Kinesthetic Sensitivity and the Learning of Two Novel Motor Tasks

by

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CHAPTER 1

INTRODUCTION

Several factors influence the learning of motor skills. Referred to as individual abilities, these factors, many genetically defined and not modifiable by practice or experience play a role in the learning of a motor skill (Schmidt, 1982, p. 431). Abilities may be cognitive (thinking, reasoning, mechanical knowlege) or physical in nature (strength,kinesthesis, speed, reaction time) and are important to the learning of a motor skill(Fleishman and Hempel, 1955). Of interest in the motor learning field is the relative importance of these abilities in motor skill learning.

One of these abilities, kinesthesis, is of particular interest to researchers in the fields of psychology and motor learning. Kinesthesis, also known as proprioception, provides and transmits information originating from the neuroreceptors found in the vestibular apparatus, joints, tendons, and muscles (Sage,1985,p. 177). The term kinesthesis is also used to describe the actual sensations arising from these transmissions (Sage, 1985, p.155).

In general, kinesthesis has been considered important in motor skill learning since it provides a variety of information to the individual. This information, according to learning theorists, is essential to the development of associations between stimuli and responses in order for learning to occur (Guthrie,1959; Hull, 1952; James, 1890). Adams (1971) in his "closed loop" theory of motor learning postulated that in learning a motor skill, an individual uses feedback to compare the results of a movement to a centrally represented idea or understanding of that movement. Any discrepancy between the feedback produced by the movement and the reference mechanism becomes a source of error identification and correction. The central or cognitive representation of the movement, called the reference mechanism, is used to detect these errors. Learning occurs from the continued interaction of movement feedback and movement outcome, thus strengthening the reference mechanism, allowing the newly acquired skill to become part of the individual's repertoire of learned movements.

Motor skill theorists have identified several stages or phases of learning. Fitts and Posner (1967), for example, postulate a hierachical and sequential process of learning motor skills. According to their view, an individual experiences three stages in the learning of a motor skill. The first stage, the cognitive or verbal stage, involves the learners' development of an understanding of the movement to be learned. During this stage, it is usually necessary to pay attention to events, responses, and cues that become unnoticed later. The second stage of learning, called the intermediate or associative stage, involves the active combination of newly experienced units of skill from the first phase of learning, which result in the creation of new patterns of movement. Subtle adjustments are made by the individual as the performance of the task becomes more efficient. Errors, which are frequent in the first stage of learning, gradually decrease. Finally, in the third or autonomous stage of learning, the skill becomes automatic and there is less reliance on conscious control of the movement by the individual. During this final stage, the individual experiences less interference from concurrent activities or distractions from the environment.

Once a motor skill becomes automatic, the production of the skill is under the control of a motor program. According to Keele (1973), a motor program is defined as a centrally represented movement pattern stored in memory. As a result, as a goal oriented movement is initiated by an individual, neural impulses are sent to the appropriate musculature in the proper timing, force, and sequence to produce the movement (Sage, 1985, p.187). Keele (1973), hypothesized four possible roles for kinesthetic sensitivity in the development and execution of a motor program. One of these functions was the idea that kinesthesis plays an important role in the acquisition of a motor program. As a motor program is learned, errors will occur, but feedback is used to correct the error and helps to adjust the motor program so that the error is not repeated. Keele described the need for a standard or model of the desired movement, a standard against which feedback is compared. If the feedback resulting from a movement does not match the model, adjustments are continually made until a satisfactory match between the two occur. At the point where no discrepancy exists between the feedback and the model of the desired movement, a motor program is fully developed, providing the desired sequence of movements.

Keele's (1973) theory of motor program development is important because it points to kinesthetic sensitivity as being crucial to the early acquisition stages of motor skill. In the later stages of skill development and execution, kinesthesis is utilized primarily as a monitor of the program. However, while the view that kinesthetic sensitivity is important in the early stages of motor skill development seems consistent with the ideas proposed by Fitts and Posner (1967) and Keele (1973), these views are not shared by Schmidt (1982) and Fleishman and Rich (1963).

Fleishman and Rich (1963) examined the role of kinesthetic sensitivity in the learning of a two hand coordination task. Forty college age males were tested for kinesthetic ability by the use of a test for determining difference limens for judgements of lifted weights. The perceptual motor task, a two hand coordination task, required the subjects to keep a target follower aligned with a small target disk which moved irregularly about a circular plate. The target follower was controlled by the use of two lathe-like handles which controlled the left/right and up/down movement of the target follower. The task was scored by the total time the subject remained on the target during each of the 40, one minute, trials used in the study. The authors concluded that sensitivity to kinesthetic cues was more important during the later stages of learning a motor skill.

Several studies undertaken to examine the role of kinesthetic sensitivity and motor skill acquisition have resulted in different findings from Fleishman and Rich. Phillips (1941), Using 10 tests of kinesthetic sensitivity, Phillips looked at the relationship between kinesthetic sensitivity and performance of two perceptual motor skills related to the putt and drive in golf. Sixty-three college aged males who had no experience in golf were used as subjects. Using correlations between subjects' performance on the tasks and their kinesthetic sensitivity, Phillips concluded that those who measured high in kinesthetic ability performed better during the initial learning of the tasks than those measured low in kinesthetic ability.

Thirteen years later, Phillips and Summers (1954), examined the relationship between motor learning and a positional test of kinesthetic sensitivity. Consistent with the Phillips (1941) study, they were interested in determining whether kinesthesis was more important in the early or later stages of motor learning. The subjects were 115 college aged females enrolled in a bowling class. Positional kinesthetic sense was measured by the subject's replication of three side arm movements and three forward arm movements. The scores from these tests were correlated with the subject's bowling scores over 24 class periods. The authors concluded that kinesthetic sense was more important in the early stages as opposed to later stages of motor learning.

Finally, Dickenson (1969), reported that kinesthetic sensitivity was equally important throughout early and late stages of motor learning. Using a badminton aiming task, he found individuals measuring high in kinesthetic sensitivity, performed significantly better throughout the learning of the task than those measured low in kinesthetic sensitivity.

While this evidence supports kinesthetic sensitivity as more important in early rather than in late stages of motor learning, this conclusion was not shared by Schmidt (1982) and Sage (1985). They argue that the findings reported by Fleishman and Rich are consistent with Fitts and Posner's (1967) three stage theory of motor learning. There is a certain logic to this position, since the Fitts and Posner theory proposes that cognitive-verbal abilities should be most important in the early stages of motor learning. However, in the specific case of kinesthesis, Fitts and Posner state that in learning a dance step, one attends to kinesthetic and visual information about the feet, early during the cognitive stage of learning, but ignore this information during the later stages (p. 12).

The inconsistencies in findings presented above support the need for further research to clarify the relationship between kinesthetic sensitivity and motor skill learning. Therefore, the purpose of this investigation was to examine the relationship between kinesthetic sensitivity and the learning of two novel motor tasks. Using Keele's (1973) view of the role of kinesthesis in the acquistion of a motor program and Fitts and Posner's (1967) three stage theory of motor learning, it was hypothesized that the relationship between kinesthetic ability and motor performance would be stronger in the earlier as opposed to the later stages of learning.

CHAPTER TWO

REVIEW OF LITERATURE

In this chapter, consideration will be given to relavent literature from the areas of psychology, physiology, and motor learning. It is presented in three sections: kinesthetic mechanisms are discussed in the first section, the second section will review deafferentation studies, and the third section will review literature that has investigated the role of kinesthesis in motor learning.

Kinesthesis

When examining research in motor learning, the terms kinesthesis and proprioception can be considered to be synonymous (Sage, 1985, p.177). Sherrington (1906), defined proprioception as the systems which transmit information from all receptors found in the vestibular apparatus, joints, tendons, and muscles. The term kinesthesis has been typically used to define the actual sensations which result from this transmission (Sage, 1985, p.155). From these two concepts, kinesthesis can be considered to be the sensory modality concerned with the position of the body and limbs in space as the result of imformation received exclusively from those receptors found in the vestibular apparatus, joints, tendons, and muscles.

The vestibular apparatus is located in the middle ear. It provides information about balance and the movement of the head. Three structures make up the vestibular apparatus. The first two, the saccule and the utricle, provide information about the position of the head in relation to gravity. They also provide information about any spinning motion the head undertakes. The last structure, the semicircular canals, are located near the saccule and utricle. These are three fluid-filled canals which lie at right angles to each other. Due to their position, they provide information concerning movement direction and rotation (Dickenson, 1976, p. 21-22; Schmidt, 1983, p. 196).

Joint receptors are located in the joint capsule, a fluid filled sheath which surrounds the joints of various bones. There are apparantly two functional types of joint receptors: Ruffini endings and Pacinian corpuscles (Burgess and Clark, 1969). These receptors are primarily concentrated in the areas of the joint capsule which are distorted most whenever a limb is used. Studies by Skoglund (1956), using cats as models, found that these receptors fire only at specific angles of the joint. Burgess and Clark (1969), examining these joint receptors in the hindlimb of the cat, found that most of these receptors fire at the extremes of movement in the joint (over 70%). Other receptors were found to fire at intermediate angles or in response to twisting motions of the joint. Also, a smaller proportion of the receptors fired only in response to extreme bending or twisting of the joint (noxious stimuli). In other investigations using cats as models, Boyd and Roberts (1953) found that discharges from the joint receptors are dependent on whether the movements are active or passive in nature. Based on these observations, the role of joint receptors in determining joint position is not as strong as once believed. Though they do provide some information, the joint receptors are not considered the only source of information for limb movement (Schmidt, 1982, p.197).

Another type of receptor thought to be used in the perception of movement is the golgi tendon organ. These receptors are located in the proximal and distal ends of the muscle at the point where the muscle connects with the tendon. Their primary function, due to their neurological connections, was once thought to only be a protective one. By way of a neurological connection to the spinal cord, they react to an overstretch of the muscle by inhibiting contraction in the muscle, thus providing a protective function if the muscle is overstretched (Dickenson, 1976, pp.17-18; Schmidt,1982, p.197). However, due to recent evidence, their role in detecting specific movements in the muscles has been inferred. Studies by Houk and Henneman (1967), and Stuart, Mosher, Gerlach, and Reinking (1972), have found anatomical evidence that each individual tendon organ was connected to five to 25 individual muscle fibers. Stuart et al found evidence that these receptors monitor contractile tension in the muscle by sampling small fractions of the total contractile force generated by the muscle, whether or not the receptors were connected to the actual muscle fibers which were contracting. Based on these observations of anatomical distribution and responses to stretch and tension in the muscle, Stuart et al concluded that the golgi tendon organs are important in the moment to moment regulation of tension in the muscle.

A third type of receptor thought to provide information about movement is the muscle spindle. These are cigar shaped receptors located parallel to the muscle fibers in the belly of the muscle (Howard and Templeton, 1966, pp.72-80; Dickenson, 1976, pp.13-17). This positioning allows the muscle spindles to be stretched along with the muscle during movement. In the center of the receptor is a mass of sensory fibers, called the nuclear bag, which become activated when distorted by the contraction or stretching of the muscle. Due to their neurological connections, as the muscle is overstretched, the muscle spindles send this information to the spinal cord via nerve afferents. These nerve afferents synapse in the spinal cord with motorneurons which supply the muscle fibers in which the muscle spindle is located, causing the muscle to contract. This information concerning the stretch of the muscle is also sent to the central nervous system. This function of the muscle spindles, providing information about muscle stretch, was once thought to be the only one. However a study by Goodwin, McCloskey, and Matthews (1972), found that these receptors may play a role in the perception of movement. Using humans as subjects, Goodwin et al found that vibration of the tendon of a muscle caused distortion in the perception of movement. In this experiment, subjects attempted to match passive movement in one arm with active movement in the opposite arm as the biceps tendon of the passive arm was vibrated. It was found that subjects misaligned the unvibrated arm with the vibrated arm as much as forty degrees. The placement of the vibrator was then reversed to the triceps tendon and the same type of misalignment occured. The interpetation was that the vibration caused a distortion in the information originating from the muscle spindles in the vibrated arm, causing a misinterpetation of the arm's position.

This was cited as evidence that the muscle spindle has a role in the velocity and positioning of a limb.

A final group of receptors, those found in the skin, are thought to provide some information about movement as they respond to distortions of the skin (Adrian, Cattell, and Hoagland, 1931). Two main types of these receptors are found. Pacinian corpuscles, which are located deep in the skin, respond to deep distortion. Merkel's discs and free nerve endings, located near the surface of the skin, respond to light distortion (Schmidt, 1982, p.201).

Taken together, all of these receptors found in the body provide information to the central nervous system concerning movements of the body. All these receptors are known to connect to the central nervous system by way of nerve afferents which ascend to the cerebellum and sensory cortex (Dickenson,1976,pp.24-32; Howard & Templeton,1966,p.81). These receptors can be considered to be part of an interlocking system, providing information collectively to the central nervous system for interpetation (Dickenson,1976,p.32).

Deafferentation

Deafferentation is considered to be the tempoary or permanent reduction or elimination of sensory information to the central nervous system. Many studies using such techniques have been undertaken since the beginning of this century. The results of these studies have been interpreted as evidence for the existence of a centrally represented movement program for the initiation and performance of purposeful movement. One of the earliest examples of purposeful movement in the absence of sensory information was reported by Lashley (1917). The human subject of this investigation was a male who had suffered a gunshot wound to the lower spine which severed all the sensory afferents from the lower limbs. Due to his condition, he was unable to replicate passive movements of his lower limbs. He was however, able to produce active movements of his legs without vision as well as a "normal" subject. These observations led Lashley to conclude that such active movements, produced in the absence of sensory information, were controlled by some central mechanism which gave commands to the appropriate musculature to produce the movement.

Of more recent interest, have been studies by Taub and his colleagues. In a decade of investigations using surgical deafferentation affecting various areas of monkey's bodies, Taub and his associates have provided much evidence for purposeful movement in the absence of sensory information.

In their first experiment (Knapp, Taub, and Berman,1958), monkeys were trained to avoid electrical shock by the flexion of a forelimb to a button which activated a buzzer and halted the electrical shock. The task was learned without vision. After surgical deafferentation of the trained limb, the monkeys were still able to perform the avoidance task as well as before the surgery after they exibited some initial deficit in performance. In a related experiment (Knapp, Taub, & Berman, 1963), monkeys who had one limb deafferentated and their nondeafferentated limb immobilized were able to learn to extend their deafferentated limb through the base of a cage inorder to grasp a food pellet under conditions of food deprivation. The authors concluded from these results that deafferentated monkeys were able to make purposeful movements in the absence of feedback under certain conditions.

In a second phase of experimentation, Taub and his associates sought to eliminate any possible extraneous cues which may have aided the performance of the deafferentated monkeys. In a 1965 study, Taub, Bacon, and Berman replicated the original 1958 study but eliminated the use of a buzzer to signal the avoidance of electrical shock. In this way, the authors reasoned, they would be able to reduce the association of the buzzer as a possible source of feedback associated with the response thus leading to a less conditioned response. The results from this study were similar to the ones obtained in the original study; the monkeys first showed some initial decrement in performance but were able to finally reach pre-deafferentation performance levels. Taub, Ellman, and Berman (1966) again replicated the original 1958 study. In this experiment, naive deafferentated monkeys were seated in a restraining chair with both their limbs immobilized. In the monkey's hand, a fluid-filled bulb was firmly taped. Without vision of their limb, the monkeys were able to learn to squeeze the bulb in order to avoid an electrical shock. What was of interest, was the observation that the deafferentated monkeys were able to exert as much pressure to the bulb as undeafferentated monkeys. The results of this experiment showed that a purposeful movement could be learned without the use of feedback from the affected limb.

Studies using human subjects have produced similar results. Laszlo, Shamoon, and Sanson-Fisher in 1969, examined the effect of various sensory deprivations on the transfer and reacquisition of a tapping task and a circle drawing task. Three groups of eight subjects were trained in both tasks. Four treatments were administered: no deprivation of feedback, deprivation of kinesthetic feedback by the use of two inflated blood pressure spygmomanometers placed above the elbow and above the wrist, deprivation of vision, and deprivation of vision along with the application of the two blood pressure cuffs. When the blood pressure cuffs were used, they were inflated above systolic blood pressure, eliminating any kinesthetic feedback from the hand. Under all of the treatment conditions, subjects attempted to perform both of the previously learned tasks in a recall and transfer condition. The tapping task involved the depression of a morse code key as rapidly as possible during a 30 second period. The circle drawing task required the subject to draw even circles on to a piece of paper as rapidly as possible with a pen which was attached to the index finger. The first group's training consisted of ten 30 s tapping trials followed by six 30 s drawing trials. The second group trained with six 30 s tapping trials followed by ten 30 s drawing trials. The third group trained with sixteen 30 s trials, alternating the tapping task and the drawing task. The results showed a positive transfer between both tasks in all of the treatments. Of greater interest was the finding that subjects in all of the reduced feedback conditions were able to perform the tasks at a level equal to those levels achieved at the end of the training period. From these results, Laszlo et al concluded that a central program was responsible for the levels of performance observed in the three reduced feedback conditions.

In a related study, Laszlo and Baguley (1971) found similar results. Two groups of 24 subjects were trained on a Morse code key tapping task. One group trained at the task with the preferred hand while the other group trained at the task with the non-preferred hand. Both groups were then tested in the task using the untrained hand with the application of two blood pressure cuffs inflated above systolic blood pressure, one placed above the elbow and the other placed above the wrist. The results showed that there was positive transfer to the untrained hand, providing further evidence for the existence of a central program for the movement.

Frank, Williams, and Hayes (1977), investigated movement control in the absence of kinesthetic feedback by the use of a blood pressure cuff technique. The task required subjects to point their left index finger at an array of four lights arrranged in an arc. The subject's left hand was held in place by the use of a restraining device. The subject was required to point their left index finger at a light after the application of of the blood pressure device above the elbow cause all sensation to be eliminated from the lower arm. During the task, the subject was unable to view the left hand due to the placement of an opaque screen above their left arm. The results showed that during the kinesthetic deprivation, subjects were able to reasonably perform the task, although performance was less accurate and more variable than a control group performing the task without kinesthetic deprivation. The authors concluded that purposeful movement can be performed in the absence of kinesthesis, although such movement suffers qualitatively.

The findings from these forementioned studies support the concept of movement being controlled by a central mechanism independent of feedback. This central mechanism can be considered to be a central motor program which produces movement by controlling the appropriate musculature in the proper sequence, force, and timing to accomplish the task. This is in line with Keele's (1973) concept of a motor program.

Role of Kinesthesis in Motor Learning

This section will review research which examined the role of kinesthesis in motor learning. The literature reviewed will include the areas of kinesthetic aftereffects, kinesthetic improvement, and the effect of kinesthesis on motor skill learning.

Kinesthetic Aftereffect

Kinesthetic aftereffect refers to a perceived change in slope, weight, or size of an object or to perceived distortion of movement, position of a limb as the result of an experience with another object. An example of kinesthetic aftereffect would be the baseball player swinging several bats before going to the plate, so the one bat will feel lighter. Another example is the use of weighted shoes when running and jumping, after removing the shoes the individual perceives that he/she can run faster (Sage, 1985. p.190).

The first study of kinesthetic aftereffects was by Gibson (1933). In this study, blindfolded subjects were required to spread and run their right fingers along a convex surface for three minutes. After the three minutes had elapsed, the subjects were given a heavy piece of cardboard with a straight edge. They were required to manipulate the straight edge in the same fashion as they did with the convex surface. The subjects reported that the straight edge felt concave, providing evidence for kinesthetic aftereffect.

Hutton (1966) examined kinesthetic aftereffect produced by walking on a gradient. Three groups of 17 blindfolded subjects walked on a treadmill set at a 10 deg. gradient for 60, 90, or 120 seconds. After walking on the graded treadmill for their prescribed time period, the subjects continued to walk on the treadmill as it was brought down to a level position. Subjects reported that they felt that they were walking down a grade when the treadmill was in the level position. The greatest effect was reported by subjects who had walked for the 120 second time period. These subjects exhibited a forward lean and would grab the two metal bars which were on either side of the treadmill when they were brought back to a level position. It was concluded that the percieved downward slope of the threadmill was the result of kinesthetic aftereffects due to adaptation of the vestibular system and kinesthetic receptors to the experienced ten degree slope.

Cratty and Amatelli (1969), used a gross walking task to examine kinesthetic aftereffects occuring in the limbs. The apparatus used in the study was a 60 ft long pathway which led to a circular pathway which had an inside diameter of 14 ft. The pathways were formed by one inch plastic pipe placed two ft apart and three ft above the floor. The subjects were blindfolded and guided themselves in the pathways by the use of a one ft section of plastic pipe held in the fist while keeping it perpendicular to the ground and against the inside of the rails. Four groups of 10 subjects took part in the study. The first group of 10 subjects held the pipe in their left hand as they walked down the straight pathway. When they reached the circular pathway, the pipe was moved to their right hand and they walked eight times around the path to the left. They then switched the pipe to their left hand as they left the apparatus by way of the straight path. The second group of 10 subjects followed the same procedures as the first group, but walked to the right in the circular path. The third group of 10 subjects held the pipe in their right hand as they walked down the straight pathway, then switched the pipe to their left hand and walked to the left eight times in the circular path. They then switched the pipe to their right hand as they left the apparatus by way of the straight path. The fourth group of 10 subjects followed the same procedures as the third group, but walked to the right in the circular path. During the experiment, subjects were required to continuously report what direction they were walking (to the right, left, or straight). As expected, 27 or 67.5% of the subjects experienced after-effects as they exited the circular pathway and walked out the straight pathway. The effects were in opposite to the direction they had walked in the circular pathway. It was concluded that the after-effects experienced were the result of distortion of the subject's frame of reference due to the stimuli they were exposed to in the circular pathway. This may have been due to hyperexcitation of the receptors in the vestibular apparatus and the proprioceptors of the limbs.

Kinesthetic Improvement

The possibility of improving kinesthetic sense has been of great interest to many physical educators. The few studies in the field have produced no convincing evidence that basic kinesthetic sensory capacity can be improved. A study by Widdop (cited in Oxendine, 1984, p.351), showed that ballet training improved the ability of college students to perform limb positioning and limb awareness tasks. However, these results just show that certain movements can be learned and have no relation to a general increase in kinesthetic ability (Oxendine, 1984, p.351).

In 1951, Lafuze tested low motor ability college women on several motor characteristics, including kinesthetic response. Kinesthetic response was measured by a battery of tests, all of which required reproduction of arm and leg movements without the use of vision. After the initial tests of motor characteristics, the subjects were assigned to one of two treatment groups. The two treatment groups were an 8 week and a 16 week daily skills clinic which provided instruction and practice on the various motor charateristics used in the study. After the completion of the particular clinic, subjects were again tested on the motor characteristics. The results proved to be inconclusive for the tests of kinesthesis as no real improvement in kinesthesis was evident. Lafuze, who had expected to see improvement in the kinesthetic measures, theorized that the results were due to a testing error.

Christina (1967), examined the use of a side arm positioning task as a test of kinesthetic sensitivity.

blindfolded male subjects reproduced various side arm movements over a 10 day period. Christina found, in most instances, that there were more exact test performances over the 10 day period. These results show improvement in kinesthesis over a 10 day period.

Cox (1976), investigated whether or not basic kinesthetic sense could be improved through practice on selected motor tasks. 36 college aged females from a volleyball class served as subjects. Three treatment groups were set up with 12 subjects in each group each treatment group lasted three weeks. Treatment 1 was the control group and did not participate in any experimental motor task. The treatment 2 group practiced a wall volley task five days a week for three weeks. The task involved the hitting of a tennis ball, with a racquetball racquet, to a target placed on a wall 30 ft from the subject. The task was scored by counting the number of hits on the target over 100 trials each day. The treatment 3 group practiced kinesthetic replication using a forearm kinesthesiometer box. Subjects performed constrained movements to one of three angles (50, 90, or 130 deg), followed by immediated replication of the angle. Each angle was randomly presented 20 times.

When a subject completed the three week treatment period, she was tested for kinesthetic recognition sensitivity by the use of a forearm kinesthesiometer box task. The criterion test required the subject to discriminate between the endpoints of two constrained movements (108 or 112 deg), over 250 equal presentations. From the results, kinesthetic recognition sensitivity was calculated. It was found that kinesthetic recognition sensitivity cannot be improved through practice on selected motor skills.

These few studies in the area of kinesthetic improvement show generally inconclusive results. However, the probability of improving a basic sensory capacity such as kinesthesis through practice seems remote and there is no real evidence that kinesthetic sensitivity can be improved. It appears that only specific learned responses can be improved (Oxendine, 1984, p.351).

Kinesthetic Ability and the Learning of Motor Skill

There have been several studies in motor learning literature concerned with kinesthetic ability and the acquision of perceptual motor skills. Phillips (1941), looked at the relationship between that sensitivity and performance of two perceptual motor skills related to the putt and drive in golf. The subjects were 63 college aged males who were naive to the golf skills used in the study. The subjects were tested on kinesthetic ability. They then learned to perform a putting task which involved playing a ten foot putt on a level surface using regulation equipment (success measured as the number of successful putts into the cup). The "drive" task involved the learning of how to hit a golf ball off a tee for accuracy at a target 18 feet away from the subject. The study was conducted for four weeks with the subjects coming in to practice the two tasks for two hours per week. By the use of correlations between the tests of kinesthesis and the two golf skills, Phillips concluded that those who measured higher in kinesthetic ability performed better initially in learning than those who measured low in kinesthetic ability.

In 1954, Phillips and Summers looked at whether there was a relationship between motor learning and performance on positional tests of kinesthesis and, if so, whether that relationship was more evident in the early stages of learning or in the later stages of learning. 115 female college age students enrolled in a physical education bowling class took part in the study. The subjects were tested for positional kinesthetic sense by the replication of three side arm movements and three forward arm movements involving the subject's preferred and non-preferred arm. Scores from these tests were correlated with improvement in the individual's bowling scores over 24 class periods. Students were further classified as fast or slow learners, based on their improvement in bowling scores. The authors concluded, based on the differences between the mean kinesthetic scores for fast and slow learners, that the kinesthetic sense was more important in the early stages of motor learning than in the later stages of motor learning.

Fleishman and Rich (1963) examined the role of kinesthetic ability in the learning of a two hand coordination task. 40 college age males were tested on kinesthetic ability by the use of a test for determining difference limens for judgments of lifted weights. Blindfolded subjects compared identically sized brass cylindrical weights of 100, 102, 104, 106, 108, 110, and 112 grams with a standard identical sized weight of 106 grams. The weights were presented in pairs (standard weight, then test weight). The subject was to decide whether the test weight was heavier, lighter, or the same as the standard weight. The difference limen was calculated for each subject and represented a measure of kinesthetic ability. The reliability of this test was confirmed at least 24 hours later with another administration of the tests. Based on their score, the individual was classified as being either high or low in kinesthetic ability. The perceptual motor task, a two hand coordination task, required the subject to keep a target follower aligned with a small target disk which moved irregularly about a circular plate. The target follower was controlled by the subject by the use of two lathe-like handles which controlled the left/right movement and forward/backward movement of the follower. The subject performed 40 one minute trials. Scoring was measured as the total time on target during a trial. Based on the scores of the two-hand coordination task, the authors found no difference in the level of performance between individuals measured high in kinesthetic ability and those measured low in kinesthetic ability in the early stages of learning. However, those high in kinesthetic ability performed significantly better in the later stages of learning than those measured low in kinesthetic ability. Therefore, it was concluded that sensitivity to kinesthetic cues was more important in the later stages of learning a motor skill.

However, in 1969, Dickenson found results different from the forementioned studies. Using a badminton aiming task, Dickenson found that those individuals measured high in kinesthetic sensitivity by the use of difference limens for judgements for lifted weights, performed significantly better throughout the learning of the task than those individuals measured low in kinesthetic sensitivity.

These four studies, which vary differently in their results, comprise the few studies in the field which look at kinesthetic ability and the learning of motor skills. The Fleishman and Rich (1963) study appears to be the most accepted (Sage, 1985; Schmidt, 1983). Based on this situation, there seems to be a need to examine further the role of kinesthetic ability in the learning of motor skills.

CHAPTER THREE

METHOD

The experiment was conducted at Kansas State University in the fall of 1985. This chapter will review the selection of subjects, research procedures, and the equipment used in the study.

Subjects

Twenty right handed male (n = 20) and twenty-one right handed female (n = 21) undergraduate volunteers were used as subjects. The mean age of the male subjects was 20.7 years (SD = 2.9 yrs.). The mean age of the female subjects was 20.2 years (SD = 2.2 yrs.). A consent form and written explanation of the study was read and signed by the subject prior to the beginning of the experiment.

Procedures

The experiment consisted of three tests of kinesthetic sensitivity and two motor learning tasks. On the first day, the subjects were tested for hand dominance using a 14 item discriminative questionnaire developed by Crovitz and Zener (1962). Based on the results of the questionnaire, subjects who were not clearly right hand dominant were excluded from further participation in the study. In order to be classified as being right hand dominant, a subject was required to score below 30 points on the hand dominance scale. Right hand dominant subjects were used in this research in order to increase the likelihood that the motor learning tasks were novel to the subjects. All tests involved the use of the left hand. The data were collected for each subject over a three day period. On day one, each subject's kinesthetic sensitivity was measured. On day two, each subject performed a rotary pursuit learning task. Finally on day three, each subject performed a ball tossing task to a target.

Measurement of Kinesthesis

Three tests of kinesthetic sensitivity were used in this research. The weight discrimination test is a classical psychophysical test of the same type used by Fleishman and Rich (1963). The two remaining tests were linear and angular kinesthetic sensitivity measurements. They take into account movements and musculature of the upper extremities. These movements are similar to the movements used in the two novel motor learning tasks employed in this study. The order of the test administration was randomly determined using an incomplete counterbalanced design (ABC, CAB, BCA).

Weight discrimination. The weight discrimination task is a measure of kinesthetic sensitivity based on a subjects ability to discriminate among weights. Weighted cannisters of identical size were used. The cannisters weighed 75, 80, 85, 90, 95, 100, 105, 110, 115, 120, and 125 grams. All cannisters were tested for accuracy in weight prior to testing. The standard weight was the 100 g weight.

For test administration, the subject was seated at a table while wearing a blindfold. The subject rested his/her left arm on the table and the weights were brought into the testing area. The subject was instructed to lift the presented weight from the left wrist, using the thumb, index and middle fingers to hold the weight. The weights were presented in pairs, the standard weight followed by a random presentation of the test weights. The experimenter placed and removed the weights from the subject's grasp, stating "standard" when the 100 g weight was presented and "test" when the second weight was presented. The subject's response of whether the second weight was heavier or lighter than the standard was recorded. There was a five second interval between the subject's response to the presentation of a second weight and the experimenter's presentation of the standard weight for the next comparison. No feedback was given. These procedures were repeated until the subject experienced each of the test weights ten times for a total of 100 trials. From the data, the difference limen (JND) was calculated as outlined in Brown, Galanter, Hess, and Mandler (1962).

Linear positioning task. A test of kinesthetic sensitivity was performed on a linear positioning device. The device consisted of a four inch metal rod mounted vertically on a frictionless slide which ran on two stainless steel rods. A pointer was attached to the slide and a linear scale marked off from zero to 100 centimeters was placed along the slide. The actual test consisted of 39 trials made up of 13 distances repeated three times. The distances used were: 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, and 80 centimeters. The distances were randomly ordered. The subject's task was to attempt to replicate the end point of a passive linear movement. The subject was asked to concentrate on the feel of the position, paying close attention to the sensations received from the limb.

To begin this test, the subject was seated and blindfolded in the testing area. The experimenter brought the linear positioning device into the testing area and placed it in front of the subject so that the 50 cm mark was at the center of the subjects upper torso. With guidance from the experimenter, the subject was instructed to grasp the handle of the device loosely with the left hand. With the pointer at the starting position (zero on the scale), the experimenter moved the subject's left hand from left to right along with the slide to one of the criterion positions. Movement speed was kept in time to the movement of a second hand of a Gralab model 172 timer. After two seconds at the criterion position, the subject was instructed to release the handle. The experimenter then returned the slide back to the starting position. The subject then was asked to regrasp the handle and immediately attempt to replicate the previous end location of the movement. Error was measured to the nearest centimeter. The subject was then asked to release the handle. A 10 s time interval took place between the end of a trial and the beginning of the next trial. This procedure was repeated until all 39 trials were completed. For analysis purposes, an error score was calculated using Henry's E (1975).

Angular positioning task. This test of kinesthetic sensitivity was performed on an angular positioning device. The device consisted of a hardwood box 20 in. high, 27 in. wide and 18.5 in. deep. In the back of the box, a slot 10 in high was cut. From the inside of the box, a "T" shaped metal handle extended through a frictionless pivot area to the outside front of the box and connected to a counter weight balanced pointer 33 cm long. A curvilinear scale measuring from zero to 180 deg was applied to the front of the box.

The test consisted of 39 trials. Thirteen angular movements were presented three times. The angular movements used involved movements of 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, and 150 deg. The angles were presented randomly to the subject. The task required the subject to attempt to replicate the end point of an angular movement. The subject was asked to concentrate on the movement location and extent.

The subject was blindfolded and the device was then brought into the testing area. The subject was seated behind the device and extended his/her left hand through the slot in the back of the box, grasping the "T" shaped handle between the index and middle fingers with the palm facing up. Care was taken so that the subjects left arm and hand would reach into the box in a straight line (no elbow flexion). With the pointer at the zero position on the scale, the required movement was pronation of the hand. The subjects were cautioned not to rest their elbow or arm on the bottom of the device during each test trial. The experimenter periodically observed the subject through a slot at the top front of the device to ensure compliance.

The experimenter moved the external pointer while the subject passively grasped the handle (thereby causing the subjects arm to pronate) to one of the criterion angles. Movement speed was in time to the movement of the second hand of a Gralab model 172 timer. After two seconds, the subject was instructed to release the handle while the experimenter returned the pointer to the starting position. The subject then was asked to properly regrasp the handle and to actively attempt to replicate the end point of the criterion angle. Error was measured to the nearest degree. The subject then was asked to release the handle. A 10 s time interval took place between the end of a trial and the beginning of the next trial. The procedure was repeated until all 39 trials were completed. In analyzing the data, an error score was calculated using Henry's E (1975).

Motor Learning Tasks

The two motor learning tasks used for this study were designed to be novel in nature. Therefore, it was expected that learning would occur as measured by the subject's performance on the tasks.

Pursuit Rotor. This novel continuous motor task was performed on a Lafayette model 30010 Pursuit Rotor set at 60 revolutions per min. A Lafayette model 54030 Electronic Chronoscope was used to record time on target to the nearest 10 msec. A Lafayette Repeat Cycle timer was used to control the turning off and on of the rotary pursuit device. To begin the task, the subject stood in front of the pursuit rotor while holding the stylus in the left hand, resting the tip of the stylus in the center of the turntable. A "ready" signal was given and a cycle timer was activated to initiate the task. Each of 30 trials consisted of a 20 s tracking period followed by a 30 s rest period. During the rest period, the subject was instructed to place the tip of the stylus in the center of the turntable. Time on target scores were recorded and knowledge of results was not given. For analysis purposes, the 30 trials were broken down into 10 three trial blocks.

Ball toss. This was a novel discrete throwing task in which the blindfolded subject practiced the throwing of a tennis ball at a standard archery target with the nondominant hand. During the throw, the subject was not allowed to shift his/her feet. The archery target was mounted on a wall with the exact center of the target being 135 cm above the floor. A restraining line was placed on the floor 5 M from the target. A screen covered the target until the subject was ready to begin.

The task was composed of five blocks of 45 throws, for a total of 225 tosses. Each block was separated by a two minute rest interval. The subject was briefed on the scoring of the task, the task itself, and the mode of feedback to be given after each throw. The scoring system was as follows: gold center(bullseye) - 50 points, red ring - 40 points, blue ring - 30 points, black ring - 20 points, white ring - 10 points, and off the target - zero points. The object of this task was to throw a tennis ball into the center of the target. Feedback was given after each throw concerning the point value and the area of the target struck by the ball. For example, if the ball hit the blue circle, but was above and to the left of center, the subject was told "30 high left".

To begin the task, the subject was blindfolded and stood facing the target with both feet behind and with the toes touching the restraining line. Throughout the testing phase, the subjects' maintained a constant, but comfortable distance between the left and right feet. To begin each toss, the experimenter placed a tennis ball into the subject's left hand. The subject then attempted to throw the ball at the center of the target. There was a five second time interval between each trial.

Feedback was given approximately 2.0 seconds after each throw. The score of the throw was recorded by the experimenter. During the three minute break between the blocks of 45 throws, the subject sat quietly facing a wall opposite the target. This procedure was followed until all five blocks of throws were completed. At no time was the subject allowed to view the target.

CHAPTER FOUR

RESULTS

The statistical analysis of the data is divided into three specific areas. They are: a) the presentation of descriptive data associated with the measurements of kinesthetic sensitivity; b) the results of a repeated measures variance analysis for the pursuit rotor task, the results of a Duncan post hoc multiple comparison test for the pursuit rotor task, and the results of correlational analysis between kinesthetic sensitivity and pursuit rotor learning; and c) the results of a repeated measures variance analysis for the ball toss task, the results of a Duncan post hoc multiple comparison test for the ball toss task, and the results of correlational analysis between kinesthetic sensitivity and the ball toss task. In all tests of significance, an alpha level of .05 was adopted.

Kinesthetic Descriptive Data

Forty one subjects took part in the study. Their performance on the weight discrimination task was measured by calculating difference limens as outlined by Brown, Galanter, Hess, and Mandler (1962). The mean score for the task (JND) was 5.702 (SD = 2.455). For the linear positioning task, Henry's E (1975) was used as an estimate of kinesthesis. The mean score was 3.512 cm (SD = 0.878 cm).

In the angular positioning task, Henry's E (1959) again was used to estimate kinesthetic sensitivity. The mean score was 10.154 deg (SD = 2.786 deg). A summary of the mean scores for kinesthetic sensitivity is in Table 1.

Table 1

Means and Standard Deviations for Kinesthetic Sensitivity Data

Measure	n	Mean	Standard Deviation
Weight Discrimination(JND)	41	5.702	2.455
Angular Positioning(DEG)	41	10.154	2.786
Linear Positioning(CM)	41	3.512	0.878

Correlations among the three measures of kinesthetic sensitivity are Table 2. As seen in this table, very little relationship exists among the three measures. Even the significant relationship of .358 between the angular and linear positioning tasks accounts for only 12.8% of the variance between them.

Table 2

Correlations Among Measures of Kinesthetic Sensitivity

Measure	JND	DEG	CM
Weight Discrimination(JND)	1.000	-0.001	0.091
Angular Positioning(DEG)		1.000	0.358*
Linear Positioning(CM)			1.000

* $p < .05$

Pursuit Rotor Data

A repeated measures ANOVA revealed a significant performance effect across the 10 3-trial blocks, $F(9,360)=162.90, p=.0001$. Further analysis using a Duncan post hoc multiple comparison test revealed that significant learning occurred among trial blocks 1 through 7, between trial blocks 7 and 9, and between trial blocks 9 and 10. Illustrated in Figure 1 are the mean time on target (TOT) scores for performance on the pursuit rotor task. As can be observed in Figure 1, steady TOT improvement was made across 10 3-trial blocks. There is, however, no clear asymptote evident in the learning data.

Simple correlations between pursuit rotor scores and the three measures of kinesthetic sensitivity are in Table 3. As observed in this table, there was no relationship between pursuit rotor learning and kinesthetic sensitivity as measured through weight discrimination or the linear positioning task. This was true, regardless of the trial block. However, in the case of the angular positioning task, a clear relationship existed between the pursuit rotor task and kinesthetic sensitivity for blocks 1 through 4. These relationships were, however, small since they only accounted for 10.3%, 18.7%, 14.2%, and 11.2% of the variance respectively. These results provided partial support for the hypothesis that kinesthetic sensitivity was more important in the early stages of motor skill learning.

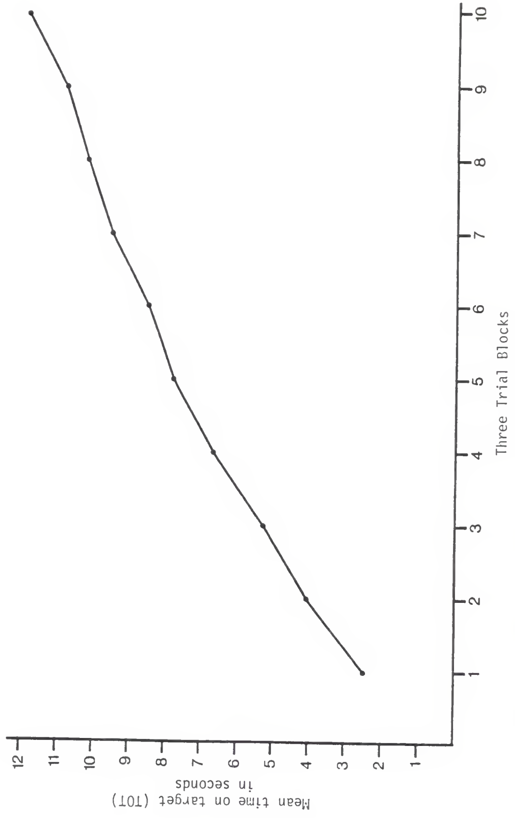

Figure 1. Pursuit Rotor Data

Table 3

Correlation Between Measures of Kinesthetic Sensitivity and Pursuit Rotor Scores

	Measures of Kinesthetic Sensitivity		
Blocks	Weight Discrimination	Angular Positioning	Linear Positioning
1	-.031	-.321*	-.044
2	.035	-.432*	-.076
3	.041	-.377*	-.040
4	-.035	-.334*	-.069
5	.021	-.275	-.062
6	.033	-.252	.021
7	.044	-.207	.036
8	.145	-.182	.030
9	.013	-.146	.111
10	.067	-.274	.037

* $p < .05$

Ball Toss Task

A repeated measures ANOVA revealed a significant performance effect across the five 45-trial blocks, $F(4,160)=30.37, p=.0001$. Further analysis using a Duncan post hoc multiple comparison test revealed the occurrence of significant learning among blocks 1 through 3 and between blocks 4 and 5. Mean ball toss scores for subject performance on the ball toss task are plotted in Figure 2.

Simple correlations between ball toss scores and the three measures of kinesthetic sensitivity are in Table 4.

Table 4

Correlations Between Measures of Kinesthesis and Scores on the Ball Toss Task

	Kinesthetic Measures		
Blocks	JND	DEG	CM
1	.078	-.115	-.063
2	.064	-.109	.026
3	.030	-.040	-.028
4	.252	-.141	-.071
5	.225	-.075	.103

No significant relationship exists between the three measures of kinesthetic sensitivity and ball tossing performance.

In summary, the results of the investigation revealed that for the ball toss task, no significant relationship existed between the measures of kinesthesis and performance. However, a significant relationship existed between kinesthetic sensitivity, as measured by the angular positioning task, and performance on the first four blocks of the pursuit rotor.

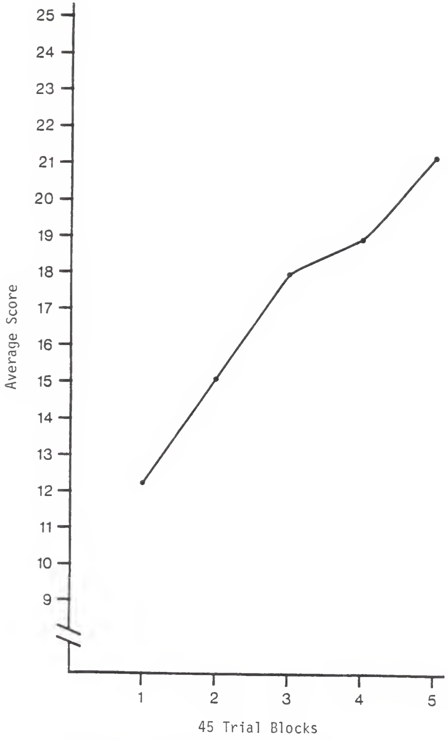

Figure 2. Ball Toss Task Scores

CHAPTER FIVE

DISCUSSION

The results of this investigation provide partial support for the research hypothesis that kinesthetic sensitivity was more important in the early stages of learning a motor task. Specifically, it was observed that for the pursuit rotor task, kinesthetic sensitivity (as measured by an angular positioning task) was important in the early stages of motor learning. This relationship between kinesthetic sensitivity and the pursuit rotor task was not a strong one, but it did exist.

The findings of this investigation differ from the previously reported results by Fleishman and Rich (1963) in two important ways. First, kinesthetic sensitivity, as measured by a weight discrimination task (JND), was not related to the learning of a continuous motor task (pursuit rotor) at any observed stage of learning. Second, kinesthetic sensitivity, measured by an angular positioning task, revealed that kinesthesis was more important in the early stages of motor learning. A comparison of the Fleishman and Rich (1963) data with the current results is displayed in Table 5.

A closer examination of Table 5 shows that the results of the current investigation from the results of the Fleishman and Rich (1963) study. The tasks used in the two studies, although both continuous in nature and involved the pursuit of a moving disk, were different. Task differences must be considered one possible reason for the observed differences between the two findings. Fleishman and Rich used a task which required the use of both hands while in the present investigation, the use of one hand was required. The two-hand coordination task used by Fleishman and Rich may utilize different spatial and temporal coordination components than those needed to perform the pursuit rotor task used in the present investigation. Obvious differences in the weight discrimination task-motor task correlations used in both studies further suggests that the tasks used in both studies were indeed different.

While it may be argued that the weight discrimination task measures some aspect of kinesthetic sensitivity, it likely captures different aspects than the angular and linear positioning tasks. Note the very low correlations between weight discrimination and the other two measures of kinesthetic sensitivity (Table 2). Thus, it was not surprising that, in the current investigation, significant correlations were observed for angular kinesthetic sensitivity but not for weight discrimination. However, a clear lack of correlation between kinesthesis as measured by linear positioning and pursuit rotor performance was noted. These observations tend to point out the situational and task specific nature of various measures of kinesthetic sensitivity (Dickenson, 1976, pp. 35-62).

One possible explanation for the disparity in the findings relative to the weight discrimination task was the psychophysical method used in each study. Fleishman and Rich used the method of limits to calculate a difference limen, while in the present study, the method of constants was used. Since the method of constants provides more information and is the preferred method (D'Amato, 1970), the validity of the Fleishman and Rich data may

Table 5

Comparison of the 1963 Fleishman and Rich results using a two Two Hand Coordination Task, and the Results of the Current Study using the Pursuit Rotor Task (Correlations)

	Measures of Kinesthesis		
	Weight Discrimination		Angular Positioning
Blocks	Fleishman & Rich #	Walkuski	Walkuski
1	.03	-.031	-.321*
2	.19	.035	-.432*
3	.15	.041	-.377*
4	.15	-.035	-.334*
5	.10	.021	-.275
6	.09	.033	-.252
7	.23*	.044	-.207
8	.28*	.145	-.182
9	.38*	.013	-.146
10	.40*	.067	-.274

* significant at .05 level

Fleishman and Rich (1963) apparently used an error, as opposed to a time on target (TOT) score. This could explain the positive correlations between weight discrimination and psychomotor performance.

be in question. The method of constant stimuli avoids the problems of habituation and anticipation found in the method of limits because the stimuli are presented in random order (Engen, 1971).

The findings of the present study, in terms of the pursuit rotor task (continuous task), supported the view that kinesthetic sensitivity was most important in the early stage of learning. The lack of a clear asymptote in the learning data leads to the conclusion that learning is still taking place and creates the dilemma of ascertaining at what stage of learning the subjects were in during trials 7 through 10. It can be argued, however, that the subjects were in the first, or cognitive stage of learning. The conclusion that kinesthesis is important early in motor task learning seems to be consistent with Keele's (1973) motor program theory in which kinesthesis was believed to be important in skill acqusition, and was later used as a monitor once the motor program had been well developed. This conclusion was also consistent with the Fitts and Posner (1967) statement that kinesthetic cues are attended to early in learning, but are later ignored.

Based on the findings of this investigation, it is proposed that theories of motor learning include the idea that kinesthesis is most important early in practice. This conclusion is different than that proposed by Fleishman and Rich (1963), and perpetuated by Sage (1985) and Schmidt (1982). However, it is consistent with motor learning investigations by Phillips (1941), and Phillips and Summers (1954).

The findings of this investigation involving the ball toss task suggest that a relationship does not exist at any point in the observed learning, between performance on a discrete task and kinesthesis. However, since the subjects were blindfolded, and relied completely on verbal feedback for error correction, kinesthesis may not have been of much use in correcting errors. In other words, the subjects may have viewed the task as being primarily spatial in nature. While control of the motor program for ball tossing may improve with the use of kinesthetic cues, they could not be adequately used to guide the ball to the target. Perhaps if subjects had been allowed to view the target, as they did in the pursuit rotor task, kinesthesis may have been utilized more effectively. This notion is supported since many of the subjects reported that they were more concerned with the location of the target in relation to themselves than how the throw felt. In the present investigation, vision was removed to theoretically encourage reliance upon kinesthesis. Perhaps this strategy actually encourages reliance upon spatial cues.

In summary, the findings of the present investigation provide partial support for the importance of kinesthetic sensitivity in the early learning of a continuous motor task. While these results are in contrast to those reported by Fleishman and Rich (1963), several factors may be responsible for the disagreement in findings. The different psychophysical methods used, as well as the task differences may account for the disparity in the results of the present investigation and the Fleishman and Rich study. One of the difficulties of the present investigation centers around the actual level of learning attained by the subjects during the novel motor tasks. The failure to achieve an asymptote in the data reveals that the subjects were still in the process of learning the tasks and had not yet reached a level of mastery.

It is suggested that future research in this area include sufficient learning trials for a novel motor task inorder to attain a clearer representation of learning. Another option would be to allow the subjects to use their dominant hand in the performance of the tests of kinesthetic sensitivity and the novel motor tasks. Perhaps by the use of the subject's dominant hand, learning would occur more rapidly, thus providing a clearer delineation of learning.

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Kinesthetic Sensitivity and the Learning of Two Novel Motor Tasks

by

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KINESTHETIC SENSITIVITY AND THE LEARNING
OF TWO NOVEL MOTOR TASKS

In a classic study, the relationship between kinesthetic sensitivity and the learning of a complex perceptual motor skill was reported by Fleishman and Rich (1963). Consistent with Fitts and Posner's (1967) proposed three stages of motor learning, Fleishman and Rich concluded that kinesthetic sensitivity was more important in the late as opposed to early stages of motor skill acquisition, a view held by many motor learning theorists (Schmidt, 1982). However, this view is not consistent with Keele's (1973) notion that kinesthetic sensitivity should be important in the early stages of motor progam development. Nor, is it consistent with studies by Phillips and Summers (1954) and Dickenson (1969), in which kinesthetic sensitivity was observed to either be most important during the early stages of motor skill learning or equally important throughout. In the present investigation, an attempt was made to provide a partial replication of the Fleishman and Rich study to discover the source of disparity in research findings. Forty-one right handed male (N = 20) and female (N = 21) undergraduates were used as subjects. Three tests of kinesthetic sensitivity were administered: a) a weight discrimination task involving the nondominant hand; b) a passive angular replication task involving pronation of the nondominant hand; and c) a passive linear replication task involving horizontal flexion of the nondominant arm. After completing the tests of kinesthetic sensitivity, the subjects subsequently learned two novel motor tasks. In both cases, the subjects practiced the novel tasks using their

nondominant hand. Task number one was continuous in nature and involved pursuit rotor tracking in which the target was moving at 60 rpm. Each subject received 30, 20 s trials with a 30 s rest period between trials. Task number two was discrete in nature and involved a ball tossing task in which subjects were blindfolded and received KR after each toss. On the ball tossing task, each subject received 225 trials with a two minute break between each 45 trial block. The data were analyzed using correlational and multiple correlation techniques. The results of the data analyses revealed that a significant relationship does not exist between the individual or combined measures of kinesthetic sensitivity and the ball tossing task at any stage of skill acquisition (blocks 1-5). For the pursuit rotor task, a significant relationship was observed between performance and angular kinesthetic sensitivity for trial blocks 1 through 4 ($\underline{P} < .05$). These results tend to refute the earlier findings of Fleishman and Rich. The results suggest that for a continuous task such as target tracking, kinesthetic sensitivity is more important in the early stages of motor learning than in the later stages. This finding suggests, consistent with Keele (1973), that kinesthetic sensitivity is particularly important in the early stages of learning a continuous motor task. When the motor pattern or program for the task is well learned, motor control shifts to an autonomus phase (Fitts & Posner, 1967), and reliance upon kinesthetic sensitivity minimized. However, in the case of a discrete motor task such as ball tossing, little relationship is observed between performance and kinesthetic sensitivity at either early or late stages of learning.