension," Psychological Review, 66:376-386, 1959.

39. Norval, M. A. "Relationship of Weight and Length of Infants at Birth to the Age at Which They Begin to Walk Alone," Journal of Pediatrics, 30:676-678, 1947.

40. Pew, R. W., and G. L. Rupp. "Two Quantitative Measures of Skill Development," Journal of Experimental Psychology, 90:1-7, 1971.

41. Poulton, E. C. "Eye Hand Span in Simple Serial Tasks," Journal of Experimental Psychology, 47:403-410, 1954.

42. Schmidt, R. A. "A Schema Theory of Motor Learning," Psychological Review, 82:225-260, 1975.

43. Straub, W. F. "Validation of a Ski Simulator," Research Quarterly, 46:92-99, 1975.

44. Whitley, J. D. "A New Motor Learning Task: The Foot Twist Tracking Test," Research Quarterly, 40:823-831, 1969.

45. Zubek, J. P. "Effects of Prolonged Sensory and Perceptual Deprivation," British Medical Bulletin, 20:38-42, 1964.

## Published Reports

46. Ammons, R. B., and C. H. Ammons, "Decremental and Related Processes in Skilled Performance." In L. E. Smith, ed., Psychology of Motor Learning. Chicago: Athletic Institute, 1970.

47. Gedda, L. M., M. Milani-Comparetti, and G. Brenci. "A Preliminary Report on Research Made During the Games of the XVIIth Olympiad, Rome, 1960." In E. Jokl, and E. Simon, eds., International Research in Sports and Physical Education. Springfield: Charles C. Thomas, Publishers, 1964.

48. Mackworth, N. H. "Researches on the Measurement of Human Performance," Medical Research Council Special Report Series No. 268. London: Her Majesty's Stationary Office, 1950.

## Unpublished Works

49. Johnson, G. C. "Human Operator Performance in Preview Tracking." Doctoral dissertation, University of California, Berkeley, 1972.

50. Klingman, S. L. "The Effectiveness of the Ski Simulator in Measuring the Foot Eye Coordination of College Skiers and College Non-Skiers," Master's project, Ithaca College, 1975.

51. Smith, D. B. "The Reliability of a Hand Eye, Foot Eye Coordination Test." Master's thesis, Washington State University, 1966.