ABSTRACT

THE RELATIONSHIP OF SELECTED MEASURES OF
PROPRIOCEPTION TO PHYSICAL GROWTH,
MOTOR PERFORMANCE, AND ACADEMIC
ACHIEVEMENT IN YOUNG CHILDREN

By

John L. Haubenstricker

The purpose of this study was to investigate: (a) the relationship of proprioception to physical growth, motor performance, and academic achievement; (b) the ability of measures of proprioception to predict measures of physical growth, motor performance, and academic achievement; and (c) the influence of sex, grade level, and instruction in physical activities upon proprioception in young children.

Measures on the One Foot Balance, Parallel Blocks, Thickness Discrimination and Weight Discrimination tests were obtained from 321 boys and girls attending the kindergarten (N=111), first (N=119) and second (N=91) grades at two elementary schools in the Waverly Public School District near Lansing, Michigan. Pretest and posttest data were secured from the children for the four proprioception tests and for the following measures: (a) Physical growth--standing height, weight, ponderal index; (b) Motor

performance--body part identification, ball bounce and catch, directionality, dynamic balance, rail balance, reaction time, standing long jump, stationary dribble; (c) Otis-Lennon Mental Ability test; and (d) Stanford Early School Achievement or Stanford Achievement tests.

The two schools were randomly assigned to experimental and control conditions, respectively. The experimental school received a planned physical education program while the children of the control school had supervised free play in lieu of an organized activity program.

Comparisons for pretest performance on the proprioception tests were made by school, grade level, and sex. The significance of the differences in performance was determined by multivariate analysis of variance procedures. Sample correlation matrices were computed on all the variables at each grade level. A multivariate multiple regression analysis was employed to estimate the relationships between each of the dependent variables and the set of four proprioception tests; and regression equations were established for the criterion dependent variables. Multivariate analysis of covariance was used to determine the influence of a planned physical education program on the proprioception of the children.

The results of the study suggested that performance on each of the tests of proprioception tends to be consistent within each grade level, but that there is great variability in individual performance on each of the tests. Significant intergrade differences were found in performance on the One Foot Balance, Weight Discrimination, and Thickness Discrimination tests; but not on the Parallel Blocks test. No significant differences were found between the two schools or between boys and girls at the three grade levels.

Intercorrelations between the proprioception test scores and the measures of physical growth, motor performance, and academic achievement reached significance most frequently with the Thickness Discrimination and One Foot Balance tests; however, none of the coefficients exceeded .46. Significant intercorrelations between the tests of proprioception and academic achievement measures were most frequent at the kindergarten level and decreased with each succeeding grade. Tests of proprioception were significantly interrelated only at the kindergarten level.

The tests of proprioception were most influential in predicting physical growth, motor performance, and academic achievement variables at the first grade level. The multiple R's obtained were generally of a low, positive nature, with the highest coefficient having a magnitude of .52.

The instructional program in physical education had a significant effect on the proprioceptive sensitivity of the kindergarten children. This effect was most pronounced in static balance performance. The posttest data revealed a significant sex effect at the first grade level; however, this difference could not be attributed to the physical education program introduced in the study.

The results of this study suggest the need for the development of a large battery of tests to assess proprioception in young children, and to improve the prediction of performance on motor skill and academic achievement measures from such tests. The need for study of the developmental nature of proprioception in preschool children was also indicated.

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By

John L. Haubenstricker

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To Beth

David

Amy

and

John, Jr.

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CHAPTER I

INTRODUCTION

Man survives in his environment by responding to the myriad of stimuli which impinge upon the many sensory systems he possesses. His reliance on the use of vision, hearing, touch, taste, and smell to maintain his existence is well known; however, his basic dependence on the sense of proprioception or kinesthesis for survival is less well understood.

Proprioception

There are some persons who consider proprioception or "muscle sense," as it is sometimes called, to be the most important of the senses man possesses (Jenkins, 1951; Steinhaus, 1966). Without the information supplied by the proprioceptive system, it would be impossible for an individual to stand, walk, talk, eat, breathe or to exhibit any kind of coordinated movement. Through proprioception the central nervous system (CNS) is provided with sensory information concerning the movement and position of the body and its various parts in space.

The importance of proprioception in voluntary movement and in some reflex activity has been recognized by physiologists for many years. The traditional role ascribed to proprioception has been that of a regulatory or feedback function in response to gravitational effects on posture and in response to volitional movement. Legge (1970) describes three ways in which the CNS uses proprioceptive information to regulate behavior:

> First, proprioception provides details of the activity of the effectors needed by the response control system in executing movements. Secondly, proprioception provides the information necessary for the controlled execution of an ordered series of responses....Thirdly, proprioception may form the basis for the organization of skilled movements when integrated with other sensory information. (p. 149)

Recent evidence suggests that proprioceptive feedback may serve a second role as a "time perception mechanism in the accurate timing of motor responses" (Adams & Creamer, 1962).

In its role as a feedback mechanism the proprioceptive system responds to numerous stimuli generated by the movement process. These include muscle tension, muscle length, rate of muscle contraction, joint angle, joint movement, head position, and surface contacts (Gardner, 1969; Granit, 1970). The receptors which convert these stimuli into nerve impulses are: (a) the muscle spindles, Golgi tendon organs, Ruffini endings, and Pacinian corpuscles found in muscle, tendon, and joint structures; (b) the semicircular canals and utricles contained in the labyrinth of the middle ear; and, (c) cutaneous receptors sensitive to touch and pressure.

The muscle spindles are located in the body of the muscle and generally lie parallel to the extrafusal muscle fibers. The spindles are stimulated by stretching of the extrafusal fibers or by contraction of the intrafusal fibers located within the spindle structure. These complex receptors have a dual sensory-motor innervation which can function as a servo-mechanism. The spindles signal changes in muscle length as well as the velocity of that change. There is conflicting opinion concerning their ability to signal the actual length of the muscle.

The Golgi tendon organ, as its name implies, is most populous in the tendons of muscles and lies in series with the muscle fibers. The Golgi tendon organ is thus stimulated both when the muscle actively contracts and when it is passively stretched. It reports tension levels to the CNS and is involved with the discrimination of weight or resistance.

The Ruffini endings are embedded in the joint capsule. They are slowly adapting receptors which primarily serve as absolute detectors of joint angle. The rate of discharge they exhibit is determined by the position of the joint. The Pacinian (paciniform) corpuscles are also located in the tissues surrounding joints as well as in the fascia of muscle. They are fast-adapting receptors and are sensitive to pressure. In addition, they appear to respond only during movement. The information provided by these joint receptors is believed to be the major factor in kinesthetic awareness (Gardner, 1969).

The vestibular proprioceptors include the semicircular canals and the otolith organs of the utricles. The former are particularly sensitive to rotational movements and are concerned with the maintenance of balance during movement. The latter respond to gravitational influences and to linear acceleration. Their function is reflected in postural reflexes and muscle tone.

Some cutaneous receptors also may serve as proprioceptors. Receptors sensitive to touch and pressure can provide the CNS with information about the shape, size, texture, and hardness of objects and surfaces. They contribute to the body righting reflexes.

After entering the spinal cord, nerve impulses transmitted along proprioceptive fibers reach the brain by one of several pathways. Some impulses are carried to the cerebellum along fibers in the anterior and posterior spinocerebellar tracts which lie in the lateral funiculi of the spinal cord. A smaller cuneocerebellar tract present in the upper segments of the cervical cord also transmits proprioceptive impulses to the cerebellum. These impulses enable the cerebellum to regulate tonus and synergize the movements of voluntary muscles (Truex & Carpenter, 1964).

Other proprioceptive impulses pass along nerve fibers located in the posterior funiculi to several nuclei located in the lower medulla. Neurons arising from these nuclei cross over to the other side of the brain stem (decussate) and ascend to the thalamus. Fibers from the thalamus project to the postcentral gyrus (somesthetic area) of the cerebral cortex. This pathway carries information related to discriminative touch, deep pressure and kinesthesis (Bell, 1970).

Proprioceptive impulses conducted by cranial nerves travel to respective brainstem nuclei. From these they are relayed to the cerebellum. Nerve impulses from the vestibular receptors are transmitted via the eighth cranial nerve to the vestibular nuclei in the brain stem, and possibly to the cerebellum (Gatz, 1970).

Information received by the higher neural centers can provide the basis for initiating movements or for modulating movement which is already underway. In some cases, proprioceptive impulses do not result in conscious awareness of movement, but initiate reflex activity for postural adjustments to gravity or to movement.

The role of proprioception in motor skill learning, and the use of proprioceptive reflexes to facilitate the acquisition of motor skills have received increased attention in recent years. However, the nature of this role and the value of proprioceptive reflexes in motor skill learning have not been clearly established.

Need for the Study

Little is known about the developmental aspects of proprioception and the changes which may occur as the result of experience. There is also limited evidence concerning the relationship of proprioception to various measures of physical maturation, motor performance, mental ability, and academic achievement, particularly in young children. In addition, virtually nothing is known about the extent to which individuals differ from each other in proprioceptive sensitivity.

Purpose of Study

It was the purpose of this study to investigate the proprioceptive sensitivity of children in kindergarten, first grade, and second grade. More specifically, the investigation sought answers to the following questions:

Question I. What is the proprioceptive sensitivity of young children to weight, positioning, length and static balance as measured by selected tests of kinesthesis?

Question II. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?

Question III. Are measures of proprioceptive sensitivity related to measures of physical maturation, gross motor performance, mental ability and academic achievement?

Question IV. To what extent can selected measures of physical maturation, gross motor performance, mental ability, and academic achievement be predicted by performance on tests of proprioception?

Question V. Is proprioceptive sensitivity in young children influenced significantly by exposure to a planned program of physical education?

Scope of the Study

The purpose of this investigation was to determine the nature of proprioceptive sensitivity in young children; and, its relationship to, and prediction of, selected measures of physical maturation, motor performance and intellectual achievement. The effects of sex, grade level, and planned instruction in physical activities were also examined. Children in kindergarten, first grade, and second grade attending two matched schools in the Waverly public school district, Lansing, Michigan were included in the study. The sample included 52 boys and 59 girls in kindergarten, 64 boys and 55 girls in the first grade, and 41 boys and 50 girls in the second grade (N = 321).

Limitations of the Study

The results of this investigation are subject to the following limitations:

a) The sample selected for this study was not a random sample, but consisted of subjects attending two schools which were matched on the basis of selected criteria. Generalizations may therefore be limited by characteristics peculiar to the subjects and the schools.

b) Although specific instructions were provided along with training sessions for the administration of each of the tests, idiosyncrasies among members of the testing team possibly may have been a limiting factor in the results obtained.

c) Environmental influences such as seasonal and daily variations in temperature and humidity; time of day; test order; and, the presence of other individuals while testing occurred, may have influenced individual performance differentially.

Definitions

Proprioceptive System.--Consists of the kinesthetic receptors and the vestibular receptors. Kinesthetic receptors (also called proprioceptors) are located in the muscles, tendons, joints, and ligaments of the body. Vestibular receptors are located in the bony labyrinth of the inner ear.

Proprioceptor.--A biological transducer located in a muscle, tendon, ligament, joint or in the labyrinth which converts various stimuli into afferent nerve impulses concerning body posture and movement.

Proprioception.--The sensory information provided by proprioceptors to the CNS concerning the movement and relative position of the body and its parts in space, and about the tension developed in voluntary musculature. This awareness to the position of the limbs and their movements is also referred to as the Kinesthetic sense.

CHAPTER II

REVIEW OF LITERATURE

The topic of proprioception has received abundant coverage in journals representing the sciences of biology and psychology, although few of these reports are specifically directed to the study of this phenomenon in children. This review therefore will be limited to studies which relate directly to the problem under investigation; namely, to studies dealing with the nature of proprioception and its underlying components, to those concerned with techniques for assessing this phenomenon, and to those studies investigating the relationship of proprioception to gross motor performance. Since research pertaining to the physiological parameters of proprioception has been given extensive consideration in the recent publications of Harrison (1961), Eldrid (1965), Shambes (1968), Goldberg & Levine (1968), Granit (1970) and Rodieck (1971), no attempt will be made to review it here.

The Nature of Proprioception

The term "proprioception" conventionally has been used in the psychological literature when reference was being made to the anatomical and neurological aspects of the proprioceptive system. The term "kinesthesis" customarily has been used to denote the sensory functions of the system. Although some investigators may consider "proprioception" to be broader in meaning than "kinesthesis," the two terms will be used interchangeably in this chapter.

Components of Proprioception

The nature of proprioception or kinesthesis is usually described by listing the sensory components of which it is comprised. For example, Wiebe (1954) listed them as "perception of movement, tension or resistance, position, space perception, balance, relaxation, and effort." Scott (1955) considered kinesthetic perception to include:

> ability to repeat muscle contractions with a force identical to that which one has just exerted; ability to put arms, legs and trunk in positions prescribed by visual or oral cues; balance and weight control; manipulative precision with the hand; orientation in space; and the ability to imitate promptly a single coordination which has been demonstrated. (p. 326)

A review of several analytical studies concerning kinesthesis and related topics may provide some clues as to why so many components have been ascribed to proprioception.

Analytical Studies

Initial evidence suggested that kinesthetic sensitivity was a general factor. Factorial studies of balance (Bass, 1939) and of motor educability (McCloy, 1940) led to the identification of a factor which was called "general kinesthetic sensitivity and control." In the former study, a loading of this factor was found on nearly all the balance tests under investigation. In the latter study, McCloy also subscribed to the concept of a general kinesthetic factor; but, in addition, hypothesized a second factor, "Sensory Motor Coordination II," to represent sensitivity to weight and force.

On the other hand, there is ample evidence which refutes the concept of kinesthesis as a general factor, and which supports the principle of specificity for kinesthetic sensitivity (Phillips, 1941; Young, 1945; Stevens, 1950; Roloff, 1953; Witte, 1953; Wiebe, 1954; Scott, 1955; Hempel & Fleishman, 1955; Fleishman, 1958). If kinesthesis is a general factor, tests claiming to measure this phenomenon should be highly related. This has not been the case, however, as the test items included in studies of kinesthesis, for the most part, have demonstrated only low, positive intercorrelations. In addition, the specificity of "kinesthetic sensitivity" is demonstrated by the low validity coefficients obtained between individual tests and criterion measures of kinesthesis. In the studies cited above, validity coefficients seldom exceeded the .60 level when individual tests were correlated with the criterion measure.

The fact that kinesthetic sensitivity is comprised of many specific components, which are unrelated to each other, does not preclude the assessment of specific components by more than one test. There is evidence which demonstrates that test items requiring similar tasks tend to be highly related to each other. Examples of such tasks are: arm circling and arm swinging (Roloff, 1953); stylus tracing with the right and left hands (Phillips, 1941); and, leg positioning in the same body plane (Stevens, 1953). In addition, factorial studies of kinesthesis generate factors which contain tests requiring similar tasks (Witte, 1953; Wiebe, 1956). In this manner, several tests may be identified which can be used effectively to measure the same component.

The components which comprise kinesthetic sensitivity are many. Witte (1953) identified seven factors of kinesthesis on the basis of 36 test items. These included: Force of Muscular Contraction of the Arm; Leg Positioning; Arm Positioning for Short Arm Movements on the Vertical Plane; Arm Positioning for Long Arm Movements on the Vertical Plane; Extent and Force of Muscular Contraction of the Arm on the Horizontal Plane; Arm Positioning on the Horizontal Plane; and, Force of Muscular Contraction of the Leg. Of the eight factors identified by Wiebe (1956) from 42 test items, four were considered to describe the "domain of Kinesthesis." These were: Arm Static Function; Arm Dynamic Function; Balance; and, Thigh-Leg Static Function. An additional factor was identified as having an

"Eye-Semicircular Canal" function. It is important to remember that the results of factorial studies are entirely dependent on the information included for analysis. For example, Witte (1953) failed to include balance items in her analysis and therefore did not identify a balance factor, even though balance consistently has been considered a component of kinesthesis (Bass, 1939; Scott, 1955).

A solution to the problem of assessing kinesthesis appears to be through the use of test batteries. Several investigators found that the measurement of kinesthesis was significantly improved when several test items were combined into a battery (Phillips, 1941; Young, 1945; Stevens, 1950; Roloff, 1953; Wiebe, 1954; Robinson, 1968). A listing of test batteries developed by these investigators, along with their respective test items and statistical characteristics, is presented in Table 2.1. It should be noted that all of the batteries contain at least two items which do not measure the same component of kinesthesis, with limb positioning and balance items appearing most frequently. Furthermore, the majority of items demonstrate good reliability, thus assuring consistency in measurement. It also can be observed that the validity of a given test battery always exceeds the validity of any of the individual test items which comprise it.

The developmental aspects of proprioception have received little attention. The results of some investigations indicate that factors underlying proprioceptive sensitivity may be subject to growth and developmental changes, particularly during the childhood years (Miles, 1922; Ortmann, 1923; Abel, 1936; Espenschade, 1947; Cumbee et al., 1957). For example, some evidence suggests that the various sense modalities are more interrelated in children than in adults (Abel, 1936). Evidence from other studies demonstrates changes occurring in the nature of the factors underlying motor coordination in girls and adult women (Cumbee, 1954; Cumbee et al., 1957). Whether such changes are due to maturational influences or to experiential factors; and, whether developmental changes take place in kinesthetic sensitivity has not been determined.

The cumulated evidence cited would appear to warrant the following conclusions:

a) Kinesthesis does not exist as a general factor, but as a combination of many specific elements.

b) The reliability of test items used to assess specific components has been demonstrated.

c) No single test can provide an effective measure of kinesthetic sensitivity.

d) Test batteries of varied items have increased the effectiveness of measuring kinesthesis.

e) Balance is the component most consistently identified as a factor of kinesthesis.

The evidence therefore indicates that the sensory components of proprioception or kinesthesis are many. They

Table 2.1

Kinesthetic test batteries proposed by various investigators

Year	Investigator	Subjects	Number	Test Battery	Item Reliability	Item Validity	Battery Validity
1941	Phillips	college men	63	arc swing	---[a]	.15[b] .11	.505
				pathway-right hand	---	-.38 .17	(putting)
				pathway-left hand	---	-.19 .10	.422
				putter target	---	.33 .27	(driving)
1945	Young	college women	37	arm side 90°	---	.87	.894
				leg raise 20°	---	.56	
				balance stick-lengthwise	.78[c]	.41	
1950	Stevens	college women	140	side arm 90° (R)	---	.64	.932
				side arm 90° (L)	---	.54	
				arm pull 15 lb. (R)	---	.64	
				arm pull 15 lb. (L)	---	.55	
				arm lift 130° (R)	---	.57	
				leg force 20 lb. (L)	---	.52	
1950	Stevens	college women	140	side arm 90° (R)	---	.64	.892
				arm pull 15 lb. (R)	---	.64	
				arm pull 15 lb. (L)	---	.55	
				arm lift 130° (R)	---	.57	
1953	Roloff	college women	200	balance stick-lengthwise	.86[c]	.55	.88
				arms side 90°	.80	.50	
				weight shifting	(.68)	.43	
				arm circling	(.64)	.56	

Table 2.1 (continued)

Year	Investigator	Subjects	Number	Test Battery	Item Reliability	Item Validity	Battery Validity
1954	Wiebe	college men	30	balance stick-lengthwise	.93	.36	.69
				leg raise 20°	.88	-.43	
				vertical space	.81	-.30	
				separate feet	.90	-.42	
1955	Scott	college women	70	arm circling	(.64)	.44	.66
				push	.54	.25	
				ball balance	.88	.25	
				body sway	.72	.43	
1955	Scott	college women	100	arm swinging	(.78)	.44	.60
				balance leap	.68	.46	
				horizontal lines	.52	.19	
				body sway	.63	.16	
1968	Robinson	5th & 6th grade boys		one-foot balance	.96		
				parallel blocks	.87	No validity coefficients were reported.	
				thickness discrimination	.76		
				weight discrimination	.85		

[a]Reliability coefficients in this study ranged from .59 to .84.

[b]Validity coefficients are for putting and driving scores, respectively.

[c]Unless otherwise noted, blanks mean that no reliability measures were obtained or reported; values represent either Spearman-Brown corrected values or test-retest reliability coefficients; and, values in parentheses are coefficients available from previous studies.

are arbitrarily classified into the following broad categories, recognizing that specificity exists within each:

a) Sensitivity to force or tension,

b) Sensitivity to position and movement,

c) Sensitivity to size and length, and

d) Sensitivity to balance and spatial orientation.

Research pertinent to each of these broad categories will be examined. Consideration will be given: to the tests and techniques used to assess kinesthetic sensitivity in each area; to factors which affect each of the components of kinesthesis; and, to the application of these techniques to research in physical education.

Sensitivity to Force or Tension

Sensitivity to force or tension has been determined through a variety of methods. These have included the lifting of weighted objects; the reproduction of force on a dynamometer or on special apparatus; and, the replication of torque.

Lifted Weights

Kinesthetic sensitivity to tension (resistance) is subject to Weber's Law. This law is based on experiments conducted by É. H. Weber in the 1830's to determine the "differential threshold" for perceiving weight; in other words, to determine how large the difference between two weights must be before this difference can be detected or noticed. Weber concluded that the size of this "just noticeable difference" in weight was a constant fraction of the magnitude of the weight stimulus itself (Holway & Hurvich, 1937). This conclusion became known as Weber's Law when it was demonstrated that the principle applied to most other sense modalities, although the constant fraction differed for each. The "differential threshold" or constant fraction for discriminating weights was found to be one-thirtieth of the standard stimulus (Woodworth, 1938). According to Weber's Law, one should be able to detect a difference between objects weighing 60 gm. and 62 gm., but not between objects weighing 60 gm. and 61 gm.

However, Weber's Law did not go unchallenged. Thorndike (1909) questioned the law and demonstrated his concern when the judgment errors of his subjects for 200 gm. standard weights were only 1.585 times as great as their judgment errors for 100 gm. standards. According to Weber's Law, the judgment errors for the 200 gm. standards should have been twice the size of those for the 100 gm. standards. Thorndike's experimental controls have been criticized for being too flexible; and, this lack of precision may have accounted for some of the differences found. Other evidence has confirmed Weber's Law (Holway & Hurvich, 1937). Today it is generally recognized that Weber's Law applies to the middle range of intensity for most sense modalities, but that it does not hold for the extreme intensities (Woodworth & Schlosberg, 1954).

Sensitivity to weight (resistance) is influenced by the presence of contrast weights; and, by the length of time a stimulus weight is presented. A contrast weight is an extra weight, not a part of the judgment series, to which a subject is exposed either prior to or at the same time he is judging a series of weights. Contrast weights both distort and decrease weight sensitivity (Holway, Golding, & Zigler, 1938; Dinnerstein, 1965; Gregory & Ross, 1967). For example, subjects trained to select three reference weights shifted them to heavier magnitudes after being exposed to an intervening "heavy" series of weights; likewise, other subjects shifted the reference weights to lighter magnitudes after being exposed to an interpolated "light" series of weights (Williams, Ross, & DiLollo, 1966). In another study, persons who received a light series of weights tended to overestimate the weights of a subsequent series of heavier weights, when compared to a control group which received the "heavy" series twice. The reverse resulted with subjects who received a "heavy" series of weights followed by a "light" series (Ross & DiLollo, 1968).

The magnitude of the distortions created by anchors (contrast weights) is directly related to the size of the anchor (Holway, Golding, & Zigler, 1938; Dinnerstein, 1965; Dinnerstein _et al_., 1966). In the study by Dinnerstein, subjects lifted anchors of various weights in one hand while simultaneously making weight judgments with the other.

Sensitivity was keenest when the non-judging hand was empty, and it decreased as the weight of the anchor deviated from the 80 gm. standard used in the judgment series. In other words, as more extreme anchors were held in the non-judging hand, the magnitude of the weight distortions (illusions) increased.

Weight sensitivity is affected by the length of time a weight is held, i.e., stimulus duration. Kinesthetic sensitivity to weight was inversely related to stimulus durations ranging from 4 sec. to 256 sec. (Holway & Zigler, 1939). However, shorter exposure time periods produced somewhat different results. The ability to judge weights was found to increase with exposure times ranging from 100 msec. to 400 msec. and then reach a plateau between 400 msec. and 900 msec. (Sekuler & Bauer, 1965).

A phenomenon analogous to physiological adaptation also occurs in the perception of weight. Sensitivity to weight increases as a function of post-exposure time in response to either anchor effects or stimulus duration effects. In other words, kinesthetic sensitivity to weight improves as time elapses following exposure to a contrast or to a prolonged stimulus weight exposure time. The time required for "recovery" is directly related to the magnitude of the anchor or of the stimulus duration (Holway, Golding, & Zigler, 1938; Holway & Zigler, 1939; Gregory & Ross, 1967; Ross & DiLollo, 1968). Gregory & Ross (1970) believe a central control system governs this adaptation phenomenon. Stevens (1958), on the other hand, maintains that this occurrence is "more like a change of modulus than like a change in sensory character" and cautions that "the fact that adaptation and semantic set are both functions of the array of prior stimuli may not in itself be a sufficient reason for treating the two phenomena as one." In other words, contrasts affecting weight judgments need not require a change in "sensory excitability," but may be due to a semantic shift, i.e., an internal renaming of weight categories. Dinnerstein and her colleagues (1965, 1966) disagree with Stevens and contend that "contextual influence on judged heaviness exists as a genuine perceptual fact, not a purely semantic one depending on category rating."

Not only actual physical weight, but also the apparent weight, of an anchor can cause shifts in the judgment of weights (Freeman & Adam, 1965). It has been postulated that these weight illusions, when expected weight does not match actual weight, may be due to a central scaling process, rather than a peripheral mechanism. This central process would allow for a wide range of weights to be estimated, with different ranges selected on the basis of the expected value of the weight. If the choice is incorrect, an illusion occurs (Ross, 1969). Study of the phenomenon of weight illusion indicates that the best weight discrimination occurs when size-weight illusion is at a minimum (Ross & Gregory, 1970), thereby demonstrating that the density of the stimulus as well as its magnitude provide the effective stimulus in lifted weights.

While the factors influencing sensitivity to weight may have more direct application to space programs where the effective weight of limbs and objects can change drastically, they also carry implications for the physical educator. For example, how is the force sensitivity of the swimmer changed by the buoyancy of the water? Is it possible to "prime" the body just prior to performance through the use of appropriate anchors? Do weighted objects such as bats and balls inhibit or facilitate motor performance and motor skill learning?

There is limited availability of tests of kinesthetic sensitivity which use the technique of lifting weights. One such test was developed in which sensitivity to weight was assessed through either absolute errors or weighted errors (Robinson, 1968). Test-retest reliability coefficients of .71 and .79 for absolute error scores, and values of .78 and .85 for weighted error scores, were obtained when the instrument was administrered to elementary school boys. The retesting occurred after one and two month intervals, respectively.

Two kinesthetic tests employing lifted weights were developed in which the "differential thresholds" were used as the index of sensitivity to weight (Fleishman & Rich, 1963; Norrie, 1967). When the instrument was applied to college males, a test-retest coefficient of .85 was obtained, with a minimum delay of 24 hours between the two administrations of the test (Fleishman & Rich, 1963). On the other hand, a low .225 reliability coefficient was secured for the test when it was administered to college females, where a two-week test-retest interval was introduced (Norrie, 1967).

The differences between the reliability coefficients cited in the studies just discussed raise some interesting questions. Are there sex differences in kinesthetic weight sensitivity? Is kinesthetic sensitivity to weight more stable in males, or were the differences in reliability coefficients due to testing procedures and to the length of time intervals between the test and retest situation? Can kinesthetic weight sensitivity be learned? Does this sensitivity change with age?

Force Reproduction

Kinesthetic sensitivity to force or pressure also follows Weber's Law, within certain limitations. The constant fraction for pressures beyond 10 lb. is .06 (Jenkins, 1947), but must be as large as .09 or .10 in order for all subjects to perceive pressure changes continually (Henry, 1953. The magnitude of the "differential threshold" is also dependent upon the rate at which pressure changes occur (Henry, 1953).

Sensitivity to force or pressure is characterized by a "range effect." Constant errors are positive at low pressure values and negative at high pressure values (Jenkins, 1947; Norrie, 1968, 1969). In other words, force reproduction tends to exceed small pressure standards and falls short of high pressure standards. Some evidence suggests that this "range effect" may be influenced by the length of the time interval between initial force production and subsequent force reproduction (Norrie, 1968); however, this has not always been the case (Norrie, 1969).

The instruments customarily used to measure kinesthetic sensitivity to force or pressure have included hand and leg dynamometers, and special stick or lever control equipment. Although dynamometers have been used quite frequently to measure force sensitivity, only a few studies report reliability coefficients for the instruments when used in this capacity (Young, 1945; Wiebe, 1954; Scott, 1955). In general, the reliability coefficients obtained for force reproduction on the dynamometer are good, ranging from .63 to .93. However, force reproduction tests exhibit only low, positive validity coefficients with criterion measures of kinesthesis.

Some use has been made of special instruments constructed for the purpose of testing kinesthetic sensitivity in force reproduction. One kinesthetic test apparatus was designed to measure kinesthetic acuity as an "overall integrated bodily response" (Henry, 1953). The apparatus required the subject to push on a padded lever in response to movement and pressure exerted on the level by a cam. Two tests were devised: a "constant pressure" test where the subject had to move the lever to maintain a constant pressure; and, a "constant position" test which required the subject to vary pressure in order to maintain the lever in a constant position. Reliability coefficients of .91 and .82 have been reported for the two rests, respectively (Mumby, 1953). Another lever apparatus was developed which allowed kinesthetic force reproductions to be made within a minimum of movement (Henry & Norrie, 1968). Within-day reliability for constant error scores ranging from .66 to .86 were secured when the test was administered to college women. A between-day reliability coefficient of .73 was obtained. The use of the force reproduction task as a measure of kinesthetic sensitivity was questioned, however, when it was determined that within-individual variability yielded a low .37 reliability coefficient (Norrie, 1970).

Other Methods

Other techniques for assessing kinesthetic sensitivity to force or tension have included torque and muscle tension reproduction tasks. Torque sensitivity functions in a manner similar to that of tactile pressure and also exhibits a negative time order effect, i.e., the tendency to underestimate the original standard when reproducing torque (Woodruff & Helson, 1965). Torque does not appear to be a significant component of the kinesthetic input required to rotate handles back to their original starting positions (Wilberg, 1969).

An attempt to obtain a "pure" measure of kinesthetic perception, one not including tactile stimuli, was made by recording muscle potential changes (Slater-Hammel, 1957). Subjects practiced contracting the triceps brachii muscle to a given tension, which was recorded in microvolts, and then tried to reproduce the tension. A within-day reliability measure of .50 was achieved, but a more significant .86 was secured on a between-day basis (something difficult to explain). No sex differences were noted. The respectable reliability of the procedure, along with its reduction of tactual stimuli and lack of sex bias, provide support for the use of this technique in future studies of kinesthesis.

Application

Attempts to determine the relationship of kinesthetic force sensitivity to various types of motor skill performance have been accomplished either through correlational studies or by comparing different groups of subjects. The techniques used to assess kinesthetic force sensitivity in these studies have included nearly all the weight judging, force reproduction and muscle tension tasks discussed previously.

Weight discrimination tasks, as measures of kinesthesis, appear to be related more to fine manipulative skills than to gross motor skills. Little or no relationships have been found between weight judging ability and ability in golf skills (Phillips, 1941); in sport-type skills (Young, 1945); and, in throwing skills (Egstrom et al., 1960). However, the possibility exists that the weight discrimination tasks in these particular studies were not refined enough to be effective as instruments of kinesthesis. On the other hand, a significant correlation of .58 was obtained between weight judging scores and performance on a two-hand coordination task (Fleishman & Rich, 1963). Weight discrimination ability is also related to technical skill in piano playing (Ortmann, 1923). In this study, weight judgment scores were also found to improve with the age of the pianists. Unfortunately, the number of subjects at each age level was too small to permit generalizations to be made.

Performance on force reproduction tests generally does not correlate substantially with performance on general motor ability tests (Young, 1945; Scott, 1955). This may be due, in part, to the inadequacy of general motor ability tests in assessing motor ability. Support for such a view is demonstrated by the fact that athletes have shown superior performance on force reproduction tasks when compared to non-athletes (Kerr & Wineland, 1933; Wiebe, 1954).

"Good" wrestlers also demonstrated superiority over "poor" wrestlers on Henry's "constant pressure" test of kinesthesis (Mumby, 1953). Accuracy in reproducing muscle tension, as measured by the recording of muscle potentials, was found to be significantly greater in physical education majors than in liberal arts majors. However, no difference was observed between the ability of males and females on this task (Slater-Hammel, 1957).

The concept of using weighted objects to facilitate motor skill learning or motor performance has received some attention in recent years, particularly in the area of throwing skills. It was found that persons who had practiced an overhand throwing skill using a light ball did as well in performing the skill with a heavy ball as individuals who had practiced the skill with a heavy ball. The reverse transfer, however, did not occur (Egstrom et al., 1960). Other evidence showed that overload warm-up significantly improved throwing velocity; however, initial throwing accuracy was decreased (Van Huss et al., 1962.) These results are consistent with the contrast effects discussed previously. The "heavy" balls would be expected to create a weight distortion when the regulation balls are thrown, i.e., the balls would appear to be lighter than they actually were. Increased velocity would result since the distortion would create the feeling that the ball is easier to throw. The weight illusion could affect judgments in releasing the ball and accuracy would be decreased. As adaptation to the weight of the regulation ball occurs, the weight illusion decreases and accuracy improves.

The effect of heavy and light equipment on the acquisition of sport-type skills by second and third grade children has been investigated (Wright, 1967). It was concluded that young children with limited strength may learn such skills more efficiently by using light-weight equipment. However, the nature of the tasks (underhand bowl, modified free throw, target throw, baseball batting), and prior experience with plastic equipment may have confounded the results obtained.

Sensitivity to Position and Movement

The techniques used to assess position sense and movement awareness may be grouped into the following categories: (a) tests requiring the production or reproduction of specified angular displacement of the body or limbs, (b) tests calling for replication of specified target locations, and (c) tests dealing with the rate, duration or extent of limb or body movement.

Angular Positioning

Investigators have devised innumerable arm, leg and body positioning tasks to obtain measures of "position sense" and "movement awareness." In general, the evidence indicates that joint angle reproduction tasks, as measures of kinesthetic sensitivity, are quite reliable at various age levels, but their validity as individual tests of kinesthesis has not been established.

Reliability coefficients ranging from .80 to .98 have been obtained for arm and leg positioning tests, such as the "arms sideward 90°" and "leg raise 20°," when these were given to adults (Young, 1945; Roloff, 1953; Wiebe, 1954) or to children (Witte, 1962). A side arm positional test of joint angle sensitivity was equally consistent in assessing joint angle perception in both the dominant and nondominant arm. Reliability coefficients ranged from .65 to .99 across 13 different angles (Christina, 1967). Reliabilities of .86 and .89 also have been secured for elbow and knee joint positioning tests, respectively. However, the presence of large intra-individual variability indicated the need for numerous trials per subject in order to obtain true scores (Norrie, 1967).

The relative influence of handedness on precision in limb positioning is not clearly established. Some evidence has demonstrated that the nondominant limb is more accurate in novel positioning tasks (Phillips & Summers, 1954; Christina, 1967), but that the dominant limb is more accurate in joint angle reproductions over ranges commonly used in daily living activities (Phillips & Summers, 1954). These findings suggest the presence of a confounding effect produced by an experience or practice factor.

There is substantial evidence that positioning accuracy is the greatest in those movement ranges which are practiced the most. This appears to be true for both the arm (Phillips & Summers, 1954; Logan, 1964; Levy, 1968), and the leg (Lloyd & Caldwell, 1965; Lloyd, 1968). Whether this increased accuracy is due to more effective kinesthetic feedback resulting from practice, or to some other factor, is not known.

Accuracy in joint angle positioning is also influenced by the manner in which positioning tasks are initially presented. In other words, response accuracy is dependent on whether verbal instructions, passive limb movement or active limb movements serve as the initial stimuli. Passive movement of a subject's arm resulted in greater accuracy on a horizontal arm positioning task than when verbal instructions were used (Berger & Stadulis, 1968); and, active movement of a leg was superior to passive movement of a leg in cueing joint angle responses (Lloyd & Caldwell, 1965; Lloyd, 1968). On the other hand, elbow positioning accuracy was not influenced by the mode of initial presentation, i.e., no difference was found in the accuracy of joint angle response when either active or passive movement of the forearm was used as the initial movement stimulus (Levy, 1968).

Factors such as additional resistance to movement and extent of movement have differential effects on limb positioning. The addition of a constant resistance had little influence on the perception of the angular distance traversed by a limb (Leuba, 1909; Bahrick et al., 1955b); however, a progressive increase in resistance (torque) as angular movement occurred resulted in a substantial over-estimation of length (Leuba, 1909), or increased sensitivity to angular movement of a limb (Bahrick et al., 1955a). The "range effect" also appears to operate with angular positioning. Attempts to reproduce small angular movements resulted in positive errors and angular displacements to match larger angular movements resulted in negative errors (Del Ray & Lichter, 1971).

Studies pertaining to mode of presentation, handedness, and to the effects of experience or practice carry important implications for teaching methodology and curriculum planning in physical education. Those dealing with the addition of weights or resistance and the influence of movement extent again raise the question of proprioceptive facilitation for the learning of motor skills.

Target Positioning

Target positioning tasks are characterized by a pointing response to some type of sensory stimulus. The primary use of such tasks by psychologists has been to identify the dimensions of psychomotor abilities (Hempel & Fleishman, 1955; Fleishman, 1958), and to determine the role of proprioception in target positioning responses

(Gibbs & Logan, 1965; Legge, 1970). Studies such as the former two demonstrate the specificity which exists among various positioning tasks, as well as their independence from gross physical tasks. Results from the latter two studies will be discussed later.

In general, target positioning tests have not been of great use as measures of kinesthesis, even though several individual tests reported in the literature have demonstrated consistency in measurement. Such tests include: a putter target test (Phillips, 1941); throwing and kicking target tests (Young, 1945); a floor target test (Roloff, 1953); vertical space point tests for the hand and foot (Wiebe, 1954); finger spread and target pointing items (Scott, 1955); and, a parallel blocks test (Robinson, 1968). Reliability coefficients for these tests ranged from .72 to .87. On the other hand, the validity of these tests with criterion scores of kinesthesis is below .50. In addition, few have been included in test batteries of kinesthesis (see Table 2.1).

Precision in pointing tasks is apparently influenced by handedness, sex, body orientation, and sensory input from the limb involved in the task. In experiments with right-handed subjects, accuracy in target pointing was the greatest with the dominant arm (Wyke, 1965; Churchill, 1965). Information concerning the pointing accuracy of left-handed subjects, though limited, suggests a similar outcome (Wyke, 1965).

The limited evidence available concerning sex differences in pointing accuracy indicates that women are more accurate than men on certain pointing tasks. In two experiments, male and female subjects were asked to match an unseen stylus on one side of a divider board, placed in the paramedian plane, with visual targets on the other side. When vertical and horizontal errors were compared by sex, the errors made by women were smaller than those made by men in the horizontal plane. However, no sex differences were noted for errors in the vertical plane (Legge, 1970).

Sensory input from the limb is equally as effective in producing accurate target pointing responses as input from visual stimuli. Little differences in pointing accuracy were noted under conditions where subjects had to: (a) match a visual scale to a target located by kinesthetic sensitivity; or, (b) locate a visual target and match it kinesthetically (Churchill, 1965). However, a difference in the direction of constant error was obtained; constant errors were negative for visual matching and positive for kinesthetic matching. In other experiments subjects were required to: (a) locate and touch an indistinct target with a pointer; (b) align a hidden arm with a visual target; and, (c) align the head and eye with an outstretched hidden arm (Gibbs & Logan, 1965). It was determined that sensory input from vision alone, from proprioception alone, or from a combination of both, produced rapid, primary movement adjustments of equal accuracy.

Orientation of the body, particularly that of the head and neck, also has an effect upon accuracy in target pointing. It was found that, with the head facing forward, accuracy of pointing was greater when the target was in front of the subject than when it was to the side. Furthermore, when the head was rotated to one side, the direction of pointing error was opposite to the direction of head rotation (Wyke, 1965). Precision of control over the arm therefore seems dependent, in part, upon the ability of a person to coordinate limb movements with the orientation of the head and neck, and possibly with the orientation of the body in general. Implications for the teaching of physical activities become obvious, particularly with the coordination of limb movements with head position in activities such as golfing, diving, gymnastics and trampolining.

Active Kinesthesis

Active kinesthesis is concerned with sensitivity to "movement" as opposed to the sense of "position" discussed in the previous two sections. Active kinesthesis implies continuous sensory feedback as movement occurs, and emphasizes the awareness of factors such as extent, direction and rate of movement.

The question of whether the central nervous system receives direct information concerning extent of movement has been raised by some investigators. Leuba (1909), without the knowledge of servo-mechanisms, hypothesized that sensory input concerning the duration and rate of movement was sufficient to compare the length of angular movements. On the basis of their investigations, Gibbs and Logan (1965) concluded that speed as well as direction of movement are monitored by proprioceptive feedback, but that "extent (of movement) is determined by integrating the rate signals in time."

Whether the central nervous system receives direct sensory information about extent of movement, or whether perception of length of movement is the result of centralized integration of rate and duration signals, does not alter the fact that "extent of movement" is subjectively perceived and that this perception can be quantified (Ronco, 1963). The psychophysical techniques of magnitude estimation and ratio reproduction were used to develop a scale of subjective magnitude of movement called the "Kine" scale. It was determined that kinesthetic sensations associated with extent of arm movement grow as a power function, i.e., 1.05, of the physical distance the arm moved. A similar scale for the sense of "rate of self-initiated arm movement" has also been constructed (Wood, 1969). The power functions for ratio and magnitude reproduction for this "rate" scale were 1.018 and .844, respectively.

A Test of Kinesthetic Recognition was developed to assess kinesthetic sensitivity in hand and arm movements (French, 1953). The test consisted of matching designs traced kinesthetically with a stylus. The test was sufficiently sensitive to distinguish between groups of retarded and non-retarded readers, even though its reliability was only .68.

Compared to "position sense" tests, relatively few attempts have been made by physical educators to assess active kinesthesis. Those tests reported in the literature which have demonstrated substantial reliabilities (.64 to .88) include: Arc Swing, Pathway-Left Hand, Pathway-Right Hand (Phillips, 1941); Arm Circling and Arm Swinging (Roloff, 1953); Sargent Jump-Duplicate and Free Throw-Duplicate (Wiebe, 1954); and, Ball Balance (Scott, 1955). Several tests of active kinesthesis have been developed by Fleishman (1958); however, few of these appear to have been adopted as measures of kinesthesis by physical educators.

Accuracy in limb movements is related to the direction and extent of movement, but not to variations in pressure designed to resist movements. Relative error (percentage error) in movement is greatest for short distance movements and decreases as a function of increased movement extent (Brown et al., 1948; Weiss, 1954). Movements away from the body are more accurate than movements toward the body (Brown et al., 1948). On the other hand, variations in pressure had no apparent effect on variability and relative error (Weiss, 1954). This latter observation is consistent with the results reported by Leuba (1909) and Bahrick et al. (1955b).

As indicated in a previous section, the "range effect" occurs with extent of movement. This phenomenon also occurred in some of the studies presently under consideration. Short distances were overestimated and long distances were underestimated, regardless whether arm movements were directed toward the body or away from the body (Brown et al., 1948). In addition, the "range effect" operated in each of the three cardinal body planes, with the exception of top-to-bottom movements in the vertical plane. Gravity was hypothesized as a facilitative factor toward overestimation in the latter case. When movements were kept at a constant length and in a horizontal plane, movements to and from the body in the midline were overestimated. Those to the right and left across the midline of the body were underestimated (Reid, 1954).

Since the kinesthetic phenomenon of underestimating movements across the body midline and overestimating movements to and from the body was analogous to a visual vertical-horizontal illusion, Reid hypothesized that the two were related. He also hypothesized that the visual illusion might be an outgrowth of the kinesthetic illusion. However, evidence contradicting these hypotheses was established when it was determined that the <u>type</u> of movement rather than the <u>direction</u> decided the direction of tactile-kinesthetic errors (Davidon & Cheng, 1964). It was found that radial distances are overestimated in relation to tangential distances when these are either parallel or perpendicular to the medial plane. Additional evidence by Cheng (1968) indicated that the radial-tangential effect occurs both in the frontal and the horizontal planes. Furthermore, it occurs whether the distances compared are adjacent to each other or are separated from each other at various angles. In addition, a proximity-effect was observed with tangential movements, i.e., distances farther from the subject were underestimated relative to those closer to the subject. Radial extents were not affected. Cheng concluded that "tactile-kinesthetic perception has modality-specific characteristics which are different from those of visual perception."

Application

Various positioning and target pointing tests have been used as tests of kinesthesis to determine the relationship of proprioception to general motor ability and to specific sports skills. The relationship between performance on such tests of kinesthesis and performance on tests of general motor ability is of a low, positive magnitude, at best (Young, 1945; Lafuze, 1951; Roloff, 1953). The inherent weaknesses of general motor ability tests have been discussed previously in this chapter.

Evidence concerning the relationship of positioning and target pointing tests of kinesthesis to specific sport skill ability is contradictory in nature. On the one hand, such tests have failed to identify superior performers in gymnastic skills (Wettstone, 1938; Stuart, 1964); in tennis and bowling performance (Roloff, 1953); or, in ball rolling ability (Witte, 1962). On the other hand, significant relationships have been obtained between such tests and golf skills (Phillips, 1941); a sports criterion score (Young, 1945); bowling (Phillips & Summers, 1954); and, basic ball skills (Smith, 1956). The fact that several of these tests were used in each of the studies again points to the specificity of these tests in measuring only one component of proprioception, and also indicates that test batteries must include items which will assess other components of proprioception as well.

In general, positioning tests appear to be quite reliable as measuring instruments across all age groups studied, but their value as predictors of motor skill or as classification instruments is fraught with conflicting evidence.

Sensitivity to Size and Length

Determination of kinesthetic awareness of apparent size or length has generally been restricted to studies involving the use of the hands. In so doing, research efforts have been directed toward the establishment of differential limen; toward the comparison of various sense modalities involved in judging size or length; and, toward the identification of those factors which affect kinesthetic judgment of size or length.

Kinesthetic Length Sensitivity

Differential thresholds for sensitivity to length are generally determined by the finger span method. With this method subjects use their thumb and forefinger to compare the length of variable objects with a standard length; or, they adjust the length of a variable apparatus to match the length of a standard stimulus. The errors in matching are then used to calculate the differential threshold for that standard length.

The threshold for a "just noticeable difference" in length has ranged from .01 to .02 when using a standard length of 50 mm. (Langfeld, 1917; Gaydos, 1958; Dietz, 1961). The fraction was one-twentieth when the standard length was 10 mm. (Dietz, 1961). This suggests that differences of 0.5 mm. could be detected by experienced individuals, whereas novice persons could only detect a difference as small as 1 mm., when making comparisons to a 50 mm. standard. Since the detectable difference for a 10 mm. standard is also 0.5 mm. (Dietz, 1961), it is obvious that Weber's Law is not applicable across the entire range of length sensitivity. However, it has been found to operate in the 35 mm. to 100 mm. range (Gaydos, 1958).

The subjective judgment of width is a power function of the stimulus width. This result has been obtained with wooden blocks, where the power function (PF) was 1.33 of the stimulus width (Stevens & Stone, 1959); with squares, PF = 1.18; and, with spheres, PF = 1.17 (Roekelein, 1968). The average error secured in matching the thickness of standard book leave thicknesses also resulted in a constant function of the standard magnitude (Tomlinson, 1960).

Few attempts have been made to measure kinesthetic sensitivity to length or width in physical education. A foot span test was reported used on two occasions (Phillips, 1941; Wiebe, 1954). In this test the subject had to spread the heels of his feet apart a distance of 12 in. A reliability coefficient of .90 was obtained for the test (Wiebe, 1954). A Thickness Discrimination Test was designed in which subjects were required to compare the thickness of six comparison blocks to a standard block. The reliability reported for the test when it was administered to fifth and sixth grade boys was .76 (Robinson, 1968).

<u>Length Sensitivity and Other Senses</u>

Evidence suggests that size or length judgments are made with near equal efficiency regardless of the sense modality employed, as long as each is used independently. This is true for vision, kinesthesis, and touch (Raffel, 1936; Kelvin, 1954; Teghtsoonian & Teghtsoonian, 1965; Stanley, 1966).

There is conflicting evidence concerning the relative dominance of one sense modality over another when both are involved in length judgments simultaneously or successively. For example, when a standard stimulus was presented kinesthetically and then followed by a comparison stimulus which was seen and "felt" simultaneously, the kinesthetic experience was subordinated to the visual experience (Raffel, 1936). The opposite result occurred when subjects again received a standard length stimulus kinesthetically, but then had to reproduce the length either visually or kinesthetically. Adults were more accurate when reproducing the length kinesthetically than when doing so visually. Children were found equally effective in making the length reproductions with either sense modality. On the other hand, no differences were found in the accuracy of length judgments between those made within a sense modality (sight-sight) and those made across modalities (sight-touch) (Kelvin, 1954). These results are not in agreement with those obtained by Raffel and Abel, but do agree with Abel's results with children. Possibly the techniques employed were an important factor, since the former two studies allowed their subjects to course their finger along the edge of the stimuli, whereas the latter study used the method of finger spanning.

Subjective perception of length is a power function of the physical length of the stimulus. This is true for visual, kinesthetic and tactual perception of length. A comparison of visual and kinesthetic judgments of length established power functions at 1.007 for vision and 0.983 for kinesthesis (Teghtsoonian & Teghtsoonian, 1965). The relationship between two methods of judgment was .95. Similar functions were obtained when judgments of length by touch and kinesthesis were compared (Stanley, 1966). The power functions for touch and kinesthesis were 1.05 and 0.94, respectively. Touch judgments were slightly more accurate at short distances (0.7 in. to 7.0 in.), but the two methods approached unity at distances of 23 to 33 in.

Factors Influencing Size and Length Sensitivity

Sensitivity to size and length is influenced by factors such as practice, systematic error, handedness, and muscle tension. Information concerning each of these is limited and often contradictory in nature.

Practice or experience has a positive effect on the accuracy with which length judgments and size judgments are made (Langfeld, 1917). Subjects who practiced rod length estimation did better on the size reproduction of designs than did two control groups (Roeckelein, 1968).

The distance at which length or size judgments are made influences the accuracy of size judgments (Bartley et al., 1955). The tendency to underestimate the size of objects increases as the objects are placed at greater distances from the body (Liddle & Foss, 1963). On the other hand, judgments of length are systematically judged toward the longer lengths, thereby producing a positive constant error in judgment (Langfeld, 1917; Gaydos, 1968).

Kinesthetic judgments of length are most accurate when they are made with only one hand (Langfeld, 1917). They are also most accurate when made with the dominant hand (Tomlinson, 1960). Evidence concerning the influence of handedness on size judgments is less clear. When objects of equal size were placed in both hands of a subject simultaneously, the object in the preferred hand was judged to be the smaller (McPherson & Renfrew, 1953). The same results were obtained with brain-injured, sensory deficit subjects, but not with control subjects (Weinstein, 1955). Another investigator found performance to be equal for both hands (Churchill, 1965). The fact that none of the studies used similar objects or procedures may be a partial reason for the lack of agreement among the results obtained.

Application

Tests of length sensitivity as measures of kinesthesis have received virtually no attention in physical education. The foot span test used by Phillips (1942) was unrelated to the acquisition of golf-type skills. The same test also failed to distinguish athletes from non-athletes

(Wiebe, 1954). The Thickness Discrimination Test by Robinson (1968) has yet to be applied to research in physical education.

It would seem, however, that this component of kinesthesis would have direct implications for the manipulation, projection and reception of objects which can be controlled with one hand, such as small balls, rackets, paddles and beanbags. For example, is kinesthetic sensitivity to length related to an individual's ability to bounce and catch a tennis ball; to throw it with accuracy; or, to receive it successfully? The possibility of such a relationship has yet to be studied.

Sensitivity to Balance and Spatial Orientation

The importance of kinesthesis in balance and that of balance in kinesthesis has been well documented (Bass, 1939; McCloy, 1940; Scott, 1955; Wiebe, 1956). The involvement of kinesthesis in spatial orientation has also received considerable attention (Miles, 1922; Travis, 1945; Worchel, 1952; Miller & Graybiel, 1966; Clark & Graybiel, 1966). In the process, a variety of approaches and techniques have been employed; and, their subsequent application to physical education has met with varying degrees of success.

In general, assessments of balance and spatial orientation have been made with the eyes of the subject either open or closed. With the eyes open, assessments were usually made to study balance or spatial orientation per se. With the eyes closed, attention was usually focused on kinesthetic and other nonvisual aspects. For this reason, primary consideration in this section will be given to studies of balance and spatial orientation in which subjects were tested with their eyes closed.

Static Balance

Techniques for assessing static balance have ranged from the use of a one foot stand, either on the floor or on a stick, to the use of special instruments such as the ataxiameter and ataxiagraph. An important feature of all these techniques has been their reliability in measuring static balance.

Floor balance and stick balance tests have been used repeatedly in studies of balance and kinesthesis. Bass (1939), among the first to standardize instructions for such tests, obtained reliability coefficients of .80 and .85 for two floor balance tests, and a set of coefficients ranging from .76 to .88 for four stick balance tests when subjects had their eyes closed. The one foot floor balance was subsequently used by other investigators in studies of motor coordination, academic achievement and proprioception (Espenschade, 1947; Ismail & Gruber, 1967; Robinson, 1968). Of these, Robinson reported a reliability coefficient of .96 for balance on the dominant foot when the test was administered to fifth and sixth grade boys. Stick balance tests, as measures of kinesthesis, also have been used quite extensively (Young, 1945; Roloff, 1953; Wiebe, 1954; Scott, 1955; Wyrick, 1969). Reliability coefficients secured for the tests in these studies, when reported, always exceeded .70.

The ataxiameter (Miles, 1922) and ataxiagraph (Fisher *et al*., 1945) have been used to measure body sway. The ataxiameter records the amount of body sway exhibited by an individual in both an anteroposterior direction and a lateral direction while the subject stands stationary on both feet. The ataxiagraph measures body sway only in the anteroposterior plane. Reliability coefficients of .48, .70 and .85 have been reported for the ataxiameter on subjects without the aid of visual cues (Travis, 1945). Substantial reliability coefficients, ranging from .76 to .89, also have been secured for the ataxiagraph (Fisher *et al*., 1945; Estep, 1957).

The importance of vision in static balance has been well documented (Miles, 1922; Birren, 1945; Fisher *et al*., 1945; Travis, 1945; Bass, 1939; Wyrick, 1969). In virtually every study conducted, performance with visual cues was superior to that without the aid of visual cues. The implication is that performance in activities which require static balance can be markedly enhanced with the aid of visual cues.

Factors such as age, sex, shoes and foot position are known to affect static equilibrium. For adults, maximum stability results when the heels are placed about 8 in. apart and the feet are parallel or with the toes averted (Miles, 1922). Most testing of body sway, however, was done with the feet in a V-position (Miles, 1922; Birren, 1945; Estep, 1957).

Performance on static equilibrium tests is generally better with shoes on than with the feet bare. This result is attributed to the fact that it is more customary in our society to wear shoes than to go barefooted. This conclusion is supported by evidence which demonstrates that individuals accustomed to working without shoes exhibit less body sway when barefooted than with shoes on (Miles, 1945).

The influence of age and sex on static equilibrium is most apparent during the childhood years. Young children, 5 to 7 years of age, sway more than adults. In addition, girls tend to demonstrate less body sway than boys at all ages until they reach maturity. On the other hand, the magnitude of body sway is the same for men and women (Miles, 1922). There is also evidence that growth in static balance, as measured by the one foot floor balance, reaches maturity by age 16 (Espenschade, 1947). Other evidence, however, suggests that such growth may occur differentially; that girls reach maturity by age 13, whereas boys may continue to improve in static balance until age 17 or 18. Contrary to body sway, static balance on a stick (rail) appears to be quite similar for adolescent boys and girls (Fleishman, 1964).

Factors, other than those just discussed, seem to have little influence on static equilibrium. Practice effects are negligible in body sway performance, at least no systematic improvements in the performance of subjects on the ataxiameter and ataxiagraph are generally noted (Miles, 1922; Fisher _et al_., 1945). Height, weight and foot size also are unrelated to body sway performance (Travis, 1945; Miles, 1922). Little evidence concerning these factors is available on the one foot balance tests.

Static equilibrium is a function separate from dynamic postural balance and vestibular functioning. Scores for body sway and nystagmus time, a test for vestibular functioning, are unrelated (Birren, 1945). In addition, a subject without nerve function demonstrated normal postural control even though unable to negotiate a balance beam. The independence of static balance from dynamic balance has also been shown when body sway was compared to stabilometer performance (Travis, 1945).

Dynamic Balance

Dynamic equilibrium has received less consideration in kinesthetic sensitivity studies than static balance. This is quite understandable since most measures of dynamic balance require the subject to move from one position to another in space. The low walking beam would appear to be a suitable instrument for such a study. However, probably for reasons of safety, this apparatus apparently has not been used while subjects were blindfolded.

On the other hand, the stabilometer has received some use in studying the kinesthetic aspects of dynamic balance. This apparatus essentially consists of an unstable platform upon which a subject attempts to maintain postural balance. It has demonstrated acceptable reliability as a test of kinesthesis (Mumby, 1953).

In some respects, results of performance on the stabilometer resembles that of body sway. For example, subjects do better with visual cues than without them. Furthermore, little learning occurs when visual cues are eliminated (Travis, 1945). However, it has been demonstrated that body sway and dynamic balance are independent of each other (Travis, 1945). In contrast to body sway, dynamic balance is significantly related to weight (-.83), to height (-.61), and to foot length (-.48). The performance of women is superior to that of men, even with body weight held constant (Travis, 1945).

A Balance Leap test has been used to measure the kinesthetic aspects of dynamic balance. The test consists of a sideward leap followed by a forward bend at the waist which has to be held for five seconds (Scott & French, 1959). Reliability coefficients ranging from .65 to .82 have been reported for the test (Roloff, 1953; Scott, 1955).

Application

The application of static and dynamic balance tests to physical education, as measures of kinesthesis, has been limited to correlational studies concerned with the relationship of kinesthesis to some specified ability or trait. In a few instances they have been used to differentiate between ability groups.

In general, relationships between kinesthesis and general motor ability, and between kinesthesis and rhythmic ability are of a low, positive nature. Reported relationships between static balance and general motor ability have ranged from .27 to .50 (Bass, 1939; Young, 1945; Scott, 1955). A relationship of .28 between static balance and ratings of rhythmic ability also has been reported (Bass, 1939).

On the other hand, static balance is not significantly related to ankle strength (Wyrick, 1969), or to academic achievement (Ismail & Gruber, 1967). Dynamic balance also is not related to judge's ratings of wrestling ability (Mumby, 1953). However, static balance tests have differentiated athletes from non-athletes (Wiebe, 1954). They also have been able to distinguish high from low groups in rhythmic and general motor ability (Estep, 1957).

Spatial Orientation

Techniques for measuring body orientation in space have included such tasks as shifting body weight, directed walking, and tilting and rotating the body. Weight shifting tasks require the subject to consciously distribute a designated proportion of his body weight onto a scale. This is usually accomplished by standing on a platform or bathroom scale with one foot and on a block of wood of equal height with the other foot. Consistency of measurement with this technique has achieved only moderate success. Reliability coefficients have ranged from .35 to .70 (Roloff, 1953; Scott, 1955; Robinson, 1968).

Walking tests have been used to measure the ability to move a specified distance or direction without assistance from visual cues. Reliability coefficients of .89 and .72, respectively, were secured for a distance walk and an accuracy walk (Wiebe, 1954). On other occasions, walking tests have failed to demonstrate acceptable reliability (Scott, 1955; Robinson, 1968); or, no attempt was made to determine their reliability (Worchel, 1952, 1955).

Walking tests have also been helpful in studying the kinesthetic sensitivity of the blind and the deaf. Contrary to popular opinion and earlier evidence (Hunter, 1954), blind subjects do not possess a special ability in kinesthetic tasks. Without the benefit of vision, they resort to the use of tactile and kinesthetic cues far more than sighted persons. There is ample evidence to demonstrate that sighted individuals will rely on visual cues before they consciously rely on kinesthetic cues (Darling, 1960; Miller & Grabiel, 1966; Miller et al., 1968; Wilberg, 1969; Wyrick, 1969).

Without the availability of visual information, an intact vestibular apparatus can distort the accuracy with which individuals walk short distances. Subjects with defective labyrinths performed significantly better on a triangle pattern walking test than subjects with normal semicircular canals (Worchel, 1952); however, over substantially longer walking distances, i.e., over 250 feet, the vestibular organs were found to play a dominant role (Worchel, 1955).

A primary purpose of body tilting and rotating techniques has been to investigate the role of the vestibular organs in spatial orientation. In fact, the well-known "Barany Chair" test is used clinically to determine the integrity of the semicircular canals, which are part of the vestibular system (Guyton, 1971). Other purposes for these techniques have been to study the physiological responses and perceptual distortions that result from body tilting or rotation.

Tilting the body leads to perceptual distortion of spatial orientation when visual cues are eliminated. For example, body tilting will result in distorted judgments of verticality. Subjects tilted 15° from the vertical *underestimated* the vertical position whether they were in a sitting, prone, or supine position (Gescheider & Wright, 1965). Other evidence, however, has demonstrated that body tilting up to 70° from the vertical results in judgments of "apparent verticality" which are in a direction opposite to that of body tilt. In other words, the tendency was to overestimate the vertical. Tilting beyond 70° up to 90° resulted in judgments of "apparent verticality" moving in the direction of body tilt (Bauermeister et al., 1964). The conflict in evidence for the smaller angles of body tilt may be due to the fact that in the former study subjects returned their tilted chairs back to an apparent vertical position, whereas in the latter study the subjects rotated a bar until they thought it was in a vertical position.

The phenomenon of adaptation occurs after the body has been subjected to an inclined position for prolonged periods of time. Discrepancies between judgments of the vertical and of body position are smallest prior to body tilt. They are the greatest just after tilting, and then begin to decrease as a function of time (McFarland & Clarkson, 1966). The same phenomenon was observed when prism glasses, designed to produce the effect of body tilt, were worn (Rierdan & Wapner, 1967).

Body tilting and rotation have demonstrated the importance of otolith functioning in spatial perception. Otolith functioning is of prime importance in perception of the horizontal. Perception of horizontality is significantly less accurate in subjects with defective labyrinths than in subjects whose labyrinths function in a normal manner. This is true when the subjects are either in the upright position or in a recumbent (side) position; and, also under conditions of body rotation. In addition, small deviations of body tilt (10°) are overestimated and larger angles of tilt (80° to 90°) are underestimated by the subjects with defective labyrinths (Miller & Graybiel, 1966; Miller et al., 1968; Clark & Graybiel, 1966).

Body rotation can also elicit sensations of movement which are nonrotary in nature. Rotation of the entire body in one direction, when accompanied by simultaneous rotation of the head in the same direction, creates the sensation to "pitch forward" or backward. It also results in a significant reduction in target pointing accuracy (Johnson & Kirkendahl, 1970). Individuals with considerable experience in rotary movements also have reported nonrotary sensations of movement which were either of a backward or of a nondirectional nature (Tillman, 1964).

Application

Few attempts have been made to apply tests of spatial orientation to physical education; and, when applied, the results have been either inconclusive or insignificant. For example, little or no relationship has been found between weight shifting tests and general motor ability (Roloff, 1953; Scott, 1955); or between rotary tests and judgments of rhythmic and motor ability (Bass, 1939). Furthermore, rotary tests do not correlate highly with static or dynamic balance (Bass, 1939). A rotary chair test by Tillman (1964) did suggest that it may differentiate between individuals experienced in rotary activities, i.e., gymnasts, and individuals unaccustomed to body rotation; however, the small number of subjects prevented meaningful statistical analyses and valid conclusions to be made.

Proprioception and Gross Motor Performance

The relationship between proprioception and gross motor performance conventionally has been investigated through correlational studies and group comparisons. Other approaches have been concerned with the role of kinesthetic cues in teaching motor skills; with the effects of practice on kinesthetic learning; and, more recently, with topics such as kinesthetic feedback and kinesthetic after-effects.

Correlational Studies

It was noted previously that most correlational studies between individual kinesthetic tests and measures of general motor ability failed to yield significant relationships. Furthermore, even composite tests of kinesthesis seldom correlated higher than .50 with general motor ability (Young, 1945; Roloff, 1953; Scott, 1955). Low, positive relationships have been the rule when relating kinesthetic sensitivity to specific motor abilities such as ball rolling (Witte, 1962); modern dance performance (Bushey, 1966); gymnastic skill (Stuart, 1964); and, wrestling (Mumby, 1953). In a few instances, correlation coefficients exceeding .60 have been secured; namely, .64 between Henry's "constant pressure" test and wrestling ability (Mumby, 1953), and .67 between sports experience and kinesthesis (LaBarba, 1967).

Skilled versus Unskilled Groups

The lack of significant relationships of the magnitude that would allow for the diagnosis and prediction of individual performance has not prevented the use of kinesthetic tests to differentiate between extreme ability groups. In the great majority of studies, tests of kinesthesis have made clear distinctions between skilled and unskilled groups; however, in a few instances such distinctions were not made (Wettstone, 1938; Lafuze, 1951; Young, 1945).

Athletes have generally demonstrated superiority on tests of kinesthesis. For example, athletes have been distinguished from non-athletes on the basis of force reproduction tests (Kerr & Wineland, 1933); static equilibrium (White, 1951); composite kinesthetic tests (Stevens, 1950; Wiebe, 1954); kinesthetic reaction time (Slater-Hammel, 1955); and, kinesthetic perception of muscular force (Slater-Hammel, 1957). In addition, skilled piano players are more proficient in weight discrimination than less skilled players (Ortmann, 1923); successful basketball players have better kinesthetic judgment than unsuccessful basketball players (Taylor, 1933); good wrestlers can reproduce constant pressure more accurately than poor wrestlers (Mumby, 1953); skilled swimmers demonstrate greater dynamic balance than less skilled swimmers (Gross & Thompson, 1957); positioning tests differentiate between fast and slow learners in acquiring ball skills (Smith, 1956); and, groups rated high in sport and rhythmic ability display superior static balance when compared to their less gifted counterparts (Estep, 1957).

Kinesthetic Cues and Teaching

The value of kinesthetic cues in teaching motor skills has not been established. Assessments of their effectiveness have ranged from those of benefit to those of detriment. Blindfolded subjects were more accurate in driving golf balls than sighted subjects after six weeks of practice; however, their performance was decidedly inferior to the sighted subjects during the first few weeks of practice (Griffith, 1931). Manual placement of a limb was superior to verbal instruction in the performance of a horizontal arm positioning task (Berger & Stadulis, 1968).

On the other hand, manual guidance without visual cues was the least effective method for teaching young children a stylus maze pattern (Melcher, 1934). When a balance test, performed with the eyes closed, was placed first in a series of balance tests, performance was decidedly inferior to that demonstrated when the test was placed later in the series (Wyrick, 1969). No significant gains were made by remedial skills, tennis, golf, and bowling classes taught with an emphasis on kinesthetic cues over comparable groups taught by conventional techniques (Coady, 1950; Roloff, 1953).

Evidence concerning the stage of motor skill learning at which kinesthetic cues may be most effective is extremely scanty. Some investigators have suggested that such cues may be most helpful during the early stages of motor skill learning (Phillips, 1941; Phillips & Summers, 1954). On the other hand, support for later kinesthetic involvement has also been demonstrated (Griffith, 1931; Fleishman & Rich, 1963). A major question in these studies appears to be the interpretation of what is meant by "early" and "late."

Practice Effects

Improved performance on tests of kinesthesis has been noted by many investigators, but not necessarily for all the tests which they used. Among those who observed kinesthetic learning with one or more of the tests they employed were Phillips (1941), Lafuze (1951), Roloff (1953), Mumby (1953), Clapper (1954) and Christina (1967). Those who failed to find kinesthetic learning with practice included Miles (1922), Fisher et al. (1945), White (1951) and Morford (1966).

Kinesthetic Feedback

In recent years, interest has grown in the storage and execution of kinesthetic responses in motor skill learning. One area currently under investigation involves the effects of interpolated activity and the length of retention intervals on the recall of kinesthetic movements. Evidence concerning the effects of interpolated activity on kinesthetic recall is conflicting. Interpolated activity which requires information reduction, i.e., adding numbers, does not affect kinesthetic recall of movements (Williams et al., 1969). Interpolated activity of a motor nature however, in some instances, has interfered with kinesthetic recall of a movement (Williams et al., 1969; Stelmach & Wilson, 1970). On other occasions, interpolated activity of a motor nature had no detrimental effect (Stelmach, 1970), and may even have improved kinesthetic sensitivity (Sekuler & Bauer, 1965). The evidence also suggests that the longer the interval between the initial movement and the kinesthetic recall, the greater the error in recall (Stelmach, 1970; Stelmach & Wilson, 1970).

Other investigators have examined the role of proprioception as a mediator for timing motor responses; for it has been hypothesized that proprioceptive feedback from the initial stage of a movement can cue the timing of a later portion of the movement (Bahrick et al., 1955b). Evidence for this hypothesis often has been gathered by increasing proprioceptive cues above normal input levels. This has been accomplished by increasing signal duration and the spring loading of instruments (Adams & Creamer, 1962); by maximizing tension cues for velocity and acceleration (Bahrick et al., 1955a; Bahrick et al., 1955b; Ellis, 1969); and, by increasing activity in the contralateral limb (Schmidt & Christina, 1969; Christina, 1970, 1971). In all cases, positive evidence was secured to support the contention that increased proprioceptive feedback levels improve the timing of motor responses.

Another approach to the study of proprioceptive feedback is to reduce sensory feedback and then to observe the effect on motor responses. Evidence indicates that response efficiency is significantly impaired when sensory feedback is reduced, at least with such skills as finger tapping and finger circling (Laszlo et al., 1969; Laszlo, et al., 1970). These results also ascribe an important role to proprioceptive feedback in motor skill performance.

The role of the proprioceptive system in postural adjustments, in voluntary movement, and in motor skill learning has received considerable attention in the past decade. For more detailed information about this role the reader is referred to the excellent publications and reviews by Adams (1971), Bell (1970), Buchwald (1965), Eldred

(1965), Fischer (1958), Gardner (1965, 1967, 1969), Gibbs (1954), Granit (1970), and Harrison (1962).

Kinesthetic After-Effects

Psychophysical literature gives considerable attention to kinesthetic after-effects. These are perceptual distortions due to prolonged sensory experience in which tactile-kinesthetic cues play a predominant role (Cratty, 1965). Most of this research, however, has been directed toward fine motor skills such as the discrimination of thicknesses, and is typified by the work of Gardner (1961), Heinemann (1961), Bakan & Thompson (1962, 1963), and Singer & Gay (1966).

Little emphasis has been placed on the after-effects resulting from gross motor actions, which are of primary interest in this review. Pioneering efforts in this area have been made by Cratty and his colleagues. These investigators have provided evidence that movement distortions can be produced as the result of walking through curved and straight pathways (Cratty & Hutton, 1964); and, by walking on a gradient (Hutton, 1966). Evidence also suggests that there may be optimal times when kinesthetic after-effects are most pronounced (Cratty, 1965; Hutton, 1966). Furthermore, the kinesthetic after-effects produced by maze walking do not appear to stem from proprioceptive feedback supplied by the arm and shoulder musculature, but possibly come from the patterns of gait employed by the subjects, or from the vestibular system (Cratty & Amatelli, 1969).

Studies discussed previously may have involved the effects of kinesthetic after-effects, although the phenomena were not recognized or labelled as such at the time. For example, the use of weighted objects may have resulted in after-effects which distorted subsequent perception of weight (Egstrom et al., 1960; Van Huss et al., 1962).

Summary

Proprioception or kinesthesis is not a general factor, but is comprised of many highly specific components. These components or sensory attributes may be grouped into four general categories which include: (a) sensitivity to force or tension; (b) sensitivity to position and movement; (c) sensitivity to size and length; and, (d) sensitivity to balance and spatial orientation.

It has been impossible to account for the sensory domain of proprioception through the use of a single test; however, assessment of proprioception has been markedly enhanced through the use of test batteries which contain individual items, each designed to measure a different sensory component of proprioception. On the other hand, no "ideal" battery of tests to assess proprioception has been identified.

The techniques of lifting weight objects and of force reproduction on some instrument have been used to assess kinesthetic sensitivity to force or tension. Pertinent information concerning this aspect of kinesthetic sensitivity includes the following:

a) Within limitations, kinesthetic sensitivity to force or tension is subject to Weber's Law. The constant fraction for lifted weights is one-thirtieth of the stimulus weight, whereas the differential threshold for pressure (beyond 10 lb.) is .06. Weber's Law does not apply at the extreme intensities of either force or tension.

b) Sensitivity to weight (resistance) is adversely affected by the presence of contrast weights and by the length of stimulus duration. The greater the contrast weight (real or apparent), and the longer the stimulus duration, the greater the distortions in kinesthetic sensitivity.

c) The phenomenon of adaptation occurs with weight sensitivity. Sensitivity improves as a function of time following exposure to contrasting weights or prolonged stimulus duration.

d) There is limited availability of tests of kinesthetic sensitivity which use the technique of lifting weights; however, instruments which require force reproduction have received extensive use as tests of kinesthesis, and have generally demonstrated good reliability.

e) Sensitivity to force (pressure) is characterized by a "range effect" in which low pressure standards are overestimated and high pressure values are underestimated.

f) Weight lifting tasks, as measures of kinesthesis, are more related to fine manipulative skills than to gross motor skills. Tests of force reproduction have demonstrated the capacity to differentiate skilled from unskilled individuals in gross motor activities.

Sensitivity to position and movement has been assessed through techniques which require angular positioning of the body or limbs; pointing at designated targets;

or, the movement of the limbs on the basis of rate, direction and distance. Significant research findings relative to "position" and "movement" sensitivity indicate:

a) Joint angle reproduction and target pointing tests have demonstrated reliability as measures of kinesthesis, but their validity as individual tests of kinesthesis has not been established. Joint angle positioning tests are commonly used in the study of relationships between kinesthesis and gross motor skills.

b) Positioning accuracy is greatest over those angular ranges which are commonly used in daily activities.

c) The dominant hand is most accurate in commonly experienced joint angle ranges, but the non-dominant hand has demonstrated superior accuracy at novel positioning angles. The dominant hand is also the most accurate in target pointing tasks.

d) The "range effect" also operates with angular positioning and extent of movement, i.e., positive errors occur when attempts are made to reproduce small angular movements or short distances, and negative errors occur when attempts are made to match large angular movements or long distances.

e) Women are superior in performance to men on some target pointing tasks.

f) The visual and proprioceptive sense modalities are equally effective in producing accurate target pointing responses, when considered separately.

g) Accuracy in target pointing is influenced by the orientation of the body, particularly by the position of the head and neck. Accuracy in target pointing is greatest when the head is facing forward and the target is located directly in front of the body.

h) Subjective estimations of "rate of movement" and of "extent of movement" are power functions of the actual rate at which a limb has moved or the physical distance it has traveled, respectively.

i) Accuracy of limb movement is related to the direction and extent of movement. Relative error is greatest with small limb movements and decreases with larger limb movements. Movements away from the body are performed with greater accuracy than movements toward the body.

j) Variations in constant pressure have little effect on angular positioning or active kinesthesis; however, sensitivity in these areas is influenced by progressive changes in torque.

Finger spanning, a technique whereby the subject uses the thumb and forefinger, is the method generally used to assess kinesthetic sensitivity to length. Judgments of size often involve the use of both hands simultaneously. Evidence from research on length and size sensitivity indicates that:

a) Sensitivity to length follows Weber's Law when the extreme limits of length are not considered. The differential threshold is .02 for extents 35 mm. to 100 mm. in length when judgments are made by novices.

b) Few attempts have been made to relate kinesthetic sensitivity to size or length to gross motor performance.

c) Vision, kinesthesis and touch, when considered separately, make assessments of size and length with near equal efficiency. The visual modality appears to dominate when visual and kinesthetic judgments of length are made simultaneously, although the evidence is not conclusive.

d) Sensitivity to size and length can be improved with practice.

e) The size of an object is underestimated as a function of its distance from the body. Judgments of length, however, are consistently overestimated.

f) Kinesthetic judgments of length and width are more accurate when made with one hand than with both hands. Accuracy is superior with the dominant hand. Evidence concerning judgments of size is inconclusive.

Kinesthetic sensitivity to balance and spatial orientation has conventionally been assessed without the aid of visual cues. Under this condition, static balance has been measured through the use of various positions while the subject was supported on one foot and through special instruments designed to assess body sway. Dynamic balance has been assessed via a balancing platform and a balance leap test. Techniques for determining kinesthetic sensitivity to spatial orientation have included such tasks as shifting body weight, walking in prescribed patterns, and tilting and rotating the body.

Results of studies dealing with these components of proprioception are:

a) Static balance is the component most consistently identified as a factor of kinesthesis.

b) Tests of static balance and body sway consistently have demonstrated substantial reliability as measurement instruments. The former have been used extensively in studies of kinesthesis.

c) Performance on body sway tests is influenced by age, sex, shoes and position of the feet. Compared to children, adults demonstrate superior performance on tests of body sway. Girls generally exhibit less body sway than boys. Body sway performance is better with shoes on than with them removed. Body sway is reduced when the feet are slightly separated.

d) Little relationship exists among measures of static balance, dynamic balance and spatial orientation.

e) Dynamic equilibrium is significantly related to weight, height and foot length.

f) Vision plays a dominant role in the performance of subjects on tests of static balance, dynamic balance, and spatial orientation.

g) Inclining or rotating the body without the aid of visual cues results in perceptual distortions of orientation in space.

h) The phenomenon of adaptation occurs after the body has been subjected to an inclined position for prolonged periods of time.

i) Proper functioning of the vestibular system is necessary for optimal sensitivity to spatial orientation.

The importance of proprioception in gross motor performance is generally recognized; however, the extent of its role in movement and the mechanisms by which it operates have not been clearly established. Conventionally, study of the relationship of kinesthesis or proprioception to gross motor performance has been through the use of correlational techniques and group comparisons.

Individual tests of kinesthesis have generally demonstrated low, positive relationships with tests of general motor ability, and with assessments of specific gross motor skills. They have, however, consistently identified skilled from unskilled subjects in the performance of gross motor activities.

Research evidence is limited or unclear with regard to the following:

a) The value of stressing kinesthetic cues when teaching gross motor skills.

b) The stage of motor skill learning at which kinesthetic cues are the most useful.

c) The amount of learning which occurs during the performance of kinesthetic tests.

d) The role of proprioceptive feedback as a mediator for timing motor responses.

e) The effect of kinesthetic after-effects produced by gross motor actions on subsequent gross motor performance or gross motor skill learning.

Questions

A review of the literature indicates that the great majority of studies concerned with proprioceptive sensitivity have dealt with adult subjects. A limited number of such investigations have involved adolescents; but, only a few have been directed at children. Of this latter group, only two studies were identified which investigated the relationship of kinesthesis to gross motor skill learning in young children (Smith, 1956; Witte, 1962). The kinesthetic tests in these studies were limited to the assessment of sensitivity to specific limb positions. Furthermore, the scope of both studies was restricted to comparisons of kinesthesis to ball skills. A third study (Robinson, 1968) involved the development of a battery of tests for assessing various aspects of proprioception in elementary school children. However, the recommended test battery has not been subjected to a controlled research setting.

Little effort has been made to investigate the developmental aspects of proprioception and the changes which may occur as the result of experience. There is some evidence which suggests that such changes may occur in the components underlying kinesthetic sensitivity. Evidence also indicates that this growth may occur differentially for young boys and girls.

Evidence is limited regarding the relationship of proprioception to various measures of physical maturation, mental ability, academic achievement and gross motor performance in young children. It was the lack of evidence concerning the status of proprioception in children and its relationship to other parameters which prompted the current study. This investigation therefore attempted to find answers to the following questions.

Question I. What is the proprioceptive sensitivity of young children to weight, positioning, length and static balance as measured by selected tests of kinesthesis?

Question II. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?

Question III. Are measures of proprioceptive sensitivity related to measures of physical maturation, gross motor performance, mental ability, and academic achievement?

Question IV. To what extent can selected measures of physical maturation, gross motor performance, mental ability, and academic achievement be predicted by performance of tests of proprioception performance?

Question V. Is proprioceptive sensitivity in young children influenced significantly by exposure to a planned program of physical education?

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to investigate the proprioceptive sensitivity of children in kindergarten, first grade, and second grade. More specifically, the study attempted to determine: (a) the relationship of proprioception to physical maturation, motor performance, and intellectual achievement; (b) the ability of measures of proprioception to predict measures of physical maturation, motor performance, and intellectual achievement; and (c) the influence of sex, grade level, and instruction in physical activities upon proprioception in young children.

Experimental Design

The sample consisted of 321 boys and girls attending the kindergarten, first, and second grades at Elmwood and Colt Elementary Schools in the Waverly Public School District, located just to the west of Lansing, Michigan. Enrollment of the children by school, grade level, and sex is presented in Table 3.1. A total of 111 children

Table 3.1

Number of children included in the sample: school, grade, and sex

Grade	Experimental		Control		Subtotals		Total
	Boys	Girls	Boys	Girls	Boys	Girls	
Kindergarten	33	30	19	29	52	59	111
First	37	25	27	30	64	55	119
Second	16	21	25	29	41	50	91
Totals	86	76	71	88	157	164	321

were enrolled in the kindergarten classes, 119 in first grade, and 91 in second grade. Total enrollment for the experimental and control schools in the three grades was 162 and 159, respectively.

The age of each child was calculated to the nearest whole month using October 1, 1969 as the reference date. The means and standard deviations for the ages of the children by grade and school are listed in Table 3.2. It can be noted that the children enrolled in the experimental school are slightly older, on the average, than the children in the control school at each age level. The greatest difference in average age is approximately one month; this occurs at the kindergarten level. Approximately one year separates the mean age of the kindergarten children from that of the first grade children. A similar span of time separates the mean ages of the first and second grade

Table 3.2

Means and standard deviations of the children included in the sample (in months): grade and school

Grade	Experimental		Control		Total	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Kindergarten	65.3	4.03	64.3	4.38	64.8	4.20
First	77.2	4.98	76.6	4.61	76.9	4.82
Second	89.1	3.94	88.7	4.01	88.9	3.97

children. The boys and girls were combined for the calculation of the mean ages, since sex was not found to be an important factor in proprioceptive sensitivity when the initial data were analyzed (see results under Question II in Chapter IV).

It should be noted that the sample size indicates a reduction of 34 subjects from the number of children initially tested in the fall. Nineteen subjects, 7 from the experimental school and 12 from the control school, moved during the schoolyear. An additional 8 children from the experimental and 7 from the control group had incomplete data records due to absences for various reasons. None of the data gathered on these 34 children were included in the analyses for the present investigation. The influence of these "lost" subjects was assessed by computing mean values for selected measures on the initial data gathered in the fall. A comparison of the mean values from data which included and excluded the children who were not present for the post-test analysis failed to show any differences between them. It was, therefore, assumed that the results of the study were not biased by the loss of these children from the original sample.

The two schools involved in the study were originally selected for participation in an experimental research project[1] by the administration of the Waverly School District. Criteria for selection included similarity in the quality of the teaching staffs; in the socio-economic status of the communities in which the schools were located; in the achievement potential of the students enrolled; and, in school facilities.

The schools were randomly assigned to experimental and control conditions. Children in the experimental school (Elmwood) received instruction in physical activities approximately 90 minutes each week. Children in the control school (Colt) received similar amounts of time in supervised free play. One of the three kindergarten classes at the experimental school received only 65 minutes

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[1]The basic purpose of this project, hereafter referred to as the Waverly project, was to determine the effects of a planned physical education program upon academic achievement in early elementary school. The project was under the direction of Drs. Wayne Van Huss and Philip Reuschlein, members of the Department of Health, Physical Education, and Recreation at Michigan State University. The current investigation was conducted within the framework of the Waverly project.

of weekly instruction in physical activities due to scheduling difficulties. The reduction in instructional time was apparently not detrimental since the gains made on the tests of proprioception by members of this class equalled or surpassed those made by members of the other two kindergarten classes (see Appendix A).

Data Collection

Data were secured from the children during the fall of 1969 and again in the spring of 1970. The fall testing was conducted in two phases during September and October. Physical growth and motor performance measures were obtained during the first phase. The proprioception tests and other measures which required less activity were secured during the second phase. Data collection for these measures was completed by the end of September, except for some follow-up testing on children who were absent during the initial testing. Academic achievement and mental ability tests were administered during October, thus approximating the standard time for fall academic achievement testing in the Waverly School System.

The sequence of testing proceeded from the experimental school to the control school for each phase of testing. The same format was followed in the spring when testing was done during the last two weeks of April and the first two weeks of May. Mental ability and academic achievement tests also were administered during this time

period. The test-retest interval was slightly over seven months for the physical growth, motor performance, and proprioception measures; that for the mental ability and academic achievement test was slightly less than seven months.

The testing team for the fall was comprised of 15 members; included were 2 university professors, 1 instructor, 3 doctoral candidates, and 9 master's candidates. All members of the testing team were from the physical education department at Michigan State University. Teachers at the two schools served as supervisors in directing the children to the stations for the purpose of submitting to the tests. Thirteen members of the fall testing team also participated in the spring data collection. They were joined by an additional 9 master's candidates enrolled in a graduate motor development course, and by 3 undergraduate physical education majors whose professional interest was in human motor development. All team members received detailed instructions and training for the tests they were assigned to administer. Whenever possible, the administration of a given test was limited to two or three members of the team. In addition, attempts were made to assign similar testing responsibilities to the members who assisted with both testing sessions.

Physical growth, motor performance, and proprioception tests were administered in a gymnasium and adjacent rooms at both schools. A station approach was used to administer the tests. Subjects moved from station to station in a random fashion, due to the unequal amount of time required at each station. Care was taken to provide rest between strenuous events, as well as between trials on such events. Test administration for all of the children of a specific classroom was completed during a two-hour session. These sessions were scheduled from 9:00 to 11:00 A.M. and from 1:00 to 3:00 P.M. Mental ability and academic achievement tests were administered in the individual classrooms or adjacent work areas. These tests were administered during various hours of the day, but never on the day in which the children participated in the motor performance tests.

Measures

Physical Growth and Motor Performance

A description of each of the physical growth and motor performance measures used in this investigation may be found in Appendix B. Included were the following items:

a) Physical Growth

1) Standing height
2) Weight
3) Ponderal index

b) Motor Performance[1]

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[1] A rather broad definition of motor performance is assumed to allow for the inclusion of such measures as "directionality" and "body part identification." These are undoubtedly more properly classified as perceptual-motor tasks.

1) Body part identification
2) Bouncing and catching a ball
3) Directionality
4) Dynamic balance--balance beam walking
5) Rail balance--1½ in. and 1 in. rails
6) Reaction time--visual and auditory cues
7) Standing long jump
8) Stationary ball dribble

Mental Ability and Academic Achievement

The mental ability and academic achievement tests used in this investigation are listed below. A more complete schedule of these tests, along with a listing of the various subtests, is presented in Appendix C.

a) Mental Ability

1) Kindergraten: Otis-Lennon; Primary I (spring)
2) First Grade: Otis-Lennon; Primary II (fall)
   Otis-Lennon; Elementary I (spring)
3) Second Grade: Otis-Lennon; Elementary I (fall and spring)

b) Academic Achievement

1) Kindergarten: Stanford Early School Achievement Test; Level I (fall and spring)
2) First Grade: Stanford Early School Achievement Test; Level II (fall and spring)
3) Second Grade: Stanford Achievement Test; Primary I (fall)
   Stanford Achievement Test; Primary II (spring)

The Otis-Lennon Mental Ability tests were administered to the three grade levels with the exception of the kindergarten classes during the fall. No test is available in this series for kindergarten children at the beginning of the school year. Kindergarten and first grade children received Levels I and II of the Stanford Early School Achievement Test, respectively. Appropriate levels of the Stanford Achievement Tests were administered to the second grade during the fall and spring.

Proprioception

A battery of four proprioception tests recommended by Robinson (1968) was administered, in modified form, to the children in the study. Detailed instructions for the administration of these tests appear in Appendix D. The tests included in the battery, and the component(s) of proprioceptive sensitivity they are designed to measure, are as follows:

a) One foot balance . . . static balance without the aid of visual cues

b) Parallel blocks . . . bilateral integration of joint angle perception

c) Thickness discrimination . . . . . . fine joint angle perception and judgment of "length"

d) Weight discrimination . sensitivity to fine muscle tension

Reliability coefficients for these tests of proprioception have been determined in several ways. Robinson computed test-retest reliability coefficients after introducing retest intervals of one and two months. He administered

the tests to 21 fifth and sixth grade boys. The four tests utilized by Robinson were also administered to a group of first grade children attending the Motor Performance Study at Michigan State University. Retest scores for these subjects were obtained after an interval of one or two weeks. The Pearson correlation coefficients obtained from these two studies are presented in Table 3.3. It can be noted that in all but two instances, the coefficients equal or surpass the minimum value conventionally accepted for tests of this type.

Table 3.3

Test-retest reliability coefficients: proprioception tests

Test Item	Robinson (N = 21)		Motor Performance Study
	One Month	Two Months	
One foot balance (mean of 3 trials)	.79	.96	.75 (27)[a]
Parallel blocks (mean of 10 trials)	.71	.80	.73 (28)
Thickness discrimination (sum of weighted errors)	.71	.54	.75 (28)
Weight discrimination (sum of weighted errors)	.81	.60	.70 (15)

[a]Number of first grade children tested.

Intraclass correlations, based on trial to trial variability, were computed for the data collected during the fall of 1969. The coefficients ranged from .66 to .85 for the One Foot Balance; from .77 to .82 for the Parallel Blocks test; from .56 to .95 for Thickness Discrimination; and, from .50 to .80 for Weight Discrimination. Of interest is the fact that the higher coefficients were obtained with the kindergarten and first grade children.

Graphic techniques were employed to determine learning and fatigue effects on test performance. It was decided to eliminate the first two trials on the Parallel Blocks test for grades one and two; and, to accept the mean of trials 3 to 10 as the criterion score. This was done to eliminate the large mean errors which occurred during the initial trials, particularly during the first trial. The mean of trials 5 to 8 was used for the kindergarten children to reduce what appeared to be learning effects during the initial trials and fatigue effects during the last two trials. In addition, only the sum of the weighted errors of the first two series were used for the kindergarten children. This procedure also reduced what was interpreted to be a fatigue effect in the series of individual scores. Scoring procedures for the other tests remained as explained in Appendix D. Scoring procedures for the fall and spring testing periods were identical.

Treatment of the Data

Design

The design of the study was basically a two group design consisting of an experimental and a control school, each receiving pretest and posttest measures. The prototype of this design is presented in Campbell and Stanley (1963), designated "Design 10." The design has the restrictions that the schools were not randomly selected from a population of schools, and that the subjects were randomly assigned to a treatment group only to the extent that they were nested within a particular school. Multivariate analysis of covariance (MANCOVA) procedures were therefore used to provide control for possible initial differences between the two schools.

Each school was partitioned by grade level and sex to determine the effects of these factors on proprioceptive sensitivity (see Question II below). In the fall data analysis, the design could be viewed as a three-factor (2 by 2 by 3) design with school, sex, and grade as the independent variables.

Significance Level

The .05 level of significance was chosen for the analyses involving inferential statistical procedures. The selection was made somewhat arbitrarily, but is supported by convention in educational research, and by the fact that observed differences at this level (more readily detectable than at the .01 level) might provide direction to future research, despite the increased risk of committing a Type I error.

Statistical Procedures

The statistical procedures used in this study, both descriptive and inferential, are identified under the research question to which they were applied.

Question I. What is the proprioceptive sensitivity of young children to weight, positioning, length, and static balance as measured by selected tests of proprioception?

Descriptive statistics including means and standard deviations were computed for each of the four proprioception tests by school, grade level, and sex. Whenever multivariate analysis of variance (MANOVA) procedures detected significant grade level differences, but no school and sex differences, percentile norms on each of the four tests were established for each grade.

Question II. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?

MANOVA (Finn, 1967) was used to test the significance of the differences between the initial (fall) performance of the children on the four tests of proprioception when grouped by school, grade level, and sex.

The results of this significance testing were used to determine on what basis percentile norms were to be established under Question I, i.e., by grade. Analyses carried out under Questions III, IV, and V were also based on the initial grade level differences found in proprioceptive sensitivity among the children.

Question III. Are measures of proprioceptive sensitivity related to measures of physical maturation, gross motor performance, mental ability, and academic achievement?

Sample correlation matrices (based on within cell differences which were pooled rather than on individual deviations from a grand mean) were computed on the variables for each of the three grade levels (Finn, 1967). Significance of the individual intercorrelation coefficients obtained from the pretest data was determined at the .05 level by referring to an appropriate table (Underwood et al., 1954, Table D, p. 231).

Question IV. To what extent can selected measures of physical maturation, gross motor performance, mental ability, and academic achievement be predicted by performance on tests of proprioception?

A multivariate multiple regression analysis (Finn, 1967) was employed to estimate the relationships between each dependent variable and the set of four independent proprioception tests at each grade level. Regression equations were established for criterion dependent variables.

Question V. Is proprioceptive sensitivity in young children influenced significantly by exposure to a planned program of physical education?

MANCOVA procedures (Finn, 1967) were used to determine the influence of a planned, instructional program of physical activities on the proprioceptive sensitivity of young children, as measured by the four tests indicated. Separate analyses were made at each grade level to determine if a significant difference in proprioceptive sensitivity existed between the children in the experimental school and those in the control school. Pretest data were used as covariates for the analyses.

It should be noted that the instructional program of physical education was not designed for the specific purpose of improving proprioceptive sensitivity; nor was it designed as a perceptual-motor program. The program was an outgrowth of the Battle Creek Physical Education Curriculum Project (1969) and emphasized the sequential development of motor skills. Consideration was given to the movement of the body and its various parts in space as well as to the more conventional rhythmic, self-testing, and ball skill activities found in elementary school physical education curricula.

CHAPTER IV

RESULTS AND DISCUSSION

The purpose of this study was to investigate the proprioceptive sensitivity of children in kindergarten, first grade, and second grade. More specifically, the study attempted to determine: (a) the relationship of proprioception to physical maturation, motor performance, and intellectual achievement; (b) the ability of measures of proprioception to predict measures of physical maturation, motor performance, and intellectual achievement; and (c) the influence of sex, grade level, and instruction in physical activities upon proprioception in young children. The results of descriptive and inferential statistical procedures applied to each of these questions will be reported.

Question I. What is the proprioceptive sensitivity of young children to weight, positioning, length, and static balance as measured by selected tests of proprioception?

Descriptive statistics were obtained for the performance of children on four tests of proprioception; namely, the One Foot Balance, Parallel Blocks, Thickness Discrimination, and Weight Discrimination. Separate means and standard deviations were computed for kindergarten, first and second grade boys and girls in both the experimental and control schools. These measures are presented in Table 4.1. The average values for performance on the One Foot Balance within each grade are quite similar for the boys and girls in both schools. The notable exception is the high mean value for the first grade girls in the experimental school (7.14) which reflects, in part, the extreme performance score of one subject. In most cases the mean performance values for the girls were slightly larger than those of the boys. Performance in static balance improved from grade to grade for both the boys and the girls. The presence of large interindividual variability in performance, however, is reflected in the magnitude of the standard deviation values.

Performance on the test for bilateral integration of joint angle perception (Parallel Blocks) was assessed by using a mean error score; therefore superior performance is indicated by a low score. There is little difference in the magnitude of the means for this test when comparisons are made between schools, grade levels, or by sex. An exception is the difference in performance

Table 4.1

Means and standard deviations for the performance of children on four tests of proprioception; presented by school, grade level, and sex

Grade	Experimental School				Control School				Total	
	Boys		Girls		Boys		Girls			
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
	One Foot Balance									
Kindergarten	2.92	2.95	3.63	2.24	2.88	1.99	3.20	1.74	3.18	2.32
First	3.93	2.85	7.14	9.41	4.59	5.57	3.93	2.84	4.75	5.56
Second	6.42	5.54	6.70	3.69	5.16	3.18	5.97	4.83	6.00	4.30
	Parallel Blocks									
Kindergarten	33.96	17.83	35.24	13.54	36.52	21.39	32.90	16.14	34.47	16.84
First	32.76	14.04	36.00	16.59	30.71	13.75	34.74	14.96	33.48	14.71
Second	29.06	13.21	40.48	12.60	32.16	14.28	34.86	13.32	34.39	13.75
	Thickness Discrimination									
Kindergarten	5.73[a]	4.22	5.00	3.42	7.68	4.81	7.07	4.41	6.22	4.25
First	6.27	4.72	3.92	3.44	5.85	3.92	6.03	3.80	5.62	4.12
Second	4.62	3.05	3.67	3.17	4.68	4.15	5.17	4.28	4.59	3.79
	Weight Discrimination									
Kindergarten	10.67	5.96	10.03	6.31	8.26	6.20	12.45	5.96	10.55	6.17
First	6.43	3.84	6.80	4.64	6.15	3.32	6.73	4.41	6.52	4.02
Second	5.44	3.01	4.57	3.36	5.96	5.53	5.38	3.53	5.36	4.04

[a]Scores for kindergarten groups represent errors for two series of judgments only.

between the second grade girls and boys in the experimental school where the mean values are 40.48 and 29.06, respectively. Large individual differences also occur in performances on this test. Contrary to the pattern in static balance, the average performance values on this test are slightly higher for the boys than for the girls at all grade levels. Again, one exception is noted; the mean value for girls (32.90) is lower than that for boys (36.52) in the control school.

Thickness discrimination was determined by summing the weighted errors obtained when comparing the thicknesses of six pairs of blocks. The series of six pairs was repeated once with the kindergarten children and twice with the first and second grade children. The mean values for twelve comparisons by kindergarten children and for eighteen comparisons by the first and second grade children are also presented in Table 4.1. In general, performance on this test was relatively consistent within each grade for both boys and girls, with the exception of a lower mean value for the first grade girls in the experimental school. The mean values for the kindergarten children in the experimental school were slightly lower than those for the kindergarten children in the control school. Despite the decreased potential for maximum errors, the kindergarten children demonstrated higher mean error performance with twelve comparisons than the other two

grades with eighteen comparisons. In addition, the error values for the first grade children are greater than those for the second grade children. No consistent sex patterns were apparent. Variability in performance among the subjects was high.

Intragrade performance on the weight discrimination task was also quite similar for the boys and girls in both schools, although kindergarten girls in the control school exhibited greater error performance than the boys in that school. Intergrade mean differences followed a sequential pattern from the kindergarten to second grade. Second grade children were the most proficient in weight discrimination. Interindividual performance variability was also large for this measure.

In summary, the means and standard deviations computed from the performance of young children on measures of proprioception sensitivity suggest that: (a) performance on each of the tests of proprioception tends to be consistent within each grade level; (b) there is great variability in performance among individuals on each of the tests; (c) slight differences in mean performance favor the girls on the test for static balance, and the boys on the test for bilateral integration of joint angle perception; and (d) substantial intergrade differences exist in performance on the One Foot Balance, Weight Discrimination, and Thickness Discrimination tests, but not on the Parallel Blocks test. The results of testing for significance differences in performance on these tests (discussed under Question II) demonstrated grade level differences, but did not suggest either sex or school differences; therefore percentile norms were established for each grade. These standards are presented in Appendix E.

<u>Question II</u>. Do measures of proprioceptive sensitivity in young children vary as a function of grade level or sex?

A MANOVA procedure was used to test the significance of the differences for the pretest (fall) performance of the children on the four tests of proprioception when grouped by school, sex, and grade level. The use of this procedure was considered appropriate since the four tests of proprioception were administered to the same subjects--thus providing four sets of dependent data. A summary of the MANOVA results is presented in Table 4.2. Examination of the generalized multivariate F ratios indicated that none of the interaction effects were significant at the .05 level. However, a significant generalized multivariate F ratio for the main effect of grade level was obtained. The F ratio of 10.62 with 8 and 612 degrees of freedom is significant at the .0001 level.

Examination of the four univariate F statistics for significance can provide information concerning which of the individual tests of proprioception are contributing

Table 4.2

Multivariate analysis of variance for performance on tests of proprioception; illustrating the effect of school, sex, and grade

Source of Dispersion	df	Variable	Univariate F	Univariate P	Multivariate F	Multivariate P
School	1	OFB[a]	0.78	.377		
		PB	0.38	.537		
		TD	4.51	.035		
		WD	0.12	.729	1.45	.217
Sex	1	OFB	3.03	.083		
		PB	2.92	.088		
		TD	2.19	.140		
		WD	0.99	.320	2.27	.062
Grade	2	OFB	11.76	.0001[b]		
		PB	0.09	.909		
		TD	4.93	.008		
		WD	32.84	.0001	10.62	.0001
School by sex	1	OFB	2.05	.153		
		PB	0.75	.386		
		TD	2.69	.102		
		WD	2.14	.145	1.67	.158
School by grade	2	OFB	0.32	.723		
		PB	0.06	.946		
		TD	0.78	.459		
		WD	0.16	.854	0.35	.945
Sex by grade	2	OFB	0.30	.739		
		PB	1.59	.206		
		TD	0.31	.737		
		WD	1.49	.228	0.97	.455
Sex by grade by school	2	OFB	1.95	.144		
		PB	0.63	.533		
		TD	0.62	.537		
		WD	1.92	.148	1.34	.222

[a]OFB = One Foot Balance; PB = Parallel Blocks; TD = Thickness Discrimination; and, WD = Weight Discrimination.

[b]Probability values were rounded off to the nearest .001 unless otherwise listed.

the most to the multivariate effect. Inspection of these statistics indicates that three of the tests are essentially responsible for the multivariate effect. These include the One Foot Balance, Thickness Discrimination, and Weight Discrimination. Performance on the Parallel Blocks test does not appear to be affected by grade level.

The relative magnitude and direction of the influence exerted by the individual tests to the multivariate effect can be determined by inspection of the least squares estimates and their standard errors. They are presented in Table 4.3. It can be observed that the significant differences for the contrast involving kindergarten and second grade occur with all three of the tests mentioned previously, but are the greatest with Weight Discrimination, followed by the One Foot Balance and Thickness Discrimination tests, respectively. The effect of each is also positive, i.e., performance increases from kindergarten to second grade. The significant differences for the first grade--second grade contrast are confined primarily to the static balance test. The point estimates of the thickness and weight discrimination tasks also indicate a positive effect due to grade level, but the magnitude of these effects is not clear since the standard errors relative to the least squares estimates are large.

Simultaneous multivariate confidence bounds developed by Roy (1957) were generated for the grade level contrasts. These are presented in Table 4.4 for the

Table 4.3

Least squares estimates and their standard errors for performance on tests of proprioception; showing grade level contrasts

Variable	Grade Contrasts[a]			
	Least Squares Estimates		Standard Error	
	Kg-G2	G1-G2	Kg-G2	G1-G2
One Foot Balance	-2.93	-1.26	.61	.60
Parallel Blocks	-0.09	-0.82	2.17	2.14
Thickness Discrimination	1.80	1.11	.58	.57
Weight Discrimination	5.24	1.23	.69	.68

[a]Planned comparisons.

Table 4.4

Roy's simultaneous multivariate 95% confidence bounds for performance on tests of proprioception; showing grade contrasts

Variable	Grade Contrasts[a]	
	Kg-G2	G1-G2
One Foot Balance	-2.93 ± 2.27	-1.26 ± 2.23
Parallel Blocks	-0.09 ± 8.07	-0.82 ± 7.96
Thickness Discrimination	1.80 ± 2.16	1.11 ± 2.12
Weight Discrimination	5.24 ± 2.57	1.23 ± 2.53

[a]Planned comparisons.

kindergarten--second grade contrast and also for the first grade--second grade contrast.

Only the relatively large effects due to the kindergarten--second grade contrast on the One-Foot Balance and the Weight Discrimination test scores are detected by this criterion. The effect of the contrast on Thickness Discrimination test scores is not detected. In addition, the effects of the first grade--second grade contrast on the four tests of proprioception are not detected by Roy's simultaneous multivariate 95% confidence bounds. It should be noted, however, that this criterion considers the four dependent variables jointly and is, in general, conservative in its assessments of contrast effects.

Univariate confidence intervals also can be generated when the individual tests of proprioception are considered separately. These are presented in Table 4.5. When this criterion is applied to the kindergarten--second grade contrast, the grade level effect exists for the One Foot Balance, and for the Thickness and Weight Discrimination tests. However, when confidence bounds are established for the grade one--grade two contrast, the grade level effect occurs only for the One Foot Balance.

It, therefore, appears that a span of two grade levels can differentiate between the performance of boys and girls on three tests of proprioception, i.e., One Foot Balance, Thickness Discrimination, and Weight

Table 4.5

Univariate 95% confidence bounds for performance on tests of proprioception; showing grade level contrasts

Variable	Grade Contrasts[a]	
	Kg-G2	G1-G2
One Foot Balance	-2.93 ± 1.22[b]	-1.26 ± 1.20
Parallel Blocks	-0.09 ± 4.34	-0.82 ± 4.28
Thickness Discrimination	1.80 ± 1.16	1.11 ± 1.14
Weight Discrimination	5.24 ± 1.38	1.23 ± 1.36

[a]Planned comparisons.

[b]Confidence bounds = least squares estimates ± 2 standard errors.

Discrimination. However, only differences in performance on the One Foot Balance test are detectable from first grade to second grade.

Since the design of the study was nonorthogonal in nature, i.e., cell frequencies were not equal, further analyses for the main effects of sex and school were not tenable without the introduction of an additional restriction. In other words, subsequent analyses for the main effects of school and sex were restricted by the fact that exact probability statements could not be estimated due to the unequal number of subjects in each cell.

With this limitation in mind, separate multivariate variance analyses were made for sex and school effects at each grade level. The results of these analyses are presented in Table 4.6. Inspection of the

Table 4.6

Multivariate analysis of variance for performance on tests of proprioception; showing the effect of school and sex

Source of Dispersion	df	Variable	Univariate		Multivariate	
			F	P	F	P
Kindergarten						
School	1	OFB[a]	0.18	.672		
		PB	0.01	.942		
		TE	5.82	.018		
		WD	0.13	.716	1.44	.227
Sex	1	OFB	1.47	.228		
		PB	0.06	.810		
		TD	0.72	.398		
		WD	1.43	.234	0.92	.457
School by sex	1	OFB	0.18	.668		
		PB	0.55	.459		
		TD	0.00	.945		
		WD	4.15	.044	1.25	.294
First Grade						
School	1	OFB	0.96	.330		
		PB	0.21	.649		
		TD	0.70	.405		
		WD	0.03	.868	0.48	.753
Sex	1	OFB	1.69	.196		
		PB	1.75	.189		
		TD	2.19	.142		
		WD	0.40	.530	1.56	.189
School by sex	1	OFB	3.63	.059		
		PB	0.02	.886		
		TD	2.82	.096		
		WD	0.02	.885	1.53	.199
Second Grade						
School	1	OFB	1.13	.289		
		PB	0.46	.501		
		TD	1.12	.292		
		WD	0.65	.422	0.78	.541
Sex	1	OFB	0.42	.519		
		PB	4.84	.030		
		TD	0.01	.908		
		WD	0.66	.420	1.60	.183
School by sex	1	OFB	0.08	.776		
		PB	2.29	.134		
		TD	0.78	.379		
		WD	0.03	.871	0.89	.472

[a]OFB = One Foot Balance; PB = Parallel Blocks; TD = Thickness Discrimination; and, WD = Weight Discrimination.

generalized multivariate F ratios indicates that no significant interaction, sex, or school effects were present at any of the three grade levels. These results would "suggest" that the performance of the children in this study on the tests of proprioceptive sensitivity is not influenced significantly by sex or school.

Question III. Are measures of proprioceptive sensitivity related to measures of physical maturation, gross motor performance, mental ability, and academic achievement?

Sample correlation matrices were computed for pretest performance on the variables for each of the grade levels. The .05 level was the criterion employed to determine the significance of the individual intercorrelation coefficients. Intercorrelations between performance on the tests of proprioception and selected measures of physical growth and motor performance are presented in Table 4.7. Twenty-eight or approximately 18% of the 156 intercorrelation coefficients obtained were significant. All but three of these involved either the One Foot Balance or Thickness Discrimination.

Performance on the One Foot Balance and the rail balance items were significantly related to each other at all three grade levels. This would be expected since all these measures assess static balance to some degree. Intercorrelation coefficients for the One Foot Balance and

Table 4.7

Intercorrelations between performance on tests of proprioception and on selected measures of physical growth and motor performance for kindergarten, first and second grades

Variable	One Foot Balance			Parallel Blocks			Thickness Discrimination			Weight Discrimination		
	Kgn	G-1	G-2	Kgn	G-1	G-2	Kgn	G-1	G-2	Kgn	G-1	G-2
Physical Growth:												
Standing height	10[a]	-20*	11	03	-19	-05	-10	01	-08	-17	-13	11
Weight	08	-20*	06	02	-25*	-07	-03	-09	-05	-17	-08	09
Ponderal index	04	00	12	04	10	-00	-10	-14	-02	-02	-07	03
Motor Performance:												
Standing long jump	23*	14	16	04	-07	-24*	-23*	-24*	-27*	-05	-06	-14
Rail balance: 1½ in. rail	32*	46*	38*	-01	-14	-01	-12	-17	07	-10	-18	10
Rail balance: 1 in. rail	32*	31*	34*	-12	-14	-08	-23*	-16	-07	-01	-09	-08
Reaction time: auditory	-13	-04	-08	10	-05	14	06	21*	21*	11	04	-06
Reaction time: visual	-10	-11	-07	15	-02	13	11	31*	19	15	-00	-06
Body part identification	02	12	07	-16	08	19	-04	-17	-25*	02	-16	01
Directionality	03	01	07	-04	06	04	-10	-15	-00	-10	-16	-01
Dynamic balance	34*	14	29*	-10	-07	00	-20*	-14	-03	04	-07	09
Bouncing and catch a ball	19	15	26*	07	-22*	-11	-11	-36*	-26*	-01	-17	05
Stationary ball dribble	26*	13	16	09	-10	-09	-12	-32*	-15	-04	-15	15

[a]Decimal points have been omitted. Kgn (N = 111), G-1 (N = 119), G-2 (N = 91)
*Significant at the .05 level.

the dynamic balance test were also significant for kindergarten and second grade children, but not for the first grade children. No consistent patterns of relationships were apparent for the One Foot Balance test and other measures of physical growth and motor performance, although several individual significant relationships were identified at specific grade levels. Significant intercorrelation coefficients for performance on the Thickness Discrimination test and the Standing Long Jump were found at all grade levels. Ability to judge thickness was also related to auditory reaction time and ball bouncing and catching ability in first and second grade children. Performance on the Parallel Blocks task was significantly related to weight, long jumping, and ball bouncing and catching ability at specific grade levels; however, it is difficult to determine whether these isolated instances of significant interrelationships represent true relationships or whether they are spurious results due to chance. The ability to discriminate weight did not correlate significantly with any of the variables used in this investigation. It should also be noted that none of the significant correlations obtained were of sufficient magnitude to be useful for predictive purposes. The highest Coefficient of Determination obtained was .21 between the One Foot Balance and the static balance test with the 1½ in. rail.

Intercorrelations for performance on the tests of proprioception and selected measures of academic achievement and mental ability are presented in Table 4.8. Eight of the intercorrelation coefficients were significant at the kindergarten level. This represents 50% of the total. However, only 7 of 28 and 2 of 28 were significant at the first and second grade levels, respectively. This indicates a trend toward greater specificity with advancing grade levels for performance on the proprioception measures as related to performance on the achievement variables. Performance by kindergarten children on the Aural Comprehension subtest and on the total Academic Achievement score was significantly related to their performance in the One Foot Balance test, and the Thickness and Weight Discrimination tests. Only Thickness Discrimination test scores correlated significantly with academic achievement scores at more than one grade level. Of interest is the fact that, at the first grade level, Thickness Discrimination scores are significantly related to all the academic achievement and mental ability scores. On the other hand, it should be noted again that all the intercorrelations between tests of proprioception and academic achievement are of low magnitude and of little predictive value. The tests of proprioception are shown in Table 4.9. Only two intercorrelation coefficients were significant, and both were found at the kindergarten level. These involved the

Table 4.8

Intercorrelations between performance on tests of proprioception and on measures of intellectual achievement

Measure	One Foot Balance	Parallel Blocks	Thickness Disc.	Weight Disc.
Kindergarten				
Academic Achievement				
Mathematics	10[a]	-02	-16	-25*
Letters & sounds	22*	05	-04	-07
Aural comprehension	30*	01	-30*	-22*
A.A.-total	24*	-05	-20*	-30*
First Grade				
Academic Achievement				
Mathematics	-08	01	-26*	-16
Letters & sounds	-03	03	-33*	-08
Aural comprehension	02	17	-20*	-09
Reading sent.	02	12	-22*	-11
Word reading	08	09	-28*	-09
A.A.-total	00	15	-31*	-14
Mental Ability	01	12	-30*	-12
Second Grade				
Academic Achievement				
Word reading	-10	-23*	-14	01
Par. meaning	07	-16	-16	-02
Vocabulary	15	03	-17	-03
Word st. skills	15	-23*	-18	-01
Mathematics	16	-09	-19	-05
A.A.-total	14	-17	-18	-02
Mental Ability	10	04	-13	05

[a]Decimal points have been omitted.
*Significant at the .05 level.

Table 4.9

Intercorrelations between tests of proprioception; presented by grade level

Grade and Test	OFB	PB	TD	WD
Kindergarten:				
One Foot Balance (OFB)	1.00			
Parallel Blocks (PB)	.24*	1.00		
Thickness Discrimination (TD)	-.22*	.08	1.00	
Weight Discrimination (WD)	.04	.06	.15	1.00
First Grade:				
One Foot Balance (OFB)	1.00			
Parallel Blocks (PB)	-.08	1.00		
Thickness Discrimination (TD)	-.09	-.12	1.00	
Weight Discrimination (WD)	-.06	-.02	.15	1.00
Second Grade:				
One Foot Balance (OFB)	1.00			
Parallel Blocks (PB)	-.01	1.00		
Thickness Discrimination (TD)	-.16	.10	1.00	
Weight Discrimination (WD)	-.01	.10	.19	1.00

*Significant at the .05 level

One Foot Balance with the Parallel Blocks test, and with Thickness Discrimination. The specificity of the four tests at the other two grade levels is readily apparent.

In summary, only the One Foot Balance and Thickness Discrimination tests correlated with measures of physical growth and motor performance with any degree of consistency.

In addition, none of the intercorrelation coefficients exceeded a value of .46. Significant relationships between performance on the tests of proprioception and the measures of academic achievement and mental ability were most frequent at the kindergarten level. Thickness Discrimination scores correlated most consistently with the academic achievement measures. The low individual intercorrelations provide a signpost for the results obtained when regression procedures were employed to determine the predictive value of the tests of proprioception.

<u>Question IV</u>. To what extent can selected measures of physical maturation, gross motor performance, mental ability, and academic achievement be predicted by performance on tests of proprioception?

A multivariate multiple regression analysis was employed to estimate the relationships between each dependent variable and the set of four independent proprioception tests at each grade level. Regression equations were established for criterion dependent variables. Statistics for the regression analysis with the four tests of proprioception are presented in Tables 4.10 (kindergarten), 4.11 (first grade), and 4.12 (second grade). The regression equations for each grade are presented in Appendix F.

Kindergarten

Examination of the F ratios in Table 4.10 reveals that 6 of the 17 dependent variables appear to be significantly influenced by the addition of these tests of proprioception to the regression equation. These include the standing long jump, the three balance items, the aural comprehension subtest, and the total score for the academic achievement test. Inspection of the multiple R's indicates that their magnitudes are quite low. The highest value at .437 was obtained for the aural comprehension subtest, thus only about 19% of the variability for performance on this test is accounted for by the regression equation. The predictive value of the equation for this test is low and the predictive value of the equations for the other dependent variables is even lower.

A chi-square test of the hypothesis of no association between the dependent and independent variables yielded a value of 87.00 which with 68 d.f. is significant at the .06 level. A step-wise regression analysis was conducted to determine the contribution of each independent variable by adding them one at a time to the regression equation. The Parallel Blocks, Thickness Discrimination, and Weight Discrimination tests all failed to make significant contributions to the regression equation. However, a chi square of 33.57 obtained for the One Foot Balance was significant ($P < .0096$, d.f. =

Table 4.10

Statistics for regression analysis with four tests of proprioception: kindergarten

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth				
Standing height	.043	.207	1.19	.320
Weight	.038	.195	1.04	.389
Ponderal index	.012	.109	0.32	.864
Motor Performance:				
Ball bounce and catch	.042	.206	1.18	.325
Body part identification	.031	.177	0.86	.489
Directionality	.020	.140	0.53	.715
Dynamic balance	.139	.373	4.29	.003
Rail balance: 1½" rail	.121	.347	3.63	.008
Rail balance: 1" rail	.164	.405	5.21	.0008
Reaction time: auditory	.047	.217	1.32	.269
Reaction time: visual	.067	.259	1.91	.114
Standing long jump	.087	.295	2.53	.045
Stationary ball dribble	.077	.278	2.22	.072
Academic Achievement				
Mathematics	.083	.288	2.40	.054
Letters and sounds	.054	.233	1.52	.202
Aural comprehension	.191	.437	6.25	.0002
Aca. Ach.--total	.171	.413	5.45	.0005

[a]All probability values are rounded to the nearest .001 unless otherwise noted.

17). The major influence exerted on the seven variables previously identified was therefore contributed by the addition of the One Foot Balance to the regression equation.

First Grade

Significant F ratios (.05 level) were secured on 13 of the 20 dependent variables for first grade children (Table 4.11). These included height, weight, standing long jump, two static balance measures, visual reaction time, ball bounce and catch, ball dribble, three academic achievement subtests--mathematics, letters and sounds, word reading--academic achievement total score, and mental ability. The highest multiple R obtained was .517 for the 1½ in. rail balance. In general, the multiple correlations generated were not of sufficient magnitude to merit consideration for predictive use.

A chi-square value of 126.38 for the test of the hypothesis of no association between the tests of proprioception and the dependent variables was significant at the .0008 level (d.f. = 80). The step-wise regression analysis did not result in significant chi-square values for the Parallel Blocks and Weight Discrimination tests. However, the Thickness Discrimination test had a chi-square value of 39.43 which was significant at P less than .0059; thus both the Thickness Discrimination and the One Foot Balance tests, in some combination, made significant contributions to the regression equation. The greatest impact of the One Foot Balance test was on the two static balance

Table 4.11

Statistics for regression analysis with four tests of proprioception: first grade

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth:				
Standing height	.103	.320	3.26	.014
Weight	.124	.352	4.02	.004
Ponderal index	.028	.168	0.83	.507
Motor Performance				
Ball bounce and catch	.220	.469	8.02	.0001
Body part identification	.060	.246	1.84	.127
Directionality	.046	.214	1.36	.251
Dynamic balance	.043	.208	1.29	.277
Rail balance: 1½" rail	.267	.517	10.39	.0001
Rail balance: 1" rail	.134	.366	4.41	.002
Reaction time: auditory	.044	.209	1.31	.271
Reaction time: visual	.106	.326	3.39	.012
Standing long jump	.081	.285	2.51	.045
Stationary ball dribble	.141	.376	4.68	.002
Academic Achievement and Mental Ability:				
Mathematics	.097	.311	3.06	.019
Letters and sounds	.117	.342	3.78	.006
Aural comprehension	.065	.256	2.00	.100
Word reading	.088	.296	2.74	.032
Reading sentences	.062	.250	1.90	.116
Aca. Ach.--total	.116	.341	3.75	.007
Mental ability	.105	.323	3.33	.013

[a]All probability values are rounded to the nearest .001 unless otherwise noted.

measures as well as the physical growth measures of height and weight. On the other hand, Thickness Discrimination contributed the most to ball bouncing and catching, the standing long jump, the ball dribble, mathematics, letters and sound, word reading, academic achievement total score, and mental ability.

Second Grade

Multivariate multiple regression analysis for 20 dependent variables at the second grade level yielded only five significant F ratios (Table 4.12). These were the standing long jump, the two static balance tests, body part identification, and the ball bounce and catch test. The multiple R's obtained were also the lowest for any of the three grades. Furthermore, the source of effect on the five significant F ratios mentioned is difficult to determine. The chi-square value (87.32) for the test of the hypothesis of no association between the dependent and independent variable was not significant (d.f. = 80, $P < .2695$). The step-wise regression analysis to determine the contribution of each variable also failed to yield significant chi-square values for any of the tests of proprioception.

In summary, multiple correlations obtained by multivariate multiple regression analysis are not of sufficient magnitude to warrant consideration of the use of the four tests of proprioception for predictive purposes.

Table 4.12

Statistics for regression analysis with four tests of proprioception: second grade

Variable	Square Mult. R	Mult. R	F	P less than[a]
Physical Growth:				
Standing height	.035	.188	0.79	.536
Weight	.022	.147	0.48	.753
Ponderal index	.016	.125	0.34	.849
Motor Performance:				
Ball bounce and catch	.135	.367	3.35	.013
Body part identification	.115	.339	2.80	.031
Directionality	.006	.080	0.14	.968
Dynamic balance	.092	.304	2.19	.077
Rail balance: 1½" rail	.166	.407	4.28	.003
Rail balance: 1" rail	.124	.352	3.03	.022
Reaction time: auditory	.075	.274	1.75	.147
Reaction time: visual	.062	.248	1.41	.237
Standing long jump	.140	.374	3.50	.011
Stationary ball dribble	.082	.286	1.91	.116
Academic Achievement and Mental Ability:				
Word reading	.076	.276	1.78	.141
Paragraph meaning	.048	.220	1.09	.364
Vocabulary	.045	.211	1.01	.409
Word study skills	.093	.304	2.19	.076
Mathematics	.058	.242	1.34	.263
Aca. Ach.--total	.070	.264	1.61	.179
Mental ability	.034	.184	0.75	.558

[a]All probability values were rounded to the nearest .001.

The limited predictability available with these tests is contributed primarily by the One Foot Balance at the kindergarten level, and by both the One Foot Balance and Thickness Discrimination at the first grade level. The effects of the tests of proprioception for predicting the dependent variables at the second grade level was indeterminable.

Question V. Is proprioceptive sensitivity in young children influenced significantly by exposure to a planned program of physical education?

MANCOVA procedures were used to determine the influence of a planned instructional program of physical activities on the proprioceptive sensitivity of young children. Separate analyses were made at each grade level to determine if a significant difference existed between the children in the experimental school and those in the control school in proprioceptive sensitivity. A summary of the MANCOVA results is presented in Table 4.13.

The chi-square test for the hypothesis of no association between the pretest (covariate) and posttest measures of proprioception yielded values of 48.52, 63.60, and 55.15 for the kindergarten, first grade, and second grade children, respectively. These values were all significant at P less than .0001 with 16 degrees of freedom. The covariates were, therefore, retained and included in the linear model assumed for the data.

Table 4.13

Multivariate analysis of covariance for performance on tests of proprioception; illustrating the effect of an instructional program of physical activities

Source of Dispersion	df	Variable	Univeriate F	Univeriate P	Multivariate F	Multivariate P
			Kindergarten			
Sex	1	OFB[a]	0.35	.553		
		PB	0.15	.695		
		TD	1.57	.213		
		WD	1.38	.243	0.77	.545
School	1	OFB	6.97	.010		
		PB	0.19	.659		
		TD	1.60	.208		
		WD	3.47	.065	2.76	.032
School by sex	1	OFB	0.30	.586		
		PB	1.47	.228		
		TD	0.01	.903		
		WD	1.65	.202	0.77	.549
			First Grade			
Sex	1	OFB	5.01	.027		
		PB	15.73	.0002[b]		
		TD	1.49	.225		
		WD	0.26	.608	6.30	.0002
School	1	OFB	1.85	.177		
		PB	1.35	.247		
		TD	0.48	.490		
		WD	0.04	.845	0.94	.445
School by sex	1	OFB	0.00	.987		
		PB	0.31	.581		
		TD	1.56	.214		
		WD	2.32	.131	1.09	.364
			Second Grade			
Sex	1	OFB	0.00	.999		
		PB	0.01	.940		
		TD	0.06	.809		
		WD	0.05	.819	0.04	.997
School	1	OFB	0.09	.768		
		PB	0.92	.341		
		TD	1.34	.251		
		WD	0.03	.869	0.57	.689
School by sex	1	OFB	0.07	.792		
		PB	4.84	.031		
		TD	0.20	.653		
		WD	0.01	.914	1.30	.279

[a]OFB = One Foot Balance; PB = Parallel Blocks; TD = Thickness Discrimination; and, WD = Weight Discrimination.

[b]Probability values were rounded off to the nearest .001 unless otherwise listed.

Kindergarten

The generalized multivariate F ratio obtained for the school by sex interaction was not significant at the .05 level (Table 4.13); however, a significant F ratio was obtained for the school main effect. The F ratio of 2.76 with 4 and 100 d.f. is significant at the .032 level. Inspection of the univariate F statistics reveals that the One Foot Balance test is primarily responsible for the multivariate effect. Some contribution may also be made by the Weight Discrimination test. Examination of the adjusted least squares estimates and their standard errors (Table 4.14) also indicates that both the One Foot Balance and the Weight Discrimination tests exhibit positive effects toward the differences found in the school contrast; however, the effect of the latter measure is obscured by the size of its standard error. The Parallel Blocks test and the Thickness Discrimination test exercise a negative influence on the school contrast.

Roy's simultaneous multivariate 95% confidence intervals were generated for the school and sex contrasts and are presented in Table 4.15. The use of this extremely conservative criterion fails to detect the effect of either the One Foot Balance or the Weight Discrimination test. However, when univariate confidence bounds are generated for each of the tests separately, the school effect on One Foot Balance performance is again detected (Table 4.16). It can also be noted that the effect is in

Table 4.14

Least squares estimates (adjusted for covariates) and their standard errors of performance on tests of proprioception; showing school and sex contrasts

Variable	School and Sex Contrasts			
	Least Squares Estimates		Standard Error	
	School	Sex	School	Sex
Kindergarten				
One Foot Balance	0.88	--	.33	--
Parallel Blocks	1.36	--	3.08	--
Thickness Discrimination	0.80	--	.63	--
Weight Discrimination	-1.79	--	.96	--
First Grade				
One Foot Balance	0.75	-1.33	.55	.56
Parallel Blocks	-2.82	-9.34	2.43	2.47
Thickness Discrimination	0.45	-0.85	.65	.66
Weight Discrimination	-0.17	-0.43	.87	.88
Second Grade				
One Foot Balance	0.72	0.02	2.43	2.45
Parallel Blocks	-2.18	-0.24	2.27	2.29
Thickness Discrimination	0.77	0.19	.67	.67
Weight Discrimination	0.14	-0.19	.83	.84

favor of the experimental school. In other words, the kindergarten children receiving the instructional program in physical education performed significantly better on the One Foot Balance test than the kindergarten children in the control school. Due to the nonorthogonal nature of the design, the presence of this significant school effect precluded meaningful analysis of the sex effect.

First Grade

The generalized multivariate F ratio for interaction effects was also not significant at the first grade level (Table 4.13); nor was the F ratio for the school main effect significant. However, a significant generalized multivariate F ratio was obtained for the sex main effect. The F ratio of 6.30 is significant at the .0002 level (d.f. = 4 and 108). Referral to the univariate F ratios indicated that the Parallel Blocks test and the One Foot Balance are primarily responsible for the multivariate effect. Information concerning the adjusted least squares estimates and their standard errors (Table 4.14) also indicates that the effects of these two tests are in an opposite direction, and that both effects are of substantial magnitude. The Parallel Blocks test exerts a positive effect whereas that of the One Foot Balance is negative in nature. Thickness and Weight Discrimination also exert influence in a positive direction, but the magnitude of their effect is obscured by the relatively large standard errors they possess.

Establishment of simultaneous multivariate 95% confidence bounds for the sex contrast (Table 4.15) identified the sex contrast effect on the Parallel Blocks test, but not on the One Foot Balance. On the other hand, the univariate 95% confidence intervals (Table 4.16) demonstrated significant effects for both of these tests.

The evidence for the first grade children failed to demonstrate a significant program effect on the proprioceptive sensitivity of these children, but it did reveal a significant sex difference in favor of the boys during the course of the seven-month period between pretest and posttest.

Second Grade

Analysis of the effect of an instructional program in physical education on the proprioceptive sensitivity of second grade children is presented in Table 4.13. It can be noted that the generalized multivariate F ratios obtained for the interaction effect and the two main effects all fail to meet the criterion .05 level of significance.

In summary, analysis of the data indicates that the instructional program in physical education had a significant effect on the proprioceptive sensitivity of the kindergarten children in the experimental school. The primary influence of this program was exerted on the proprioceptive component of static balance. MANCOVA

Table 4.15

Roy's simultaneous multivariate 95% confidence bounds for performance on tests of proprioception; showing school and sex contrasts

Variable	Contrasts	
	Exp. - Con.	Boys - Girls
Kindergarten		
One Foot Balance	0.88 ± 1.05	--
Parallel Blocks	1.36 ± 9.79	--
Thickness Discrimination	0.80 ± 2.00	--
Weight Discrimination	-1.79 ± 3.05	--
First Grade		
One Foot Balance	0.75 ± 1.75	-1.33 ± 1.78
Parallel Blocks	-2.82 ± 7.73	-9.34 ± 7.85
Thickness Discrimination	0.45 ± 2.07	-0.85 ± 2.10
Weight Discrimination	-0.17 ± 2.77	-0.43 ± 2.80
Second Grade		
One Foot Balance	0.72 ± 7.80	0.02 ± 7.86
Parallel Blocks	-2.18 ± 7.29	-0.24 ± 7.35
Thickness Discrimination	0.77 ± 2.15	0.19 ± 2.15
Weight Discrimination	0.14 ± 2.66	-0.19 ± 2.70

Table 4.16

Univariate 95% confidence bounds for performance on tests of proprioception; showing school and sex contrasts

Variable	Contrasts	
	Exp. - Con.	Boys - Girls
Kindergarten		
One Foot Balance	0.88 ± 0.66[a]	--
Parallel Blocks	1.36 ± 6.16	--
Thickness Discrimination	0.80 ± 1.26	--
Weight Discrimination	-1.79 ± 1.92	--
First Grade		
One Foot Balance	0.75 ± 1.10	-1.33 ± 1.12
Parallel Blocks	-2.82 ± 4.86	-9.34 ± 4.94
Thickness Discrimination	0.45 ± 1.30	-0.85 ± 1.32
Weight Discrimination	-0.17 ± 1.74	-0.43 ± 1.76
Second Grade		
One Foot Balance	0.72 ± 4.86	0.02 ± 4.90
Parallel Blocks	-2.18 ± 4.54	-0.24 ± 4.58
Thickness Discrimination	0.77 ± 1.34	0.19 ± 1.34
Weight Discrimination	0.14 ± 1.66	-0.19 ± 1.64

[a]Confidence bounds = least squares estimate ± 2 standard errors.

revealed a significant sex effect at the first grade level in favor of the boys at both schools. The effects were centered primarily on the proprioceptive components assessed by the Parallel Blocks tests and by the One Foot Balance. No significant differences by sex or school were obtained for the second grade children.

Discussion of the Results

Means and standard deviations were computed for the performance of children on four tests of proprioception; namely, the One Foot Balance, Parallel Blocks, Thickness Discrimination, and Weight Discrimination tests. These descriptive statistics indicated that the performance of boys and girls at a given grade level is similar for each of the four tests. However, grade level differences were found for the One Foot Balance, Weight Discrimination, and Thickness Discrimination measures. No intergrade differences were evident for performance on the Parallel Blocks test. The MANOVA procedures applied to the pretest data yielded essentially the same results. The change in performance on the three tests was identified for the kindergarten--second grade contrast; but only performance on the One Foot Balance was found to change significantly from the first to the second grade level.

These results suggest that some of the components of proprioceptive sensitivity are still undergoing developmental change during the age period studied. Whether this is the result of maturation and experience is not determinable from the results obtained. The significant effects which resulted from exposure to an instructional program at the kindergarten level provide evidence for the experience factor. On the other hand, the general gains made by all the students between the pretest and posttest could be the result of either experience or maturation, or a combination of both.

The improvement of static balance with age has been reported previously (Miles, 1922; Espenschade, 1947; Fleishman, 1964). The results obtained in this study are in general agreement with the findings of earlier studies. The lack of significant sex differences in static balance performance, however, is not consistent with earlier reports (Miles, 1922; Fleishman, 1964). Static balance was the component affected the most by the instructional program in physical education at the kindergarten level. This component is also significantly related at this grade level to motor performance measures such as the standing long jump and ball dribbling; and, to various academic achievement measures including the aural comprehension subtest, the letters and sounds subtest, and the academic achievement total test score. These results indicate that performance in static balance can be modified. The significant relationship of static balance to motor performance and academic achievement measures suggests that attempts to

improve static balance in kindergarten children through instruction in physical activities may merit some consideration.

Growth in the ability to perceive fine joint angle variations follows a pattern similar to that of static pattern. This ability was significantly related to ability on the standing long jump, body part identification, ball dribbling, and ball bouncing and catching. In addition, it was significantly related to the entire battery of academic achievement subtests and mental ability at the first grade level (see Table 4.8). It was also significantly related to the aural comprehension subtest and the academic achievement total score at the kindergarten level. The ability to make fine angle judgments would appear to be of vital importance for fine manipulative tasks such as small object handling, which often occurs in the physical activities presented to young children. Its importance was demonstrated, in part, by the significant relationship of Thickness Discrimination scores to the two ball skill items included in the study. Academic skills such as the ability to print and write letters also appear to be dependent on sensitivity to length and fine joint angle adjustments. Unfortunately, the importance of this ability in fine manipulative tasks has received limited attention in research.

Sensitivity to weight was also found to change with age. This is in agreement with the results obtained

by Ortmann (1923), with young piano students. The absence of relationships between weight judgment scores and activities such as the ball bounce and catch, and the ball dribble tests is somewhat surprising. From a logical standpoint, sensitivity to force or resistance seems to be a crucial factor for successful performance on such tasks. Possibly such fine discriminations as those required for lifting weights are not required for these activities.

Performance on the limb positioning task (Parallel Blocks) did not change significantly from one grade level to the next, nor were sex differences apparent with this task. Witte (1962) also did not find sex differences on arm positioning measures administered to children, ages 7-9. In addition, no significant relationships were found between the arm positioning measures and the ball rolling tests she used. The results of the present study generally confirm these findings, with the exception that a low, significant correlation (-.22) was obtained between performance on the Parallel Blocks test and the ball bouncing skill of first grade children. The lack of grade level differences on this task is difficult to explain. To assume that this function is already mature in the five-year-old child is in conflict with the significant posttest results obtained with the first grade children. In this case, the boys performed significantly better than the girls on this task, yet they were equal in performance at the beginning of the school year. In addition, no sex differences were noted at the beginning or the end of the school year with the second grade children. No plausible explanation for this phenomenon can be offered.

Results of the correlational analyses are in general agreement with those obtained in previous studies. The significant intercorrelations between measures of proprioception and those of physical growth, motor performance, and academic achievement are generally of a low, positive nature. As such, they are of little predictive value, either as individual tests or collectively as a battery of tests. The specificity of such measures has been demonstrated previously with adults (Fleishman, 1958; Scott, 1955; Hempel & Fleishman, 1955). The results of this study suggest that this is also true for young children. However, the values do suggest that significant intercorrelations occur more frequently at the kindergarten level than at the other two grade levels, and particularly with the academic achievement measures. Furthermore, the only significant intercorrelations which occurred among the tests of proprioception were also obtained from the kingergarten children. These results, plus the fact that the only significant program effects occurred with the kindergarten children, raise an interesting question. Is the apparent trend toward greater specificity with advancing grade levels an actual occurrence or just a chance phenomenon that occurred with this sample of children?

If such a trend does exist, it could imply a greater interdependence among the various functions of the central nervous system for the behavioral responses of young children. For example, it is estimated that neurological growth is about 90% complete by age seven (Watson & Lowry, 1967). However, this refers to growth in size. It is feasible that neurological differentiation is not complete in the five-year-old child, so that there is greater common use of central neural processes for various types of behavioral output. As differentiation proceeds, specificity increases so that fewer significant relationships are noted among measures of different abilities. That such a phenomenon occurs among the sense modalities is suggested by Abel (1936). Such a trend would also provide a plausible explanation for the significant effect of instruction in physical activities on the proprioceptive performances of kindergarten children, but not on such performances by first and second grade children.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the relationship of selected measures of proprioception to physical growth, motor performance, and academic achievement in young children. Measures on the One Foot Balance, Parallel Blocks, Thickness Discrimination, and Weight Discrimination tests were obtained from 321 boys and girls attending the kindergarten, first and second grades at Elmwood and Colt Elementary Schools in the Waverly Public School District near Lansing, Michigan. There were 111 kindergarten, 119 first grade, and 91 second grade children (157 boys and 164 girls) included in the study. Pretest and posttest data were secured from the children for the proprioception tests as well as for the following measures:

a) Physical Growth

1) Standing height
2) Weight
3) Ponderal index

b) Motor Performance

1) Body part identification
2) Bouncing and catching a ball
3) Directionality
4) Dynamic balance--balance beam walking
5) Rail balance--1 1/2 in. and 1 in. rails
6) Reaction time--visual and auditory cues
7) Standing long jump
8) Stationary ball dribble

c) Mental Ability

1)	Kindergarten:	Otis-Lennon; Primary I
2)	First Grade:	Otis-Lennon; Primary II
		Otis-Lennon; Elementary I
3)	Second Grade:	Otis-Lennon; Elementary I

d) Academic Achievement

1)	Kindergarten:	Stanford Early School Achievement Test; Level I
2)	First Grade:	Stanford Early School Achievement Test; Level II
3)	Second Grade:	Stanford Achievement Test; Primary I
		Stanford Achievement Test; Primary II

The two schools were randomly assigned to experimental and control conditions, respectively. The experimental school received a planned physical education program while the children of the control school had supervised free play in lieu of an organized activity program.

Means and standard deviations were computed for each of the four proprioception tests on the pretest data and comparisons were made by school, grade level, and sex. Percentile tables were constructed for each test and grade. The significance of the differences in performance by children on the tests of proprioception was determined by MANOVA for school, grade level, and sex.

Sample correlation matricies were computed on all the variables for each of the three grade levels. A multivariate multiple regression analysis was employed to estimate the relationships between each of the dependent variables and the set of four proprioception tests at each grade level, and regression equations were established for the criterion dependent variables. MANCOVA procedures were used to determine the influence of a planned physical education program on the proprioceptive sensitivity of the children at each grade level.

The results of the study suggested that performance on each of the tests of proprioception tends to be consistent within each grade level, but that there is great variability in individual performance on each of the tests. Intergrade differences were found in the performance of children on the One Foot Balance, Weight Discrimination, and Thickness Discrimination tests; but not on the Parallel Blocks test. No substantial sex differences were evident among the three grade levels.

The MANOVA procedure determined the existence of significant grade level differences in performance on the One Foot Balance, Thickness Discrimination, and Weight Discrimination tests. The grade level differences were most pronounced in the performance of static balance. No significant differences were found between the two schools or between boys and girls at the three grade levels.

Correlations between Thickness Discrimination and the One Foot Balance test scores reached significance most frequently with measures of physical growth, motor performance, and academic achievement. The Parallel Blocks and Weight Discrimination tests were significantly related to the physical growth, motor performance, and academic measures only in isolated instances. None of the intercorrelations were of sufficient magnitude to be useful for predictive purposes, i.e., they were below .50. Significant intercorrelation values between the proprioception measures and academic achievement measures were most frequent at the kindergarten level and decreased with each increasing grade level. Tests of proprioception were significantly interrelated only at the kindergarten level.

Results of the multivariate multiple regression analysis revealed that the tests of proprioception were most influential in predicting physical growth, motor performance, and academic achievement variables at the first grade level. However, the multiple R's obtained were generally low, with the highest coefficient secured having a magnitude of only .517.

The instructional program in physical education had a significant effect on proprioceptive sensitivity only at the kindergarten level. This effect was most pronounced in static balance performance. A significant sex effect was demonstrated at the first grade level; however, this difference could not be attributed to the physical education program introduced in the study.

Conclusions

The following conclusions are drawn from the results of this study:

a) The performance of young children on the One Foot Balance, Parallel Blocks, Thickness Discrimination, and Weight Discrimination tests of proprioception is consistent within each grade level; however, there is great individual variation in performance on each of the tests.

b) Improvement in performance occurs with each succeeding grade level on the One Foot Balance, Weight Discrimination, and Thickness Discrimination tests; but growth in performance on the Parallel Blocks test does not occur.

c) Evidence concerning sex differences is inconclusive. Although no significant sex differences were evident from the pretest data, significant differences were obtained between first grade boys and girls on posttest analyses.

d) Only the One Foot Balance and Thickness Discrimination tests contributed a consistent significant correlation to the matrix of tests involving physical growth and motor performance.

e) None of the individual intercorrelations, nor the multiple correlations, were of sufficient magnitude to predict measures of physical growth, motor performance, and academic achievement with any degree of accuracy.

f) Thickness Discrimination scores correlated most consistently with measures of academic achievement.

g) The relationship of measures of proprioception to measures of physical growth, motor performance, and academic achievement decreases with succeeding grade levels. Relationships among the tests of proprioception demonstrate their specificity in assessing unrelated components of proprioceptive sensitivity.

h) A planned program of physical education can have a positive influence on the proprioceptive sensitivity of kindergarten children; however, beneficial effects for first and second grade children have not been demonstrated.

Recommendations

The following suggestions are recommended for future research concerned with proprioceptive sensitivity in young children:

a) The low intercorrelations and multiple correlations obtained with the test battery used in this study indicates the need for a more extensive selection of tests to assess proprioceptive sensitivity in young children; and, to predict performance on other measures.

b) There is need for a longitudinal study to determine the developmental changes which take place in the various components of proprioceptive sensitivity; and, also to determine the extent to which they can be modified.

c) The study of proprioceptive sensitivity needs to be extended to younger age levels to determine if the frequency and magnitude of the intercorrelations obtained with five-year-old children are also present with three- and four-year-old children.

d) The frequency with which ability in fine joint angle perception (Thickness Discrimination) correlated with measures of motor performance and academic achievement merits further research and suggests the inclusion of additional tasks assessing fine manipulative skills in the study of proprioception in young children.

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APPENDICES

APPENDIX A

PERFORMANCE ON PROPRIOCEPTION TESTS

Table A.1

Mean performance and gain in performance on four tests of proprioception by children in three kindergarten classes receiving different amounts of instructional time in physical education

Classroom and Instructional Time		PB[a] Mean	OFB[b] Mean	TD[c] Mean	WD[d] Mean
Classroom A (90 min.)	Spring:	14.05	2.37	6.09	9.28
	Fall:	14.26	1.95	6.38	10.67
	Gain:	-0.21	+0.42	-0.29	-1.39
Classroom B (85 min.)	Spring:	12.46	3.34	3.32	8.76
	Fall:	12.96	3.87	4.67	11.83
	Gain:	-0.50	-0.53	-1.35	-3.07
Classroom C (65 min.)	Spring:	11.26	4.57	4.00	8.40
	Fall:	13.24	3.59	5.04	10.20
	Gain:	-1.98	+0.98	-1.04	-1.80

[a]PB = Parallel Blocks--a negative gain score denotes improvement.

[b]OFB = One Foot Balance--a positive gain score denotes improvement.

[c]TD = Thickness Discrimination--a negative gain score denotes improvement.

[d]WD = Weight Discrimination--a negative gain score denotes improvement.

APPENDIX B

PHYSICAL GROWTH AND MOTOR PERFORMANCE MEASURES

APPENDIX B

PHYSICAL GROWTH AND MOTOR PERFORMANCE MEASURES

Physical Growth

Purpose: To assess the status of physical growth and body physique.

Facilities and Equipment: A room or space at least 8 ft. by 10 ft. Anthropometric equipment (anthropometer or device for measuring linear growth, scale for measuring weight).

Procedures:

Weight: The subject should be nude or as briefly attired as possible. Record the weight to the nearest pound.

Standing Height: Measurements are taken with the subject standing against the wall. Heels are placed together, in contact with the wall. Hands are allowed to hang freely at the sides. The head is positioned in the Frankfurt plane. A two-meter, metal anthropometer is placed parallel to the wall, at the midfrontal plane. The sliding bar of the anthropometer is brought down, without pressure, on the vertex. Height is recorded to the nearest millimeter.

Ponderal Index[1]: The Ponderal Index is computed by dividing the height (inches) by the cube root of weight (pounds). Compute to two decimal places.

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[1]R. W. Parnell, Behavior and Physique (an introduction to practical and applied somatometry) (London: Edward Arnold, Ltd., 1958).

Motor Performance

Body Part Identification

Purpose: To measure the ability to identify parts of one's body essential in understanding movement and physical activity.

Facilities and Equipment: An isolated space at least 10 ft. by 12 ft. in size.

Procedures: The examiner and subject stand face to face at an intervening distance of approximately 6 to 10 feet.

Instructions to the Subject: "I am going to ask you to point to different parts of your body. If I ask you to point to your nose you will do this (examiner points to his own nose)."

Instructions to the Examiner: The following body parts will be used, and in the order presented here: knee, elbow, ribs, neck, chin, shoulder, thigh, ankle, hips, calf, chest, wrist, thumb, sole, palm, heel, biceps, abdomen, brain, heart.

Scoring: One point will be awarded for each correct response by the child. Maximum points: 18.

Bouncing and Catching a Ball

Purpose: To measure catching ability.

Facilities and Equipment: Five standard-sized tennis balls and a smooth surface.

Procedures: The subject bounces and catches a standard-sized tennis ball, using only one hand at a time for the bouncing and catching. Two 30-second trials are allowed. If a ball is missed and rolls away, it need not be retrieved by the subject, rather another ball is substituted by the examiner and the test continues without interruption.

Instructions to the Subject: "You are to bounce and catch this tennis ball, using only one hand at a time for bouncing and catching. Try to bounce and catch it as many times as possible in 30 seconds. If you miss the ball and it rolls away, I will give you another ball so that you can continue the test. You will be given 2 trials."

Motor Performance

Bouncing and Catching a Ball: (Continued)

Instructions to the Examiner: Do not permit the subject to "trap" the ball with the body or assist in catching the ball with any other body part. The subject must catch the ball with only one hand at a time.

Scoring: Score one point for each successful catch in the 30 second time period. The better of two trials is recorded.

Directionality

Purpose: To determine if the subject is aware of the different directions in which his body may move.

Facilities and Equipment: An isolated space at least 10 ft. by 12 ft. in size.

Procedures: The examiner and subject stand face to face at an intervening distance of approximately 6 to 10 ft.

Instructions to the Subject: "I am going to ask you to move your body in different directions. If I ask you to take two steps forward you will do this (instructor takes two steps forward). Wait until I finish giving you directions each time, because you may have to make more than one movement at a time."

Instructions to the Examiner: Be sure that the child understands that he is to wait until you have finished speaking before he attempts the movement or movements you have described.

The following sentences will be given to the child, in the order presented below:

1. Take 2 steps backward.
2. Take 2 steps to the front.
3. Take 1 step to the left.
4. Bend down (and up again).
5. Take 2 steps to the rear.
6. Take 1 step to the right.
7. Reach up with both arms.
8. Touch the top of your head.
9. Touch the bottom of your foot.

Motor Performance

Bouncing and Catching a Ball: (Continued)

10. Now, I want you to move forward and to the side at the same time, as many steps as you can take. (stop)
11. Turn yourself half way around. (and return)
12. Now, move backward and to the side at the same time.
13. Turn yourself all the way around.
14. Rotate your head.
15. Start turning in a clockwise direction until I say stop.
16. Step forward.
17. Move your right arm in a horizontal direction.
18. Start turning in a counter clockwise direction. (stop)

Scoring: One point for each correct movement. Maximum: 18 points.

Dynamic Balance (Balance Beam Walking Test)

Purpose: To measure dynamic balance.

Facilities and Equipment: A twenty-foot balance beam with a two-inch walking surface, constructed by joining (end to end) and supporting two ten-foot beams (2 in. by 4 in.).

Procedures: The subject is to mount the beam and walk in heel-toe fashion for the length of the balance beam. When the subject reaches the end of the beam, a turn is made and the subject walks back in the opposite direction. The subject continues walking in this manner until balance is lost or the maximum time period (90 sec.) has elapsed. Two trials will be awarded.

Instructions to the Subject: "You are to mount the beam and walk in a heel-toe fashion for the length of the balance beam. When you reach the end of the beam, turn around and walk back in the opposite direction. Continue in this manner until you lose your balance, or until I tell you to stop. You will be given two trials."

Instructions to the Examiner: The heel-toe position should be demonstrated to the subject. The subject should be timed from the moment he mounts the balance beam until he touches the floor or beam support area, runs on the beam,

Motor Performance

Dynamic Balance: (Continued)

or fails to continue walking in a heel-toe manner. The arms may be used to aid balance, but may not contact the floor or beam. Administer two trials to each subject. If the child falls off the beam when first mounting the apparatus, count it as a practice trial. Both trials are to be taken successively.

Scoring: The score is recorded to the nearest whole second. The better of two trials is recorded. Maximum score: 90 seconds.

Rail Balance

Purpose: To measure static balance.

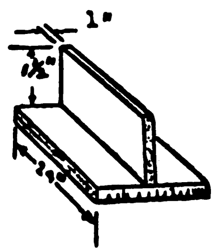
Facilities and Equipment: The balance rails are two pieces of wood 1 and 1-1/2 inches wide, 1-1/2 inches high, and 24 inches long. The rails are mounted on a base as shown below.

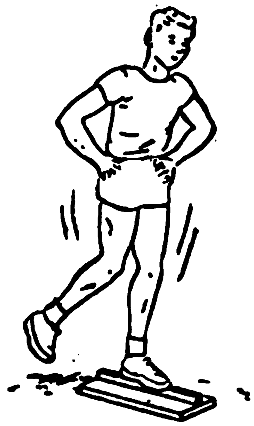
Procedures: The subject should face a wall so that distractions are reduced. The student is to balance with one foot on the rail in a lengthwise fashion, i.e., parallel to the long axis of the rail. The eyes are kept open and the arms and non-supporting leg may be used to assist in maintaining balance, providing they do not touch the supporting leg, the rail, or the floor surface. Each subject is allowed a number of trials with the preferred foot. Testing continues until the test administrator is assured that a reasonable assessment of the subject's performance has been obtained. It is particularly necessary that the subject's attention is directed to the task at hand. With the younger age groups, the subject's attention is critical. The subjects are encouraged.

Instructions to the Subject: "You are to balance as long as possible on one foot. As soon as you touch any other part of your body to the floor or to the rail the trial has ended. You may move your arms and free leg in any way to assist you in balancing on the rail, but you may not move your foot on the rail. I will start the watch whenever you have started your balance."

Motor Performance

Rail Balance: (Continued)





Instructions to the Examiner: Assume a position to the side and slightly to the rear of the subject. Start the watch when the subject removes his foot from the supporting surface. The trial ends if the foot on the rail shifts to and fro or if any other part of the body touches the floor or the rail.

Scoring: Record the time in seconds that balance is maintained on the rail. The better of two trials is recorded to the nearest whole second for each rail width. Maximum score for each rail width: 99 seconds.

Reaction Time

Purpose: To determine the rate of response to an auditory and a visual stimulus.

Facilities and Equipment: One table, two chairs, one Athletic Performance Analyzer. A quiet space.

Procedure: The subject is seated at a table, upon which the Athletic Performance Analyzer rests. The examiner sits at the table on the side opposite the subject. The subject is told to depress the button as quickly as possible after hearing the signal or seeing the light on the Performance Analyzer.

Motor Performance

Reaction Time: (Continued)

The subject is allowed 6 warm-up trials (3 audio- and 3 visual) during which time corrections and suggestions for improvement are made. At the conclusion of the 6 trials the subject engages in 5 successive trials with an auditory stimulus and 5 trials with a visual stimulus.

The order in which the 5 auditory trials and the 5 visual trials were presented is determined by random selection. The delay between the instructor's command "ready" and the stimulus (0 to 2 seconds) is also randomly determined for each trial.

Instructions to the Subject: "You are to place your thumb on this button (switch). I will say "ready" and shortly thereafter you will (see) (hear) the signal. When you (see) (hear) the (light) (sound) you are to push your thumb down as quickly as possible."

Instructions to the Examiner: Be sure that the clock is reset after each trial. The pattern of times between the "ready" signal and the stimulus must be observed and reset after each trial. Record each score without verbalizing.

Scoring: Each trial is recorded to the nearest 1/100 second. If the subject is not ready or other disturbances interfere with the trial another trial should be substituted. The average of the 5 visual trials is the visual reaction time score. The average of the 5 auditory trials is the auditory reaction time score.

Standing Long Jump

Purpose: To measure power and balance.

Facilities and Equipment: The test should be conducted on a hard surface which provides adequate traction for bare feet or gym shoes. Tumbling mats should not be used for the jumping surface. A take-off restraining line is established. Another line marked in inches is laid down perpendicular to the restraining line.

Procedures: The subject starts with both feet behind the restraining line. Demonstrate the proper method of bending

Motor Performance

Standing Long Jump: (Continued)

the knees and use of the arms as an aid in jumping. Each subject is allowed three trials.

Instructions to the Subject: "You are to jump as far as possible. Be sure to begin and end the jump on two feet. You may jump whenever you are ready."

Instructions to the Examiner: Each child is permitted three attempts, taken in succession. If a child falls upon landing, disregard the jump and substitute another trial. The scorer should stand near the point where the child is expected to land. Do not permit preliminary movements such as shuffling of the feet prior to take off.

Scoring: The score is the distance measured to the largest half-inch between the restraining line and the heel closest to the restraining line. Record the best of three trials.

Stationary Ball Dribble

Purpose: To measure the ability to dribble a ball. Hand-eye coordination.

Facilities and Equipment: Five 6-inch playground balls and a smooth surface.

Procedures: The subject dribbles (bounces without catching) a six-inch playground ball one-handed. Two 30-second trials are allowed. If the ball is missed and rolls away, it need not be retrieved by the subject; another ball is substituted by the testor and the testing continues without interruption.

Instructions to the Subject: "You are to dribble the ball as many times as you can in 30 seconds. If you miss the ball and it rolls away, do not go after it, I will give you another ball so that you can continue the test. You will be given two trials."

Instructions to the Examiner: The ball must be dribbled with one hand at a time. If the ball gets away from the subject, replace it immediately with another ball.

Motor Performance

Stationary Ball Dribble: (Continued)

Scoring: Score one point for each successful dribble in the 30-second testing period. The better of two trials is recorded.

APPENDIX C

MENTAL ABILITY AND ACADEMIC ACHIEVEMENT MEASURES

APPENDIX C

MENTAL ABILITY AND ACADEMIC ACHIEVEMENT MEASURES

Fall	Spring
Kindergarten	
No mental ability test	Otis-Lennon[1]: Primary I (K)
SESAT[2]: Level I	SESAT: Level I
1. Environment	1. Environment
2. Mathematics	2. Mathematics
3. Letters and sounds	3. Letters and sounds
4. Aural comprehension	4. Aural comprehension
First Grade	
Otis-Lennon: Primary II (K)	Otis-Lennon: Elementary I (J)
SESAT: Level II	SESAT: Level II
1. Environment	1. Environment
2. Mathematics	2. Mathematics
3. Letters and sounds	3. Letters and sounds
4. Aural comprehension	4. Aural comprehension
5. Word reading	5. Word reading
6. Reading sentences	6. Reading sentences
Second Grade	
Otis-Lennon: Elementary I (J)	Otis-Lennon: Elementary I (K)
SAT[3]: Primary I (W)	SAT: Primary II (W)
1. Word reading	1. Word meaning
2. Paragraph meaning	2. Paragraph meaning
3. Vocabulary	3. Science and Social Studies Concepts
4. Spelling	4. Spelling
5. Word study skills	5. Word study skills
6. Arithmetic	6. Language
	7. Arithmetic computation
	8. Arithmetic concepts

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[1]Mental ability test.

[2]Stanford Early School Achievement Test.

[3]Stanford Achievement Test.

APPENDIX D

PROPRIOCEPTION TEST BATTERY

APPENDIX D

PROPRIOCEPTION TEST BATTERY

One Foot Balance

Purpose: To measure the ability to maintain static equilibrium while blindfolded.

Equipment and Facilities: 1 blindfold, 1 stop watch, and a smooth, warm surface.

Procedures: The subject, barefooted and blindfolded, is asked to balance on his preferred foot as long as possible without touching his free foot to the floor or against his supporting leg.

Time begins when the non-preferred foot is removed from the floor and it stops when the weight-bearing foot is moved or when the free foot touches either the floor or the supporting leg. The arms may be moved in any direction to maintain balance. Three trials are given.

Instructions to the Subject (suggested): "Watch me stand on one foot (demonstrate . . . show me how you can balance on one foot . . . can you do it with your eyes closed? . . . now let's see how long you can balance on your favorite foot with this blindfold over your eyes . . . we will give you three trials . . . you may begin your first try any time you are ready . . . that was good, stand on both feet and rest a bit (record score) . . . now let's try it again . . . good, rest on both feet . . . now once more . . . that was very fine . . . you may take off the blindfold . . . thank you."

Instructions to the Examiner: Demonstrate the one foot balance before administering the test to the subject. The subject is not allowed to rest one foot on top of the other nor should his free leg be in contact with the supporting leg. After the subject has tried the balance with his eyes open first and then with them closed, he should be blindfolded. He may begin the first trial as soon as he is

One Foot Balance (continued)

ready; time begins when the free foot is removed from the floor. The subject should stand on both feet between trials while the score is being recorded.

Scoring: Record each trial to the nearest 1/10 second. The subject's score is the average of the three trials.

Parallel Blocks

Purpose: To measure bilateral integration of joint angle perception.

Equipment and Facilities: 1 parallel blocks test apparatus, 1 blindfold, 1 small table, 2 chairs, and a small room or quiet area.

Procedures: The subject is seated, blindfolded, at the table opposite the examiner. The midline of the apparatus is placed to coincide with the midline of the subject. The subject is seated close to the table to reduce body rotation and lateral movements; the head is directed forward.

The subject holds a small wooden block between the thumb and forefinger of each hand and slides them in their respective grooves until he thinks they are exactly opposite each other. The blocks may be moved back and forth alternately prior to their final positioning. Before each trial the blocks are positioned at ends opposite each other in their respective grooves. The initial position of the blocks is determined randomly by the examiner with each block placed at each end of the groove an equal number of times.

The arms of the subject must not touch the table surface while performing the test--they should move freely in space. When the subject feels the blocks are directly opposite each other he removes the thumb and forefinger from each block and rests his arms and hands on the table to either side of the apparatus.

Ten trials are given. The subject is not told his score.

Instructions to the Subject (suggested): "Here is a game I think you will like to play . . . let me show you how it works . . . we put our thumb and forefinger on each of these blocks, like this, and then slide them down the grooves until we think they are exactly opposite each other . . . like this . . . here, you try it . . . that was easy, wasn't it? . . . the game is really played with this

Parallel Blocks (continued)

blindfold on . . . let me help you put it on . . . I will help your hands find the blocks at the beginning of each trial . . . you will have ten trials . . . remember to move the blocks so that they are exactly opposite each other and when you think they are . . . remove your thumb and forefinger from each block and rest your arms on the table."

Instructions to the Examiner: After the subject is seated, introduce the apparatus. Demonstrate the positioning of the thumbs and forefingers on the blocks; be sure the arms are not touching the table. Show how the test is performed and how the hands are removed from the blocks without moving the blocks. Allow the subject one trial without the blindfold to check his understanding of the procedures. Blindfold the subject and begin testing. THE SUBJECT'S HANDS MAY HAVE TO BE GUIDED TO THE BLOCKS AT THE OUTSET OF EACH TRIAL. Be sure the subject's head remains in a straight forward position during the testing.

Scoring: After the subject has removed his hands from the blocks, the position of each block, using the edge closest to the examiner, is recorded to the nearest millimeter. The difference between the two scores is determined and recorded in the "difference" column as indicated below:

	Left Block	Right Block	Difference
Trial 1	137	148	11
Trial 2	145	153	8
"	"	"	"
"	"	"	"
"	"	"	"

The subject's final score is the mean of the ten "difference" scores.

Thickness Discrimination

Purpose: To measure the ability to discriminate between fine variations in joint angles and the ability to differentiate among "lengths."

Equipment and Facilities: 1 set of 3 in. by 4 in. blocks consisting of: (a) a standard block 18 mm. in thickness; and (b) comparison blocks 15, 16, 17, 19, 20 and 21 mm. in thickness, respectively. Also 1 apparatus board for presenting the blocks, 1 blindfold, 1 small table, 2 chairs, and a small room or quiet area.

Thickness Discrimination (continued)

Procedures: The subject is seated, blindfolded, at the table opposite the examiner. The apparatus board is held at a convenient angle (about 30°) to the surface of the table so that the blocks can be readily located by the subject.

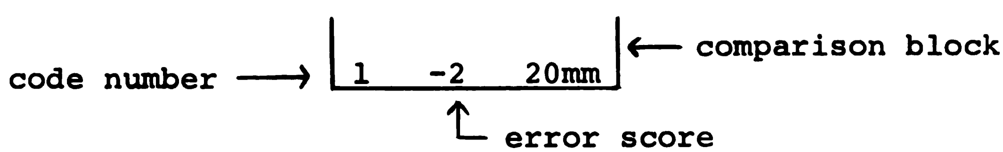
The standard block is placed permanently on the right extension of the apparatus board (from the examiner's viewpoint) and the comparison blocks are placed on the left extension with the numbers located on the blocks facing the examiner. The blocks are presented in pairs until each comparison block has appeared with the standard block. The standard block is always presented first to the subject; the order of presentation for the comparison blocks is randomized.

The subject is to feel the thickness of the blocks by placing his thumb on the underside of the block and his fingers on the top side. The preferred hand is used. After each pair of blocks has been felt, the subject indicates which block is thicker (fatter) by tapping the chosen block. If the subject hesitates, repeat the pair once more.

The series of six pairs is presented three times. The subject is not told if his choice was right or wrong.

Order of Presenting Comparison Blocks: The numbers one through six are randomly ordered for each series of comparisons to be made. These may be prepared prior to the time of testing from a table of random numbers.

The comparison blocks are presented in the order of their corresponding code numbers which appear in the lower left-hand corner of the blocks. For example, the random order of the three series for a subject may be: 256341, 541263, and 651342.



Instructions to the Subject (suggested): "I have a game here which is fun to play . . . let me show you how it works . . . we take two blocks and put them on these extensions, like this . . . then we feel them with our favorite hand, like this . . . we try to find out which one is thicker (fatter) by feeling with our thumb and fingers . . . then we tap the one we think is the thickest (fattest), like this . . . try it with your eyes open first . . . feel this one first . . . then this one . . . which one was the

Thickness Discrimination (continued)

fattest? . . . good . . . now let's try one with our eyes closed . . . do you understand how the game is played? . . . now let's put this blindfold on and play the game . . . I will give you two blocks to feel and you tell me which one is the fattest (thickest) by tapping the one you picked. You will have 18 tries, but I will have to mix up the blocks after every six tries."

Instructions to the Examiner: After the subject is seated, introduce the test as a game. Demonstrate the position of the thumb and fingers on the blocks. Show how the blocks are placed on the plastic extensions and explain that he will be expected to tap the block he thinks is the thickest (fattest). Let the subject attempt a trial without the blindfold to check if he understands the procedure. When this is assured, place the blindfold over the subject's eyes and begin testing.

Scoring: The test is scored by a weighted error system where:

a) a correct response is scored as "zero."
b) an error of one mm. above or below the standard is scored as "1."
c) an error of two mm. above or below the standard is scored as "2."
d) an error of 3 mm. above or below the standard is scored as "3."

The error number for each comparison block is the middle number at the base of the block. The "plus" or "minus" signs are used to indicate the direction of the error as follows:

a) use a "plus" when a thinner comparison block (15mm, 16mm, 17mm) is judged to be thicker than the standard block.
b) use a "minus" when a thicker comparison block (19mm, 20mm, 21mm) is judged to be thinner than the standard block.

The subject's final score is the sum of the weighted errors for the three series.

Weight Discrimination

Purpose: To measure the ability to discriminate between fine variations in muscle tension.

Equipment and Facilities: 1 set of weights consisting of identical small glass bottles containing lead shot and

Weight Discrimination (continued)

packed with cotton including: (a) a standard weight bottle weighing 75 gm.; and, (b) comparison weighted bottles of 60, 65, 70, 80, 85 and 90 gm., respectively. Also 1 blindfold, 1 small table, 2 chairs, and a small room or quiet area are needed.

Procedures: The subject is seated, blindfolded, at the table opposite the examiner. The entire forearm of the subject is placed on the table with preferred hand pointing toward the examiner. The hand is placed on the table with the palm toward the surface of the table. The thumb and forefinger are spread to allow for the insertion of the weighted bottles.

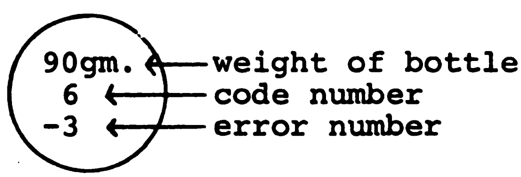
The subject grasps the bottle with the thumb and first two fingers and lifts the bottle slightly using the hand only--the forearm should remain in contact with the table. All weights are lifted in the same manner. The weights are presented in pairs until each comparison weight has appeared with the standard weight. The standard weight is always presented first; the order of presentation for the weights is randomized.

After lifting the comparison weight, the subject indicates which weight was the heaviest, the first weight or the second weight. If the subject hesitates, repeat the pair once more.

The series of six pairs is repeated three times. The subject is not told if his choice is correct or incorrect.

Order of Presenting Comparison Weights: The numbers one through six are randomly ordered for each series of comparisons. These may be prepared prior to the time of testing from a table of random numbers.

The comparison weights are presented in the order of their corresponding code numbers which appear as the middle number on the cap of the bottle. For example, the random order of the three series of a subject may be: 136425, 216543, 163542.



Instructions to the Subject (suggested): "I have a game that is fun to play . . . here are two bottles . . . I would like you to lift each bottle, like this . . . and

Weight Discrimination (continued)

then tell me which bottle was heavier, the first one or the second one . . . you can just say 'Number One' or 'Number Two' . . . now you try it . . . lift this one . . . then this one . . . which one felt heavier? . . . good . . . that was easy . . . let's see if you can do as well with this blindfold on . . . I will give you two bottles to lift and you tell me which one is the heaviest. You will have 18 chances, but I will have to mix up the bottles after every six tries."

Instructions to the Examiner: After the subject is seated, introduce the test as a game. Demonstrate the proper position of the arm and the correct manner for lifting the bottles. Explain that the weights will be presented in pairs and that he will be expected to indicate which of the two is the heaviest. Allow the subject one trial without the blindfold to see if the procedures are understood. When the correct procedure is demonstrated, place the blindfold on the subject and begin testing.

Scoring: The test is scored by a weighted error system where:

a) a correct response is scored as "0."
b) an error of 5 gm. above or below the standard weight is scored as "+1" or "-1."
c) an error of 10 gm. above or below the standard weight is scored as "+2" or "-2."
d) an error of 15 gm. above or below the standard weight is scored as "+3" or "-3."

The error number for each comparison weight is the lowest number on the cap of the bottle. The "plus" and "minus" signs are used to indicate the direction of the error as follows:

a) a "plus" is used when a lighter comparison weight (60, 65, 70 gm.) is judged to be heavier than the standard weight.
b) a "minus" is used when a heavier comparison weight (80, 85, 90 gm.) is judged to be lighter than the standard weight.

The subject's final score is the sum of the weighted errors for the three series.

APPENDIX E

PROPRIOCEPTION NORMS: PERCENTILE SCORES BY GRADES

Table E.1

Proprioception norms: percentile scores for kindergarten (N = 111)

Percentile	O.F.B.[a] (sec.)	P.B.[b] (mm.)	T.D.[c] (errors)	W.D.[d] (errors)	Percentile
100th	17	3	0	0	100th
95th	7	11	0	1	95th
90th	5	17	1	2	90th
80th	4	20	1	3	80th
75th	4	22	1	4	75th
70th	3	24	2	5	70th
60th	2	27	4	7	60th
50th	2	31	5	9	50th
40th	2	33	6	11	40th
30th	1	37	8	13	30th
25th	1	39	8	14	25th
20th	1	41	9	15	20th
10th	1	53	11	17	10th
5th	1	67	13	19	5th
0	1	99	17	34	0

[a]OFB = One Foot Balance

[b]PB = Parallel Blocks

[c]TD = Thickness Discrimination

[d]WD = Weight Discrimination

Table E.2

Proprioception norms: percentile scores for first grade (N = 119)

Percentile	O.F.B.[a] (sec.)	P.B.[b] (mm.)	T.D.[c] (errors)	W.D.[d] (errors)	Percentile
100th	47	10	0	0	100th
95th	15	12	0	0	95th
90th	8	14	1	1	90th
80th	5	19	1	2	80th
75th	4	20	2	3	75th
70th	4	22	2	3	70th
60th	3	26	3	4	60th
50th	2	29	4	5	50th
40th	2	34	5	6	40th
30th	2	38	6	7	30th
25th	1	39	7	8	25th
20th	1	41	8	9	20th
10th	1	48	10	11	10th
5th	1	65	13	13	5th
0	1	73	19	19	0

[a]OFB = One Foot Balance

[b]PB = Parallel Blocks

[c]TD = Thickness Discrimination

[d]WD = Weight Discrimination

Table E.3

Proprioception norms: percentile scores for second grade (N = 91)

Percentile	O.F.B.[a] (sec.)	P.B.[b] (mm.)	T.D.[c] (errors)	W.D.[d] (errors)	Percentile
100th	27	9	0	0	100th
95th	13	13	0	0	95th
90th	11	15	0	0	90th
80th	8	21	1	1	80th
75th	7	22	1	2	75th
70th	6	23	1	2	70th
60th	5	27	2	3	60th
50th	4	31	2	4	50th
40th	3	36	4	4	40th
30th	3	38	5	6	30th
25th	3	42	5	6	25th
20th	2	44	6	6	20th
10th	2	48	8	10	10th
5th	1	62	12	11	5th
0	1	71	19	23	0

[a] OFB = One Foot Balance

[b] PB = Parallel Blocks

[c] TD = Thickness Discrimination

[d] WD = Weight Discrimination

APPENDIX F

REGRESSION EQUATIONS FOR EACH DEPENDENT VARIABLE: BY GRADES

Table F.1

Regression equations for each dependent variable: Kindergarten

Dependent Variable	Regression Equation
Physical Growth:	
Standing height	≅ 111.10 + .18(OFB)[a] − .13(WD) − .07(TD) + .01(PB)
Weight	≅ 42.25 + .22(OFB) − .16(WD) + .03(TD) + .00(PB)
Ponderal index	≅ 12.57 + .00(OFB) − .00(WD) − .01(TD) + .00(PB)
Motor Performance:	
Body part identification	≅ 10.53 + .07(OFB) + .02(WD) − .02(TD) − .03(PB)
Bouncing and catching a ball	≅ 6.04 + .41(OFB) + .05(WD) − .21(TD) + .01(PB)
Directionality	≅ 7.97 + .02(OFB) − .02(WD) − .03(TD) − .00(PB)
Dynamic balance	≅ 6.50 + .75(OFB) + .05(WD) − .21(TD) + .01(PB)
Rail balance: 1½ in. rail	≅ 9.82 + 1.09(OFB) + .13(WD) − .11(TD) − .04(PB)
Rail balance: 1 in. rail	≅ 4.40 + .38(OFB) + .00(WD) − .09(TD) − .03(PB)
Reaction time: auditory	≅ 0.36 − .01(OFB) + .00(WD) − .00(TD) + .00(PB)
Reaction time: visual	≅ 0.39 − .01(OFB) + .00(WD) + .00(TD) + .00(PB)
Standing long jump	≅ 35.27 + .52(OFB) − .03(WD) − .28(TD) + .01(PB)
Stationary ball dribble	≅ 25.05 + 1.39(OFB) − .09(WD) − .20(TD) + .03(PB)
Academic Achievement:	
Mathematics	≅ 50.46 + .46(OFB) − .41(WD) − .25(TD) − .02(PB)
Letters and sounds	≅ 49.98 + 1.03(OFB) − .15(WD) + .05(TD) + .00(PB)
Aural comprehension	≅ 49.29 + 1.36(OFB) − .37(WD) − .58(TD) − .01(PB)
Total	≅ 49.68 + .96(OFB) − .41(WD) − .19(TD) − .05(PB)

[a]Letters denote the titles of the four proprioception tests: OFB=One Foot Balance; WD=Weight Discrimination; TD=Thickness Discrimination; and, PB=Parallel Blocks. It should be noted that scores on the latter three tests are error scores.

Table F.2

Regression equations for each dependent variable: first grade

Dependent Variable	Regression Equation
Physical Growth:	
Standing height	≅ 118.68 − .21(OFB)[a] − .02(TD) − .19(WD) − .07(PB)
Weight	≅ 47.86 − .25(OFB) + .09(TD) − .17(WD) − .11(PB)
Ponderal index	≅ 12.89 − .00(OFB) − .01(TD) − .00(WD) + .00(PB)
Motor Performance:	
Body part identification	≅ 12.46 + .05(OFB) − .03(TD) − .08(WD) + .01(PB)
Bouncing and catching a ball	≅ 13.42 + .10(OFB) − .58(TD) − .18(WD) − .11(PB)
Directionality	≅ 9.25 − .00(OFB) − .06(TD) − .07(WD) + .01(PB)
Dynamic Balance	≅ 10.99 + .23(OFB) − .34(TD) − .12(WD) − .06(PB)
Rail balance: 1½ in. rail	≅ 16.83 + 1.29(OFB) − .51(TD) − .58(WD) − .14(PB)
Rail balance: 1 in. rail	≅ 6.93 + .27(OFB) − .19(TD) − .08(WD) − .05(PB)
Reaction time: auditory	≅ 0.30 − .00(OFB) + .00(TD) + .00(WD) − .00(PB)
Reaction time: visual	≅ 0.34 − .00(OFB) + .01(TD) − .00(WD) + .00(PB)
Standing long jump	≅ 41.51 + .12(OFB) − .34(TD) − .02(WD) − .03(PB)
Stationary ball dribble	≅ 36.18 + .19(OFB) − .86(TD) − .30(WD) − .10(PB)
Academic Achievement and Mental Ability:	
Mathematics	≅ 50.06 − .21(OFB) − .62(TD) − .33(WD) − .12(PB)
Letters and sounds	≅ 50.09 − .12(OFB) − .81(TD) − .10(WD) − .01(PB)
Aural comprehension	≅ 50.06 + .02(OFB) − .41(TD) − .15(WD) + .10(PB)
Word reading	≅ 50.05 + .12(OFB) − .63(TD) − .11(WD) + .05(PB)
Reading sentences	≅ 50.07 + .02(OFB) − .47(TD) − .18(WD) + .07(PB)
Total	≅ 50.05 − .03(OFB) − .50(TD) − .18(WD) + .05(PB)
Mental ability	≅ 40.82 − .01(OFB) − .52(TD) − .15(WD) + .04(PB)

[a] Letters denote the titles of the four proprioception tests: OFB=One Foot Balance; WD=Weight Discrimination; TD=Thickness Discrimination; PB=Parallel Blocks. It should also be noted that scores on the latter three tests are error scores.

Table F.3

Regression equations for each dependent variable: second grade

Dependent Variable	Regression Equation
Physical Growth:	
Standing height	≅ 123.46 + .15(OFB)[a] − .15(TD) + .21(WD) − .03(PB)
Weight	≅ 53.22 + .11(OFB) − .15(TD) + .27(WD) − .05(PB)
Ponderal index	≅ 12.96 + .01(OFB) − .00(TD) + .00(WD) − .00(PB)
Motor Performance:	
Body part identification	≅ 13.74 + .01(OFB) − .13(TD) + .02(WD) + .03(PB)
Bouncing and catching a ball	≅ 19.52 + .34(OFB) − .43(TD) + .18(WD) − .05(PB)
Directionality	≅ 10.86 + .04(OFB) + .00(TD) − .01(WD) + .01(PB)
Dynamic Balance	≅ 18.36 + 1.08(OFB) + .12(TD) − .38(WD) + .01(PB)
Rail balance: 1½ in. rail	≅ 23.76 + 1.92(OFB) + .64(TD) + .42(WD) − .04(PB)
Rail balance: 1 in. rail	≅ 9.13 + .66(OFB) + .00(TD) − .14(WD) − .05(PB)
Reaction time: auditory	≅ 0.29 − .00(OFB) + .00(TD) − .00(WD) + .00(PB)
Reaction time: visual	≅ 0.32 − .00(OFB) + .00(TD) − .00(WD) + .00(PB)
Standing long jump	≅ 44.81 + .19(OFB) − .39(TD) − .13(WD) − .10(PB)
Stationary ball dribble	≅ 47.97 + .37(OFB) − .45(TD) + .53(WD) − .07(PB)
Academic Achievement and Mental Ability:	
Word reading	≅ 49.88 + .19(OFB) − .32(TD) + .14(WD) − .16(PB)
Paragraph meaning	≅ 49.91 + .11(OFB) − .36(TD) + .04(WD) − .11(PB)
Vocabulary	≅ 50.03 + .29(OFB) − .40(TD) − .01(WD) + .04(PB)
Word study skills	≅ 49.87 + .28(OFB) − .38(TD) + .09(WD) − .16(PB)
Arithmetic	≅ 49.93 + .31(OFB) − .42(TD) − .03(WD) − .05(PB)
Total	≅ 49.90 + .22(OFB) − .33(TD) + .05(WD) − .10(PB)
Mental ability	≅ 42.00 + .18(OFB) − .36(TD) + .19(WD) + .03(PB)

[a] Letters denote the titles of the four proprioception tests: OFB=One Foot Balance; WD=Weight Discrimination; TD=Thickness Discrimination; PB=Parallel Blocks. It should also be noted that scores on the latter three tests are error scores.