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Right cerebral hemispheric lateralization for spatial perception has been reported by using visual and tactile spatial tasks in brain-damaged patients, split-brain patients, and normal subjects. The main purpose of the present study was to investigate whether or not kinesthetic spatial perception was dominantly processed with the right cerebral hemisphere as well. In addition to this lateralization effect, the variables of sex, response verbalization, and active versus passive movement were manipulated in the present study. Sex and response verbalization have previously been reported to affect lateralization.

Thirty two male and 32 female Caucasian right handed subjects without left-handed relatives participated in two kinesthetic spatial positioning tasks. A thumb angular position discrimination task was administered by the method of constant stimuli (MOCS) and yielded two criterion measures, difference limen (DL) and constant error (CE). The second task of thumb angular position reproduction was administered by the method of average error (MOAE) and yielded three criterion measures; constant error (CE), absolute error (AE), and variable error (VE).

A mixed type of analysis of variance was calculated for each of the five criterion measures and was used to test for the effects of manipulated variables. The following results were obtained; (1) a significant difference existed between responses of right and left thumbs in the difference limen (DL-MOCS); (2) actively produced constrained standard movement produced negative time error (undershoot) while passive condition resulted in positive time error (overshoot) in reproduction task. No sex or response verbalization effects were found for lateralization.

HEMISPHERIC PROCESSING OF KINESTHETICALLY ORIENTED SPATIAL PERCEPTION

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CHAPTER I

INTRODUCTION

Normal human behavior in part depends upon maintaining spatial orientation that is calibrated through many of the sensory modalities. Spatial orientation includes the dimensional relation of the body to the environment and the relative position of body parts. The coding of kinesthetic information on the positional relationship between body parts plays an important role in purposeful human movements.

Recent investigations in cerebral hemispheric lateralization have indicated that visual spatially oriented information is more readily processed within the right cerebral hemisphere. This raises the possibility of similar cerebral lateralization for spatial information provided by other sensory modalities. Therefore, investigation of cerebral lateralization effects in kinesthetic spatial perception could expand our understanding of control of human movement.

Purpose of the Study

The main purpose of this study was to investigate whether or not kinesthetically oriented spatial perception was processed predominantly by one of the cerebral hemispheres.

Kinesthetic spatial perception was measured by the discriminabilty of thumb position (difference limen) and by the difference in subjective equality of a thumb position to a previously set standard position (constant error). These two criterion measures were obtained through a thumb angular position discrimination task measured by the Method of Constant Stimuli. Additionally, three criterion measures were also obtained by a thumb angular position reproduction task determined by the Method of Average Error. These were a sign difference between a standard position and a subjectively reproduced position (constant error), the absolute value of this difference (absolute error), and the variability of reproduced position with respect to the standard (variable error).

Since the variables of sex and necessity of language processing have been reported to show hemispheric lateralization, these were used as independent variables in this study. In addition, effects of sidedness of response and presentation condition of standard movement were investigated.

Significance of the Study

A great number of investigations have shown the left cerebral hemispheric lateralization for language processing. The right hemisphere, on the other hand, has been reported to process spatial information somewhat more dominantly.

However, the majority of these investigations employed visually oriented tasks and fewer researchers have used tactual tasks. Only two researchers (Colley, 1984; Roy and McKenzie, 1978) employed a kinesthesis dependent spatial task in which thumb position reproduction errors were measured. In research on motor control, kinesthetic processing has been intensively investigated by employing a limb position reproduction task. Although a body of research evidences on the kinesthetic processing, such as characteristics of kinesthetic memory and effect of efferent discharge on kinesthesis, have been reported, the hemispheric laterality effect has not been taken into consideration except for the two reports cited above. In the present study, thumb position discrimination and reproduction tasks were measured.

This investigation on kinesthetically oriented spatial perception could provide information relative to cerebral hemispheric lateralization and motor control.

Hypotheses to Be Tested

The main purpose of this study was to examine whether the lateralized effects of a thumb positioning task existed or not. If this lateralized effect exists the results presumably arise from the cerebral hemispheric lateralization. The review of literature has established that cerebral hemispheric lateralization has been observed in language processing in favor of the left hemisphere and spatial perception dominantly processed in the right hemisphere. The degree of hemispheric lateralization has been implied to be different between males and females. In the area of motor control research, the limb positioning task has been employed in many studies. The active standard movement presentation has been reported to be reproduced more accurately than by the passive movement condition.

On the basis of these research interests, four null hypotheses were developed and tested in this study. Each hypothesis was tested on each of the criterion measures.

Hypothesis one (Sidedness): No significant difference exists between responses performed by the right and left thumbs.

Hypothesis two (Sex): No significant difference exists between responses of male and female subjects.

Hypothesis three (Standard Movement Mode): No significant difference exists between responses made by the active standard movement and passive standard movement.

Hypothesis four (Response Mode): No significant difference exists between performances reported verbally and nonverbally.

Limitation of the Study

The nature and specificity of present experimental conditions impose some limits on the interpretation of results.

All possible efforts were made to make the subjects physically and mentally comfortable. Each subject was encouraged to concentrate on their performance throughout the experiment. The expected results were not revealed to the subjects until the completion of the experiment. Despite these experimental controls, unmeasurable and uncontrollable factors such as motivation, tension, and fatigue might have produced random fluctuations in the results of this experiment, reducing the possibility of demonstrating lateralization effects.

Specific experimental conditions impose limitation on generalization of results. Caucasian right-handed university students served as subjects. An angular position discrimination task measured by the Method of Constant Stimuli and a reproduction task measured by the method of Average Error were used to investigate the kinesthetic spatial perception. The difference limen, two kinds of constant errors, absolute error, and variable error were criterion measures in this study. Only the thumb was used for the task. Only one angular position, 45 degree, was used throught the experiment. These specific aspects of the experiment would be limitations of the present study.

CHAPTER II

REVIEW OF LITERATURE

Two kinesthetic tasks, oriented thumb angular position discrimination and thumb angular position reproduction, were employed in the present study to investigate the laterality of cerebral hemispheric processing.

In the present section, previous research related to the present study are reviewed and discussed. The research areas reviewed are those of cerebral hemispheric laterality, neural organization for control of the thumb, limb positioning tasks in general, and measurement of thumb positioning.

Cerebral Hemispheric Laterality

The human brain is divided into two cerebral hemispheres. Although each hemisphere shows overall anatomical symmetry, the existence of hemispheric laterality or functional asymmetry between two hemispheres has been demonstrated in many investigations. The term "cerebral hemispheric laterality" generally refers to the substantial differences found between behaviors that are controlled from the right hemisphere and those controlled from the left hemisphere. Cerebral hemispheric laterality has been observed most clearly in language processing.

Language Processing and Hemispheric Laterality

Mid-ninteenth century researchers, Mark Dax and Paul Broca are cited as the first researchers who observed aphasia, loss of language ability, following left brain damage (Springer and Deutsch, 1981).

Studies on split-brain patients, whose corpus callosum (the largest commissure connecting right and left hemispheres) was cut to reduce the effects of epilepsy, have revealed a great deal of knowledge on cerebral hemispheric lateralities. Visual tachistoscopic presentation which projects a stimulus either in the right or in the left visual field for 50 to 100 msec has been intensively used for the investigation of hemispheric lateralization. By using the tachistoscopic and other neuropsychological tests, the studies of split-brain patients revealed that each hemisphere functioned independently and the left hemisphere processed language activity much more than the right hemisphere (Bogen and Vogel, 1962; Gazzaniga and Sperry, 1967; Gazzaniga, Bogen, and Sperry, 1965).

The internal carotid artery on each side of the brain supplies blood to the hemisphere on the same side. Thus, when sodium amytal, which functions as an anaesthesis, is injected into the carotid artery on one side, the hemisphere on the same side is inactivated (Wada and Rasmussen, 1960). This method, often called the Wada test, has contributed to the determination of which hemisphere controls language processing in patients undergoing brain surgery. For example, after sodium amytal is injected to the hemisphere which controls language processing, the patient cannot continue counting numbers. The Wada test conducted on individuals who had no history of early brain damage showed that the language processing was inactivated if sodium amytal was injected through the left carotid artery (Rasmussen and Milner, 1977).

An electroencephalogram (EEG) provides a means to investigate brain function in terms of the electrical activity. Alpha activity, which is characterized by a wave frequency of 8 to 12 cycles a second, reflects the resting state of the brain. The comparison of EEG wave frequency on neurologically intact right and left hemispheres showed that relatively less alpha activity was observed from the left hemisphere than from the right hemisphere while the subject was involved in a language task (Galin and Orstin, 1972). The EEG amplitude, which reflects the degree of brain activity, was found to be larger in the left temporoparieral records than in the right during verbal activity (Morrell and Salamy, 1971).

Using the tachistoscopic method in the normal subjects, Kimura (1966) reported that letters were more accurately identified in the right visual field (projected to the left hemisphere). When two words were presented simultaneously, one to each hemisphere, all subjects were reported to recognize more of the right visual field words which would go directly to the left hemisphere (McKeever and Huling, 1971).

In a reaction time task, the procedure is to elicit a motor response to a visual stimulus presented to the right or left visual field. When the visual stimulus composed of letters and hand motor control were processed within the same hemisphere, the response was faster than when the visual information was required to be transferred to the opposite hemisphere for motor output (Berlucci, Heron, Hyman, Rizzolatti, and Ulmita, 1971). A verbal naming reaction time task revealed that the capital letters presented to the right visual field resulted in faster responses than presentation to the left visual field (Moscovitch and Catlin, 1970). The increase in reaction time when verbal stimuli are projected to the left visual field (to the right hemisphere) is proposed to be due to the additional time required for interhemispheric transmission to the left hemisphere.

Anatomical asymmetry has also been reported in the human brain. The prolongation of the left Sylvian fissure and larger left temporal plane which is the upper surface of the temporal lobe and bordered anteriorly by Heschl's gyrus, posteriorly by Sylvian fossa and laterally by the Sylvian fissure, was confirmed on adults (Geschwind and Levitsky, 1968) and on infants (Witelson and Pallie, 1973; Wada, Clark, and Hamm, 1975).

These findings strongly support the existence of lateralized language processing in the left hemisphere. In the present study, the verbal response mode which is exclusively involved in the left hemisphere processing and nonverbal response condition which only depends on the contralateral side of hemisphere for motor control were compared.

Spatial Information Processing and Hemispheric Laterality

Spatial orientation plays an important role in responding to given stimuli and in directing behavior. Information for spatial orientation arises through sensory modalities such as vision, audition, kinesthesis, and tactile sensitivity. The relationship between spatial processing and hemispheric lateralization also has been intensively investigated.

Disorders of spatial perception are observed as defects of object localization, dimensioning of two objects, avoidance of obstacles, perception of movement in the sagittal plane, and occular movement (Hecaen, 1978). Patients with right hemispheric lesion are well known to show deficits cited above (Nebes, 1977). Some studies in split-brain patients and brain damaged individuals have also indicated that the right hemisphere plays a major role in the nonlinguistic spatial tactile matching tests in which patients were to pick up the same shape out of different test shapes by touching with either right or left hand (Fontenot and Benton, 1971; Milner and Taylor, 1972; Nebes, 1972).

In normal individuals Kimura (1966) reported that the dot enumeration task, which required counting the number of dots presented tachistoscopically, showed left visual field (right hemisphere) superiority over the right visual field. The task of identifying the location of a single dot within a square presented in the right or left visual field also showed left visual field superiority in male subjects but no difference in females (Kimura, 1969). Depth perception, which was judged by the ability to discriminate the distance between tachistoscopically presented standard and comparison rods, was also reported to be processed better in the left visual field (Durnford and Kimura, 1971).

Dichaptic perception, identifying meaningless shape by palpating them, also demonstrates that the score performed with the left hand was better than the right hand for right-handed boys (Witelson, 1974), but no difference between hands in girls (Witelson, 1976). Left hand superiority has also been found for the reading of Braille (Hermelin and O'Connor, 1971a, 1971b). This has been interpreted that tactually presented linguistic stimuli are initially analyzed in a spatial code by the right hemisphere.

For visually oriented spatial perception, the left visual field is superior for shape identification. By tactile sensation better performance is demonstrated with the left hand. For both situations the processing of spatial orientation is suggested to be lateralized to the right hemisphere. Assuming this to be true, a kinesthetic task without involvement of left hemisphere language processing would be predicted to produce better performance with the left thumb (controlled by the right hemisphere).

Sex and Hemispheric Laterality

MacCoby and Jacklin (1974), after an intensive review of literature, concluded that females generally demonstrated superior verbal ability, whereas males usually demonstrated superior spatial ability. The fact that males and females differ in the performance suggests the possibility that cerebral lateralization might differ between males and females.

The effect of removal of the temporal lobe to alleviate epileptic seizure indicated that deficits in verbal tasks following left hemisphere surgery and in visuo-spatial tasks following operation on the right hemisphere were more predictable in males than in females (Lansdell, 1962).

Verbal and nonverbal tasks were compared between right-handed males and females with unilateral lesions (McGlone, 1977). The results indicated that males showed the expected pattern of verbal intellectual decline following left hemisphere lesions. On the other hand, females did not show the expected decline of verbal intellectual ability after unilateral brain injury.

Electroencephalographic(EEG) studies on healthy individuals indicated that the ratios of EEG power measured from the temporal lobe were different for males between two tasks which were designed to utilize the right and left hemisphere respectively. On the other hand, no significant difference was observed for females between the same two types of tasks (Ray, Morell, and Frediani, 1976).

Using tachistoscopic presentation Hannay and Malone (1976) examined the relationship between nonsense word stimuli and hemispheric processing in intact individuals. The results showed that the right visual field (projected to the left hemisphere) had superiority over the left visual field in male subjects, while no visual field difference was found in females.

As the above evidence indicates, it is suggested that males have a greater degree of lateralization for verbal processing in the left hemisphere and spatial functions in the right hemisphere, while females have a lesser degree of lateralization. Sex difference was also investigated in the present study.

Handedness and Hemispheric Laterality

A body of research evidence has revealed the relationship between handedness and hemispheric lateralization of language processing. Rasmussen and Milner (1977), using the Wada test, reported that over 95% of 140 right-handed persons without clinical evidence of early damage to the left hemisphere had speech function lateralized to the left hemisphere. Of 122 non right-handed persons, 70% also showed left hemispheric lateralization. Of remaining 30%, 15% showed right hemispheric control of speech and another 15% had speech function represented bilaterally.

Goodgrass and Quadfasal (1954) reported that 43% of 103 left-handers displayed dysphasia, language disorder, with unilateral left hemispheric lesion and 41% when the lesion was in the right hemisphere. The prognosis for recovery from aphasia following the left-side stroke was reported to be better in left-handers than in right-handers (Subirana, 1958). In the recovery process, the remaining opposite hemisphere is believed to take over the function of the damaged hemisphere. This suggests that left handers may have greater potential for bilateral control than do right-handers.

In a study using tachistoscopic presentation, the intact right-handed person showed a greater capability for verbal identification in the right visual field than in the left visual field, while left handers demonstrated less difference between the right and left visual fields (Bryden, 1965). A dichotic listening study, in which different acoustic stimuli were presented to the right and left ear simultaneously and subjects were then asked to recall what was heard, indicated that right handers recalled significantly more verbal stimuli from the right ear than from the left ear. Left handers, however, generally showed a smaller difference between the right and left ears (Bryden, 1975; Curry and Rutherford, 1967).

Although the standardization of handedness is not always consistent among researchers, it has been concluded that hemispheric lateralization is more prominent in right-handers than in left-handers, and that variability of lateralization is greater in left handers (Beaumont, 1974; Hicks and Kinsbourne, 1978).

In addition to these findings, the different degree of hemispheric lateralization between with and without left-handed relatives has been reported. Clinical evidence indicated that right-handers with familial sinistrality, were more likely to recover language functions after left hemisphere trauma than those with non-familial sinistrality (Hecaen, De Agostini, and Monzon-Montes, 1981; Searleman, 1977). Results from dichotic listening and tachistoscopic studies on right-handers indicated more variability of left hemisphere lateralization for verbal processing in sinistral familial subjects than in non-familial subjects (Hines and Satz, 1971; Piazza, 1980).

Dual-task method, in which manual performance for each hand was compared in conditions with and without a concurrent verbal task, has revealed that the concurrent verbal tasks interfered more with right-hand performance than with the left hand and that this pattern was more pronounced for non-familial sinistral right-handers than familial sinistral right-handers (Hicks, 1975; Kee and Bathurst, 1984).

These findings strongly suggest the need to employ only the right handed subjects without left-handed relatives for investigation of hemispheric laterality to increase the homogeneity of direction for the cerebral lateralization.

Laterality of Manual Task

Beaumont (1974) reviewed the studies on handedness which had been reported earlier than the establishment of hemispheric lateralization concepts and pointed out that without exception the use of preferred hand produced superior fine motor control. However, since the independence and processing specificity of each hemisphere had been reported, the lateralized effect of a manual task could be expected by taking into consideration the nature of manual task, which is dominantly controlled by either one of the hemispheres.

Brain damaged patients with left-sided lesions were found to show inpairment on copying sequential hand movements relative to the right hemisphere damage patients (De Renzi, Motti, and Michelli, 1980; Kimura and Archibald, 1974). Kimura (1977) reported that patients with left hemisphere lesions were worse at acquisition of a manual sequence task by either hand. This clinical evidence indicates the critical importance of the left hemisphere for sequential motor control.

A number of investigations have demonstrated a right-hand superiority for rate of rapid tapping in normal subjects (Lomas and Kimura, 1976; Piazza, 1977; Todor and Doane, 1978). These laterality effects are believed to arise from the functional lateralization of the hemispheres and the contralateral motor control of tapping. Consistent with findings of decreased hemispheric laterality of language activity in left handers, Peters and Durding (1979) reported that left-handers displayed a smaller between-hand difference than right-handers in both the rate and regularity of the intertap interval.

Dual task procedures, in which two tasks are performed simultaneously and interference is observed, revealed that speaking depressed performance of dowel balancing more for the right hand than the left (Hicks, 1975; Kinsbourne and Cook, 1971). Using normal subjects, Lomas and Kimura (1976) found that sequential finger and arm movements were maximally impaired in the right arm by a concurrent speaking task. This impairment of manual task by concurrent speaking is proposed to be due to the overlapping in cerebral processing of speaking and manual control. Therefore these tasks were suggested to be both dominantly processed in the left hemisphere.

On the other hand, left hand superiority on manipulo-spatial tasks such as block design and part-whole discrimination was reported in split-brain patients (Bogen and Gazzaniga, 1965; Nebes, 1972). In normal subjects, a finger flexion task was better performed with left finger than with the right (Kimura and Vanderwolf, 1970). Left hand superiority was also reported on hand posture and finger spacing tasks (Ingram, 1975). The spatial components of these postural tasks were believed to play a roll in eliciting left side superiority.

A dual task of finger tapping concurrent with block design activity demonstrated that the left finger performance was relatively more impaired than that of right finger, an indication of more right than left hemisphere involvement in these spatial tasks (Hellige and Longstreth, 1981; Kee, Bathurst, and Hellige, 1984).

Using an arm positioning task, in which a standard position of the arm was reproduced as exactly as possible, Christina (1967) found that the left arm deviated less than the right arm in male high school students. Roy and McKenzie (1978) did not find this arm laterality effect, but found left thumb superiority over the right in a similar positioning task.

The review of literature on lateralization of manual task indicates that while sequential manual tasks were performed better by the right hand, spatial manual tasks were processed better with the left.

Efferent and Afferent Innervation of the Thumb

Since thumb abduction and adduction were employed in the present positioning task, an understanding of thumb neural organization of kinesthesis and motor control is of importance.

Neural Organization of Thumb Kinesthesis

The mechanoreceptive sense includes the tactile senses such as touch, pressure, vibration, and kinesthesis which generate information about relative positions and rate of movement of the different parts of the body. Major types of kinesthetic receptors are; (1) Ruffini endings, which are the most abundant and located in the deeper tissue of the body, (2) Golgi tendon receptors, which are the stretch recepters found in the ligaments around the joints, and (3) a few Pacinian corpuscles which are found in the tissue around the joint (Guyton, 1976). Since Ruffini endings and

Pacinian corpuscles also serve as the tactile recepters, the modalities of the tactile and kinesthetic senses are closely related and in fact are carried in the same spinal pathway, the posterior white columns.

The first cell bodies of these receptors are located in the spinal ganglia and these fibers make synapses at three different sites; (1) the lower motoneuron in the anterior gray horns, (2) the base of posterior horn (nucleus dorsalis) to form the spinocerebeller tract, and (3) the nuclei of gracilis and cuneatus which terminate the posterior white column and form the brain stem medial lemniscus. Of these three routes only the posterior white column conveys information directly to the conscious level. The second fibers from the nuclei gracilis and cuneatus immediately cross to the opposite side in the decussation of the medial lemniscus and go directly to the thalamus. The neurons from the thalamus project to the somesthetic area of the cerebral cortex (Clark, 1979; Ranson, 1959). Kinesthetic information arising from the left thumb reaches the right hemisphere and visa versa.

Neural Organization of Thumb Motor Control

The descending cortical (pyramidal) and subcortical (extrapyramidal) pathways to the spinal cord control movement.

Findings in the cat (Kuypers and Brinkman, 1970; Sterling and Kuypers, 1968) suggested that the motoneurons in the dorsolateral part of spinal cord distribute to distal extremity muscles, while the ventromedial part projects to axial and proximal limb muscles. By way of pyramidal and extrapyramidal pathways, each hemisphere is connected with the dorsolateral part of the cord contralaterally and with its ventromedial part bilaterally. These findings in the cat indicated that the distal extremity was exclusively controlled by the contralateral hemisphere. Brinkman and Kuypers (1972) studied the ipsilateral and contralateral hemispheric control of the arm, hand, and finger movements in split-brain monkeys in which the visual information from opened eye is projected to the hemisphere on the same side. When the animals, with one eye closed, were presented with a small piece of food in a board, the hand ipsilateral to the open eye reached to the food accurately by arm movement, but the hand and fingers could not pick the food out of the board. However, the hand and fingers contralateral to the open eye were brought toward the food, and once reached, the hand and fingers could pick up the food. These results indicated that each hemisphere controlled the hand and finger movements contralaterally, but arm movements could be controlled ipsilaterally as well as contralaterally.

These neuroanatomical and behavioral findings indicated that thumb movement is controlled by the opposite hemisphere.

Limb Positioning Task

In the review of literature, it was pointed out that only two studies, Roy and McKenzie (1978) and Colley (1984), employed thumb positioning tasks as an experimental device to measure the limb position reproduction deviation errors. This spatial location judgement was evaluated for hemispheric lateralization effects in both studies.

On the other hand, the arm positioning task has been extensively used in research on motor control. An arm positioning or an arm raising task, in which the deviation of positional reproduction from a specified criterion position is measured, was reported to be a reliable test of kinesthesis. Many investigators reported high reliability coefficients for arm positioning; 0.86 (Norrie, 1967); 0.67-0.80 (Roloff, 1953); 0.91 (Scott, 1955); 0.83-0.88 (Wiebe, 1954); and 0.79 (Young, 1945). Since kinesthetic information processing is likely to be similar for arm and thumb positioning tasks, the preceding reports suggest that the thumb positioning task will produce reliable measures.

The arm positioning task has been employed for investigation of many topics in motor control research. On lateralization effects, Christina (1967) reported less deviation of positional reproduction with the nondominant arm. However, Philips and Summers (1954) found that no consistent difference was obtained between preferred and nonpreferred hands in the test range of 0 to 180 degree. Wyke (1965) found that the right arm was better than the left with the head normally oriented. No arm difference between right and left was found in simultaneous bilateral arm positioning task (Roy and McKenzie, 1978). Although the arm positioning task is a spatial task, the results were not consistent among researchers. These equivocal results might be explained by the assumption of some bilateral hemispheric control of the arm (shoulder muscle). This would suggest that thumb positioning task would show more consistent effects of brain lateraliization since the thumb is unilaterally controlled.

In a limb positioning task, a target position (end location) or a target distance presented by the standard movement is reproduced. In a study of end location reproduction, a subject is required to indicate only the end location which is presented by the standard movement, starting the reproduction from the different starting position of standard movement. In this condition the distance cue of standard movement is not necessary. A distance cue is investigated by having a subject reproduce only the distance presented by the standard movement. The subject starts reproduction of distance at the different starting position from that of standard movement. The end location cue presented by the standard movement is no longer necessary.

In a study of comparison between end location and distance reproduction, the end location cue has been found to produce better retention than distance cue (Colley and Colley, 1981; Laabs, 1973; Posner; 1967). The present study employed the location plus distance condition, which has been reported to produce better performance than the distance cue alone (Keel and Ells, 1972). The subject reproduced the same distance from the same starting point as a standard thumb movement.

The effect of a cognitive plan for the standard movement has been investigated. In such an experiment a subject is required to determine when (or where) the standard movement will terminate prior to movement initiation and this condition has been named "preselected condition" (Stelmach, Kelso, and Wallace, 1975). This is contrasted with conventional standard movement presentation, in which the termination point is previously determined by the experimenter and the subject has no information when the standard movement would be stopped. This conventional presentation mode has been termed as the "constrained condition". The comparison of preselected and constrained conditions showed that the preselected condition produced less errors than those of constrained movement (Roy and Diewert, 1978; Runnings and Diewert, 1982; Stelmach, Kelso, and Wallace, 1975). It was supposed that the superiority of preselected condition was due to efference being used in a feedfoward process to sensitize sensory centers (Stelmach, Kelso, and Wallace, 1975).

However, since the preselected mode requires extra trials to determine the test position, the present study employed the constrained presentation mode due to the limited experimental time allowed to each subject.

Another issue to consider in the standard presentation mode is the availability of the efferent motor command. In an active condition, in which the subject produces the standard movement voluntarily, the efferent motor system is utilized. A passive condition requires the subject to relax his/her test limb while the experimenter moves it to the standard position. The information on the efferent motor command is no longer available in the passive condition.

The comparison of reproduction accuracies between active and passive conditions obtained by the constrained method has sometimes indicated that the active mode produced more accurate responses than those of passive mode (Kelso, 1977; Marteniuk, Shields, and Campbell, 1972; Roy, 1978; Roy and Diewert, 1978). However, other researchers have failed to find significantly different reproduction accuracy between active and passive conditions (Jones, 1972; 1974; Summers, Levey, and Wrigley, 1981).

Using the preselected method some researchers have reported that the active standard mode produced less production errors than the passive mode did (Hall and Leavitt, 1977; Jones, 1974; Kelso, 1977; Marteniuk, 1974). However, in one study active mode superiority over the passive presentation was not found in preselected method while preselected method produced less errors than the constrained method (Roy and Diewert, 1978).

Although these findings generally suggest the superiority of active mode over the passive condition, results are still inconsistent. In the present study, the condition of both active and passive standard movements were compared by the constrained method.

Measurement of Thumb Angular Positioning

In the present study, two tasks, thumb angular position discrimination and thumb angular position reproduction, were employed to measure kinesthetic spatial perception.

Angular Position Discirmination Task

The method of constant stimuli (MOCS) was used for measurement of discrimination. The method of constant stimuli is generally regarded as the most accurate method to obtain psychophysical measures, such as absolute threshold, difference limen, and point of subjective equality (Guilford, 1954). Against a standard stimulus the subject is required to judge whether the comparison stimulus is greater than the standard or not. Several levels of comparison stimuli are presented several times at random and the relationship between the comparison stimulus value and proportion of times it is judged greater than a constant standard stimulus is plotted (psychometric function).

The difference limen is calculated from the psychometric function as one-half of difference between that comparison stimulus judged as greater 75% of the times and that judged as greater 25% of the time (Galanter, 1962). This difference limen estimates that the subject is able to discriminate 50% of the time the direction of the difference between the standard and comparison stumuli. This difference limen measures the subject's sensitivity to change in a stimulus.

The constant error is calculated as the difference between the standard simulus (Point of Objective Equality) and the comparison stimulus judged greater than the standard 50% of the time (Point of Subjective Equality). The constant error does not measure subject's discrimination ability, but whether or not the neutral point of the subject's scale of sensation is shifted from the physical neutral point.

Angular Position Reproduction Task

In the method of average error, after a standard stumulus is given, a subject is required to reproduce the same intensity as the standard. Using the procedure of the method of average error in the positon reproduction task, measures of constant error, absolute error, and variable error were obtained (Woodworth, 1938). Constant error (CE) is a measure of the deviation of a response from the target with regard for the sign or direction: $CE=\sum(X-T)/k$ (X is score, T is target, and k is number of trials). Absolute error (AE) is a measure of the deviation of a response from the target without regard for the sign or direction the deviation: $AE=\sum|X-T|/k$. Variable error (VE) is a measurement of the variablity (standard deviation) of CE.

Among AE, CE, and VE, the variable which represents the most meaningful expression of accuracy has been debated in the study of motor performance. Henry (1974) studied the correlational analysis of these variables and suggested that total variability "E", $E=\sqrt{(CE)^2+(AE)^2}$, was the correct measure of individual errors about the target. Schutz and Roy (1973) showed that AE was dependent on CE and VE and thus was predictable. In spite of such discussion no consistent use of a specific measure has been established. Some investigaters have chosen AE (Jones, 1972; Schmidt, 1975) and others have employed CE and VE (Keele and Ells, 1972; Laabs, 1974). All three variables are sometimes reported (Marteniuk, 1973; Stelmach and Kelso, 1975; Stelmach, Kelso, and Wallace, 1975). The total variability, "E", has not been used as a single measure. Due to the lack of concensus about which dependent variable should be used, reporting all three measures is recommended (Roy, 1976). Therefore, three criterion measures of AE, CE, and VE were obtained in the angular position reproduction task in the present study.

The topics of cerebral hemispheric lateralization, neural organization for control of the thumb, limb positioning tasks, and measurement of thumb positioning have been reviewed in this section. Left cerebral hemispheric lateralization for language processing and right hemispheric dominance for spatial perception are suggested by the literature. The possibility of sex difference in degree of hemispheric lateralization has been reported. Based upon this research evidence, four sets of null hypotheses were tested by using thumb angular position discrimination task (MOCS) and thumb angular position reproduction task (MOAE).

CHAPTER III

METHODOLOGY

Subjects

Prior to subject recruitment, the approval of the use of human subjects was granted by the Oregon State University Committee for the Protection of Human Subjects (Appendix A).

A letter of invitaion (Appendix B) describing the nature of this study, qualifying status as a subject, and explaining basic procedure was distributed in several undergraduate psychology classes at Oregon State University in the fall term of 1983. The subjects who qualified were 20 to 29 year old caucasian right-handers having no left-handed relatives. Thirty two male and 32 female subjects participated in this experiment and each subject earned credits for their classes.

Upon arrival for the experiment, each subject was asked to complete an informed consent form (Appendix C) and subject information form (Appendix D) to confirm his/her status as a subject.

Equipment

The instrument for this investigation was a finger positioning apparatus composed of arm board, hand resting board, angle board, and pointer (Figure 1). The apparatus

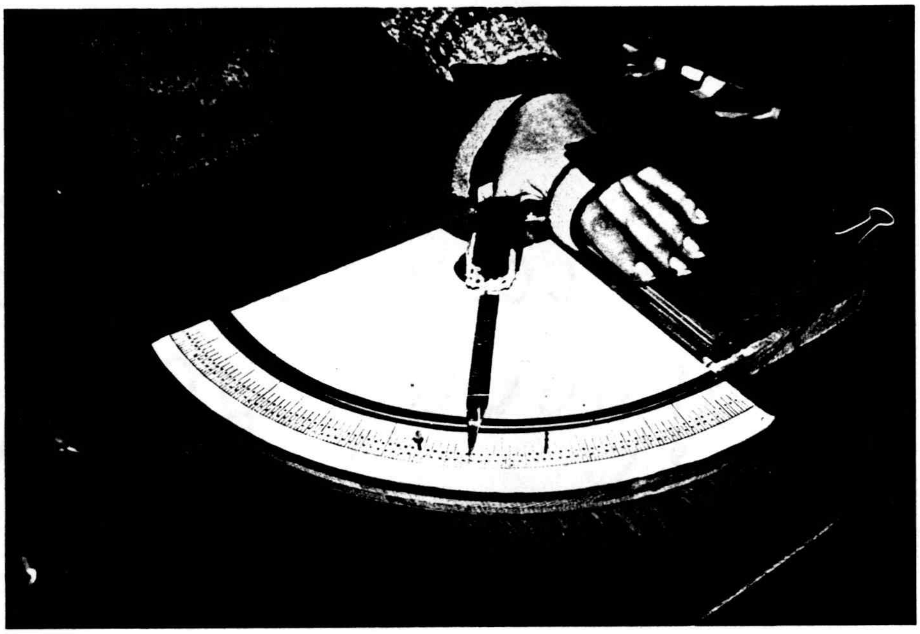


Figure 1. Finger positioning apparatus.

was constructed by the experimenter.

In order to obtain the fulcrum of thumb abduction, a stroboscopic photograph was taken on the thumb abduction movement in the pretest (Figure 2). The carpometacarpal joint, where the first metacarpal and multangulum major join (Wells, 1971), was confirmed to be the fulcrum of the thumb movement. The area of the hand resting board which touched the thenar eminence was removed so that the muscles responsible for thumb abduction could move freely without touching the board. Two velcro straps were fixed to the hand resting board. The board was adjustable so that the carpometacarpal joint fell on the center of the measuring angle.

A scale calibrated in half degrees from 0 to 90 degrees was secured on the angle board. Zero degrees was defined as a line passing through the center of the measuring angle and parallel to the middle finger. The proximal and distal phalanges of the thumb were fixed at the bottom of the pointer by a surgical splint, cushion, and velcro. The friction between the pointer and angle board was minimized by bearings. The pointer was blocked at specified angles by a stopper made of a nail inserted into holes spaced at half degree intervals.

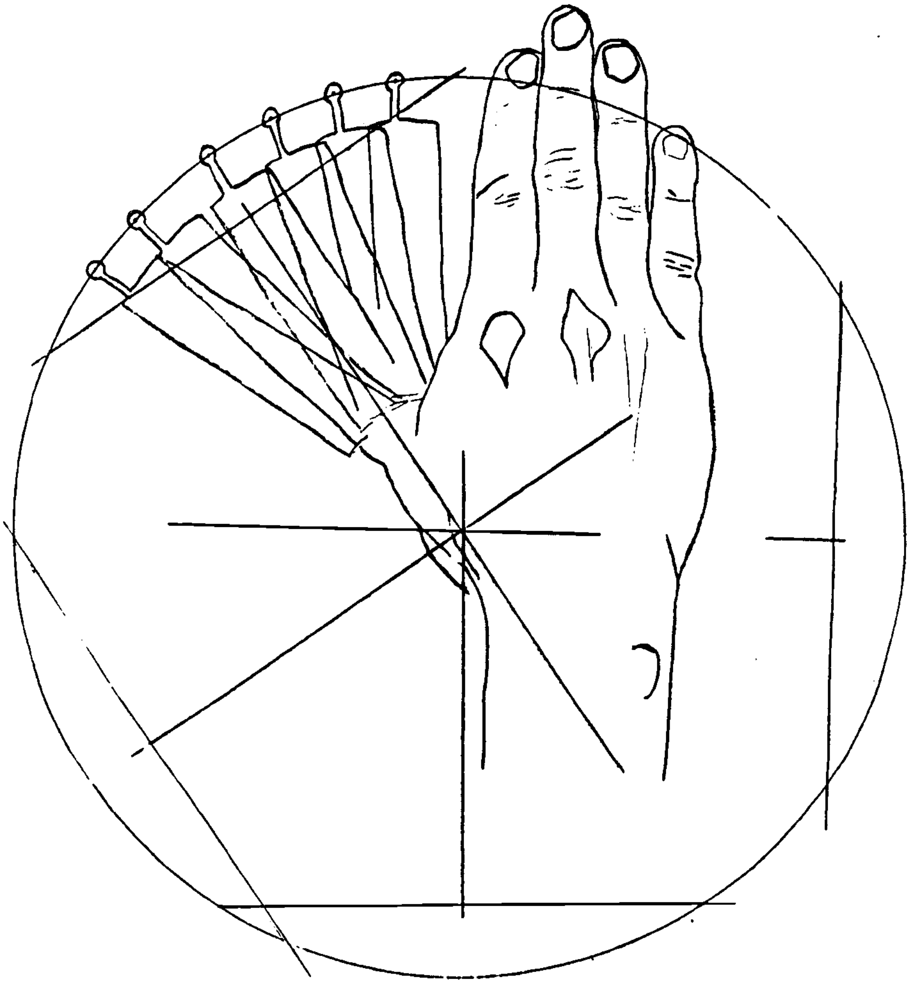


Figure 2. Stroboscopic presentation of thumb abduction.

Experimental Design

Independent and Dependent Variables

The independent and dependent variables of this study are listed in Table 1. Four independent variables were investigated using the Method of Constant Stimuli (MOCS) to measure discrimination of thumb position. Each independent variable had two levels; (1) Sidedness (Right vs Left), (2) Sex (Male vs Female), (3) Standard Movement Mode (Active vs Passive), and (4) Response Mode (Verbal vs Nonverbal). The variables of (2) Sex, (3) Standard Movement Mode, and (4) Response Mode were analyzed as between-group comparisons and the variable of (1) Sidedness was done as a within-group (trials) comparison.

In addition, the thumb angular position reproduction task was measured using the Method of Average Error (MOAE). For this second task, only three independent variables were manipulated. They were; (1) Sidedness (Right vs Left), (2) Sex (Male vs Female), and (3) Standard Movement Mode (Active vs Passive). The variables of (2) Sex and (3) Standard Movement Mode were compared between-groups and (1) Sidedness was a within-group comparison. It was not possible to manipulate the reponse mode variable used in the MOCS procedure since all responses were by finger movement in this MOAE procedure.

Table 1. Independent and Dependent Varibles.

		Independent Variables			Dependent Varibles				
					Discrimination task		Reproduction task		
Group #	Sex	Movement Mode	Response Mode	Sidedness (Trial)	MOCS		MOAE		
					DL	CE	CE	AE	VE
1	M	Active	Verbal	R+L					
2	M	Active	Nonverbal	R+L					
3	M	Passive	Verbal	R+L					
4	M	Passive	Nonverbal	R+L					
5	F	Active	Verbal	R+L					
6	F	Active	Nonverbal	R+L					
7	F	Passive	Verbal	R+L					
8	F	Passive	Nonverbal	R+L					

Note;
M; Male,
F; Female,
R; Right,
L; left,
DL; difference Limen,
CE; Constant Error,
MOCS; Method of Constant Stimuli,
MOAE; Method of Average Error,
AE; Absolute Error,
VE; Variable Error.

For the dependent variables (criterion measures) the difference limen (DL) and constant error (CE) were obtained by the thumb angular position discrimination task (MOCS procedure) and were abbreviated as DL-MOCS and CE-MOCS in this study. For the thumb angular position reproduction task (MOAE procedure) criterion measures of constant error (CE), absolute error (AE), and variable error (VE) were determined and named CE-MOAE, AE-MOAE, and VE-MOAE, respectively.

Grouping and Measuring Order

Thirty two male subjects were randomly assigned to one of 4 groups and each group was numbered from group 1 through group 4. Thirty two female subjects were also randomly assigned to one of 4 groups and named group 5 to group 8 (Table 1). Each group had 8 subjects and was assigned to one of four experimental conditions in the position discrimination (MOCS) experiment; (1)Active-Verbal, (2)Active-Nonverbal, (3)Passive-Verbal, and (4)Passive-Nonverbal condition. Each group was also assigned to the same condition of (1)Active or (2)Passive as MOCS in the MOAE exeriment. The group number and their experimental condition are listed in Table 1. Each subject participated in both MOCS and MOAE experiments with both right and left thumbs under the experimental condition specified by his/her group number.

To counterbalance the effects of order of measurement, a Latin Square Design was employed within group 1 through 4 and group 5 to 8 (Table 2).

Null Hypotheses

In the present study, the following four sets of null hypotheses were tested by each of the criterion measures which were obtained by the thumb angular position discrimination (MOCS) and reproduction (MOAE) tasks.

Hypothesis one (Sidedness): No significant difference exists between responses performed by the right and left thumbs. This was examined by comparing responses made by the right and left thumbs of all subjects, group 1 through 8, for each of five criterion measures.

Hypothesis two (Sex): No significant difference exists between responses of male and female subjects. Comparison of responses made by group 1 through 4 and group 5 through 8 was made to test the hypothesis two for each of five criterion measures.

Hypothesis three (Standard Movement Mode): No significant difference exists between responses made by the active standard movement and the passive standard movement. This hypothesis was tested by comparing responses made by groups 1, 2, 5, and 6 and groups 3, 4, 7, and 8 for each of five criterion measures.

Hypothesis four (Response Mode): No significant difference exists between performances reported verbally and

Table 2. Measurement Order for Discrimination (MOCS) and Reproduction (MOAE) Tasks.

		Discrimination Task (MOCS)		Reproduction Task (MOAE)	
	Group	Right	Left	Right	Left
Male	1 n=8	(1)	(2)	(3)	(4)
	2 n=8	(2)	(3)	(4)	(1)
	3 n=8	(3)	(4)	(1)	(2)
	4 n=8	(4)	(1)	(2)	(3)
Female	5 n=8	(1)	(2)	(3)	(4)
	6 n=8	(2)	(3)	(4)	(1)
	7 n=8	(3)	(4)	(1)	(2)
	8 n=8	(4)	(1)	(2)	(3)

Note; (1) through (4) are measurement order.
MOCS; Method of Constant Stimuli,
MOAE; Methos of Average Error.

nonverbally. This hypothesis was tested by comparing responses made by groups 1, 3, 5, and 7 and groups 2, 4, 6, and 8 for two criterion measures, DL-MOCS and CE-MOCS.

Experimental Procedure

The experiment of thumb angular position discrimination task (MOCS) was performed in four different conditions; (1)Active-Verbal, (2)Active-Nonverbal, (3)Passive-Verbal, and (4)Passive-Nonverbal. The thumb angular position reproduction experiment(MOAE) had two conditions; (1)Active and (2)Passive. Each subject participated in either one of four conditions in MOCS and in one of two conditions in MOAE.

Active-Verbal Condition for Thumb Angular Position Discrimination Task (MOCS)

Group 1 and group 2 participated in the Active-Verbal condition in MOCS experiment.

The subject was blindfolded with the eyemask and sat on the chair (Figure 3). Both arms were rested on the arm board with palm down on the hand board. The trial hand was fixed to the hand board at the position where the carpometacarpal joint fell on the center of the measuing angle so that the thumb could produce smooth rotatory movement. The thumb was fixed comfortably to the pointer by the cushion, splint, and velcro. The resting position was a 30° angle between the thumb and middle finger.

Figure 3. General view of experiment.

On the command "Up to standard", the subject abducted (spread out) his/her thumb on the angle board until blocked by the stopper set at the standard angle, 45°. After memorizing this standard angle for three seconds, the command "Down to rest" was given and the subject returned the thumb to the resting position. The resting period was three seconds. On the next command "Up to test", the subject again abducted the thumb until blocked at the comparison angle which ranged between 42° and 48° . After three seconds of judging, the command "Judge and down" was given and the subject reported whether the comparison angle was larger or smaller than the standard angle. The report "Larger" or "Smaller" was made verbally and no "Equal" response was allowed. After three seconds of resting, another trial was started. In the Active-Verbal condition, the subject always moved his/her thumb actively and reported the judgement verbally. The commands were prerecorded in a casset tape recorder and each command was heard by both subject and experimenter through the head-phones.

Seven sets of comparison angles (42°, 43°, 44° , 45° , 46°, 47° , and 48°) were presented 8 times in random order. Two random tables were prepared and the odd number subjects in each experimental group were examined by the first table (Appendix E) and the even number subjects by the second table (Appendix F). Each response was recorded on the recording form.

After the instruction was given, the subject practiced several times and the correct procedure was confirmed. The formal practice was conducted seven times before the 56 actual trials started.

Active-Nonverbal Condition for Thumb Angular Position Discrimination Task (MOCS)

Group 2 and group 6 participated in the Active-Nonverbal condition.

The procedure of the Active-Nonverbal condition was the same as the Active-Verbal condition except that the subject indicated his/her judgement of "Larger" or "Smaller" by the thumb movement instead of by verbal report. When the comparison angle was judged to be smaller than the standard angle, the subject was required to abduct (spread out) his/her thumb further and to return to the resting position. When the subject judged the comparison angle to be larger than the standard angle, the thumb was adducted closer to the resting position and then returned to the resting condition.

Passive-Verbal Condition for Thumb Angular Position Discrimination Task (MOCS)

Group 3 and 7 participated in the Passive-Verbal condition.

The procedure for the Passive-Verbal condition was identical to the Active-Verbal condition except that the experimenter moved the subject's thumb to both standard and comparison angles. The subject was required to relax his/her thumb as much as possible. The judgement was reported verbally.

Passive-Nonverbal Condition for Thumb Angular Position Discrimination Task (MOCS)

Group 4 and 8 participated in this Passive-Nonverbal condition.

The experimenter moved the subject's thumb abductly and/or adductly to the standard and/or comparison angles. The subject reported his/her judgement by active thumb movement which was identical to the Active-Nonverbal condition. The rest of the procedure was the same as in the Active-Verbal condition.

Active Condition for Thumb Angular Position Reproduction Task (MOAE)

The posture of subject and instruments used in MOAE were the same as those used in the discrimination (MOCS) experiment.

Groups 1, 2, 5, and 6 were measured by the Active condition in MOAE.

On the command of "Up to standard", the subject abduct (spread out) his/her thumb until blocked at the standard angle of 45°. After memorizing this position for three seconds, another command "Down to rest" was given. The subject was to move the thumb actively. After three seconds of resting, the subject attempted to replicate the standard angle on the command "Reproduce". The reproduced angle was recorded to the quarter of a degree. Three practices and 10 trials were performed.

Passive Condition for Thumb Angular Position Reproduction Task (MOAE)

Groups 3, 4, 7, and 8 participated in the Passive condition in MOAE experiment.

The passive condition procedure was identical to the active condition except that the experimenter moved the subject's thumb up to the standard position and also the experimenter returned it to the resting position after the three seconds memorizing period at the standard position. However, the subject reproduced the standard position actively in the trial.

CHAPTER IV

ANALYSIS AND INTERPRETATION OF DATA

Analysis of Data

Through the first experiment, thumb angular position discrimination task measured by the Method of Constant Stimuli (MOCS), the difference limen (DL-MOCS) and the constant error (CE-MOCS) were calculated by means of the probit analysis. By the second experiment, thumb angular position reproduction task measured by the Method of Average Error (MOAE), the constant error (CE-MOAE), absolute error (AE-MOAE), and variable error (VE-MOAE) were obtained. Each subject performed both discrimination and reproduction tasks with both right and left thumbs and the five criterion measures (two by MOCS and three by MOAE) were obtained for both thumbs. The main effects of the independent variables (sidedness, sex, movement mode, and response mode) and interaction of these were examined by the analysis of variance for each criterion measures.

Probit Analysis of the Method of Constant Stimuli(MOCS)

In the thumb angular position discrimination task, each judgement of whether the comparison angle was larger or smaller than the standard angle (45°) was recorded. For each subject, the percentage of responses in which the comparison angle (42°-48°) was judged to be "Larger" than the standard angle (45°) was plotted against the comparison angle. The shape of the psychophysical function as measured by the MOCS represents a sigmoid curve, a tilted "S" shape (Coren, Porac, & Ward, 1979). By totaling the 128 trials, using both right and left thumbs of all 64 subjects, the sigmoid curve was confirmed in this study (Figure 4).

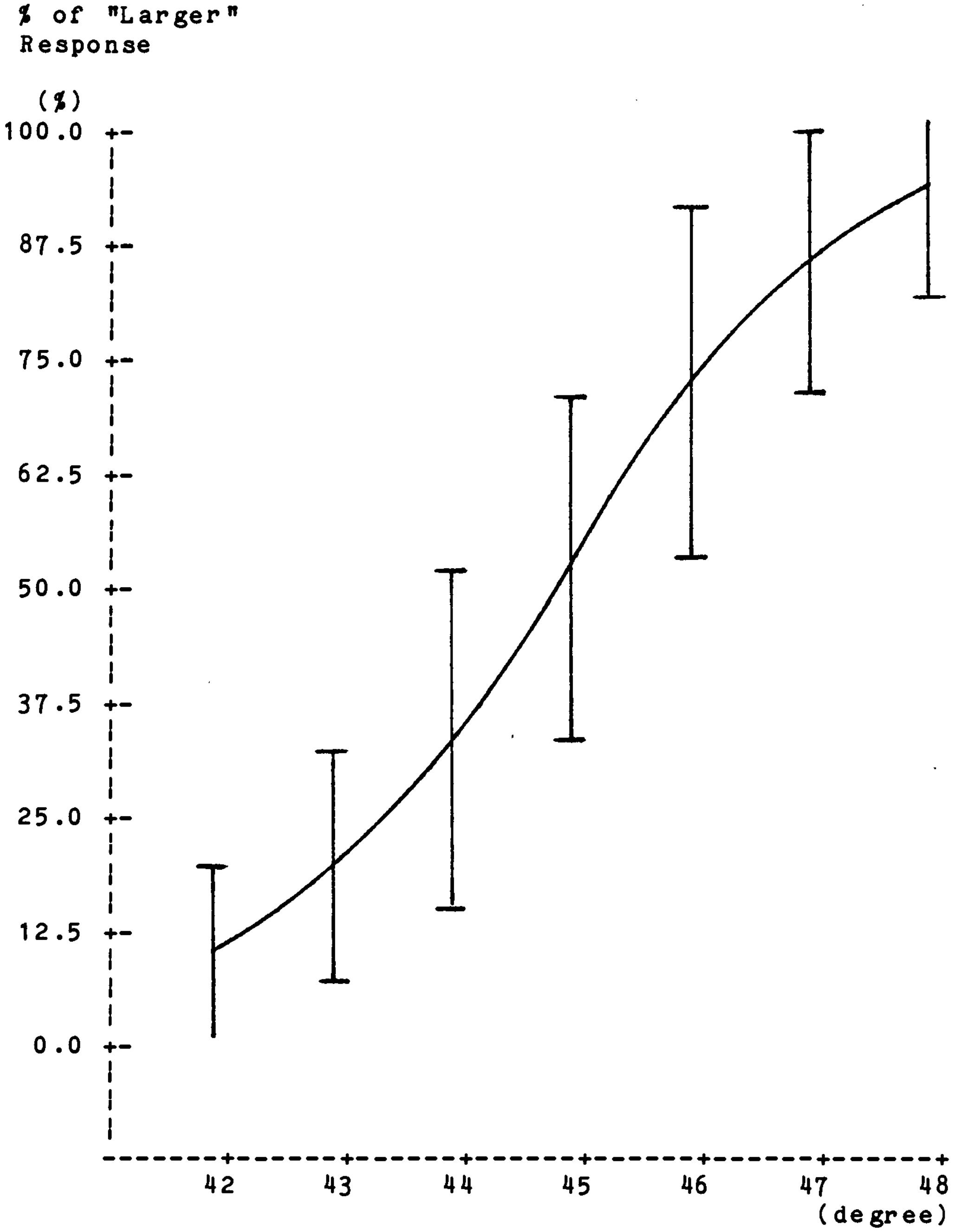
The difference limen (DL-MOCS) and constant error(CO-MOCS) measured by the MOCS were defined as follows;

DL-MOCS = (Comparison angle at 75% of "Larger" response minus that at 25%)/2

CE-MOCS = Comparison angle at 50% of "Larger" response minus standard angle(45°).

A pictorial representation of DL-MOCS and CE-MOCS is presented in Figure 5. In order to calculate the DL-MOCS and CE-MOCS, three comparison angles corresponding to 75%, 25%, and 50% of response were estimated by the probit analysis (Appendix G-1).

As the first step of probit analysis, the number of "Larger" response, "r", out of 8 attempts at each comparison angle was converted to percentage response, p, ($p = r/8 \times 100$). The percentage was transformed to the "empirical probit" according to the table of transformation of percentages to probits (Beyer, 1968). If no "Larger" response ($p=0$) or all "Larger" responses ($p=100$) were recorded, $p=1$ or $p=99$



Comparison Angle

Figure 4. Average response in psychometric function measured by MOCS.

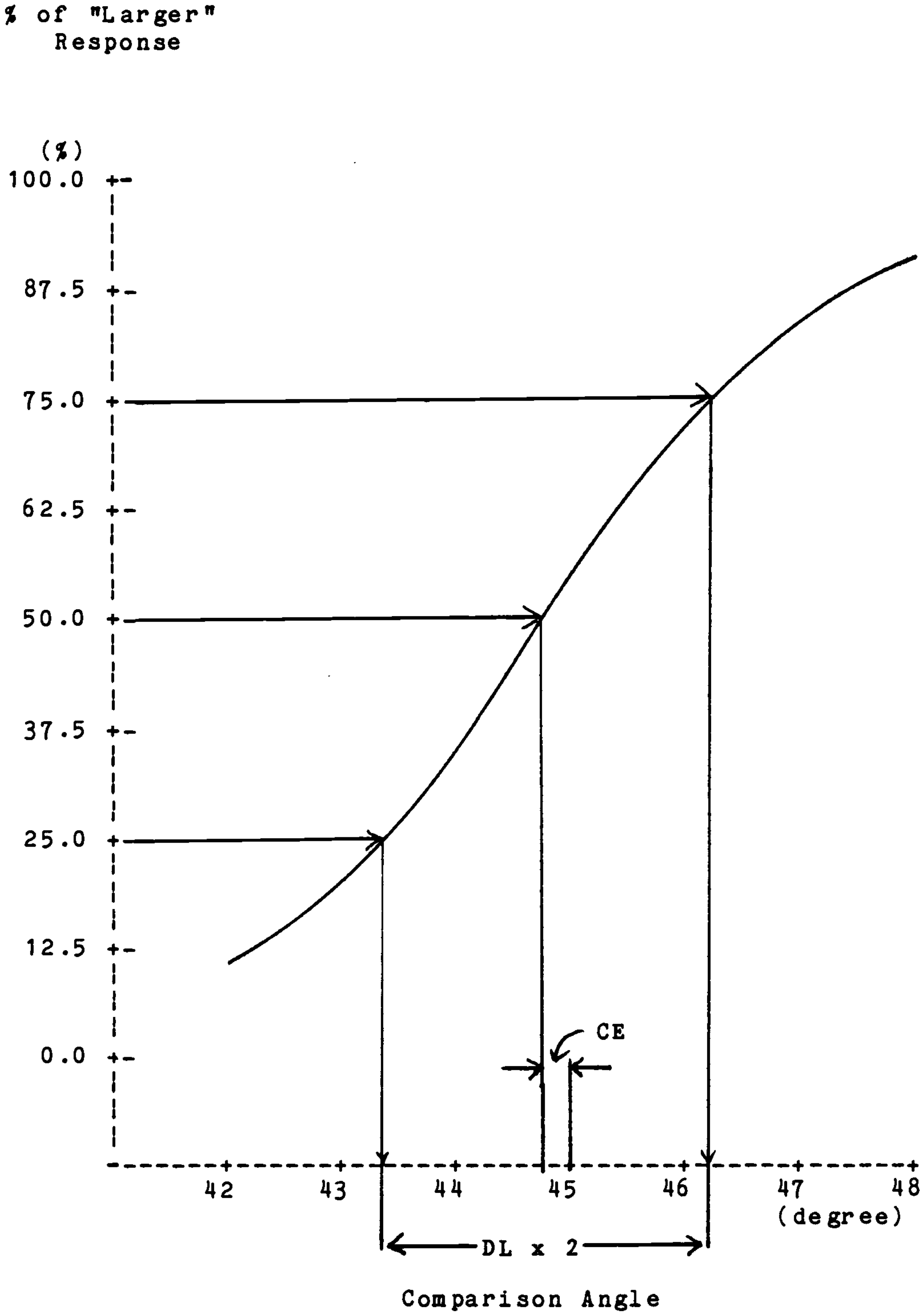


Figure 5. Pictorical representation of DL-MOCS and CE-MOCS in psychometric function.

was substituted for p=0 or p=100 in the probit transformation since p=0 or p=100 does not have finite empirical probit.

The empirical probits were plotted against the comparison angle, ranging from 42° to 48°. Since the relationship between the probit and comparison angles should be linear, the provisional straight line to fit the points were drawn by the method of least square (Appendix G-2).

Another probit, the "expected probit", which is the probit on the provisional line at each comparison angle, was calculated from the regression function of the provisional straight line.

For each expected probit, "Y", the weighting coefficient "w" (Appendix G-3) was obtained from the Weighting Coefficient Table (Finney, 1971b) and multiplied by the number of total trials, 8. This value, "w" x 8 is the weight attached to the expected probit.

Corresponding to each expected probit, "Y", and empirical proportion of response, "p", the working probit "y" (Appendix G-4) was obtained from the table (Finney, 1971c). The working probit "y" is determined to take finite value if "p" is zero or 100, and to locate nearer to the empirical probit than the expected probit.

After the weight and working probit at each comparison angle has been obtained, a weighted linear regression of working probit "y" on the comparison angle was calculated by the method of weighted least squares (Appendix G-5).

Whether or not the observed data agree satisfactorily with the expected data on the weighted regression line was examined by the chi-square test (Appendix G-6). Homogeneity was assumed for the observed and expected data on the weighted regression line if the chi-square test was non-significant. For these homogeneous data (111 out of 128 results), three comparison angles corresponding to probits of 4.33 (equivalent of 25% response), 5.00 (50% response), and 5.67 (75% response) were estimated from the linear equation of the weighted regression line to compute DL-MOCS and CE-MOCS.

Seventeen out of 128 chi-square test results showed significant discrepancies between observed and expected values at the 5% level. The weighted linear regression line was modified for these 17 results by grouping the observations. The most deviated observation from the weighted regression line was found visually and averaged together with one or two neighboring observations. The modified weighted regression line was obtained using these grouped sets of observations and again examined for goodness of fit by the chi-square test. All of the 17 observations showed no significant discrepancies between the grouped sets of observations and the modified linear regression line. Three angles, at 25%, 50%, and 75% of "Larger" responses, were estimated from the linear equation of grouped weighted regression line. The difference limen (DL-MOCS) was calculated as half of the difference between the 75% response angle and the 25% response angle. The constant error (CE-MOCS) was obtained as the difference between the 50% response angle and the standard 45° angle.

Analysis of Method of Absolute Error (MOAE)

The constant error (CE-MOAE), absolute error (AE-MOAE), and variable error (VE-MOAE) were obtained by the method of average error (MOAE) in the reproduction task and calculated according to the following definitions;

$$\text{CE-MOAE} = \left[\Sigma(X_i - 45^\circ)\right]/n$$

$$\text{AE-MOAE} = \left(\Sigma\,|X_i - 45^\circ|\right)/n$$

$$\text{VE-MOAE} = \sqrt{\Sigma(X_i - 45^\circ)^2/n},$$

where "X" is the trial angle, "n" is the number of trials, 10, in this experiment.

Analysis of Variance (ANOVA)

Since five criterion measures were obtained in the present investigation, five sets of analysis of variance (ANOVA) were calculated in order to test the hypotheses. On the DL-MOCS and CE-MOCS, both of which were obtained by the method of constant stimuli (MOCS) in the discrimination task, the main effects and interactions of four independent variables (sidedness, sex, standard movement mode, and response mode) were examined by the 2x2x2x2 ANOVA. Since the variable of sidedness was compared as the within-group comparison and other three variables of sex, standard movement mode, and response mode were done as a between group comparison, the ANOVA used was of mixed type. On the CE-MOAE, AE-MOAE, and VE-MOAE, which were obtained by the method of average error (MOAE) in the position reproduction task, three independent variables (sidedness, sex, and standard movement mode) were manipulated. Since the first variable was compared as a within-group and other two variable were done as a between-group, the ANOVA was also a 2x2x2 mixed type. F values computed in these ANOVA were tested for significance.

Results

The means and standard deviations were calculated for each of five criterion measures for each level of independent variable separately and for overall effects (Table 3).

The Pearson's Product-moment correlation coefficient matrix of five criterion measures on each of right and left thumb is given Table 4. The correlation coefficients were found to be generally small (r=-0.29 to r=0.49) except for the one (r=0.71) obtained between AE-MOAE and VE-MOAE on the left thumb.

Table 3. Means and Standard Deviations of Criterion Measures in Degrees Separated for Each Level of Each Comparison.

			DISCRIMINATION TASK		REPRODUCTION TASK		
			MOCS		MOAE		
Variables	Levels		DL	CE	CE	AE	VE
Sex	Male (n=64)	M	1.50	-0.24	-0.05	1.89	1.68
		SD	0.62	0.66	1.41	0.65	0.54
	Female (n=64)	M	1.51	0.00	0.15	2.06	1.90
		SD	0.49	0.70	1.76	0.92	0.58
Movement Mode	Active (n=64)	M	1.45	-0.17	-0.38	1.86	1.81
		SD	0.47	0.62	1.36	0.72	0.51
					**		
	Passive (n=64)	M	1.57	0.06	0.48	2.10	1.95
		SD	0.63	0.75	1.71	0.86	0.61
Response Mode	Verbal (n=64)	M	1.47	-0.10			
		SD	0.56	0.69			
	Nonverbal (n=64)	M	1.55	-0.14			
		SD	0.55	0.68			
Sidedness	Right (n=64)	M	1.65	-0.06	-0.06	2.00	1.89
		SD	0.62	0.73	1.60	0.75	0.58
			***				
	Left (n=64)	M	1.37	-0.17	0.16	1.95	1.87
		SD	0.44	0.64	1.60	0.85	0.55
Total (n=128)		M	1.51	-0.12	0.05	1.98	1.88
		SD	0.56	0.68	1.60	0.80	0.56

Note; ** p<.01

*** p<.001

each F-ratio is shown in Table 5 and 6.

Table 4. Correlation Matrix of Five Criterion Measures.

		MOCS				MOAE					
		DL-MOCS		CE-MOCS		CE-MOAE		AE-MOAE		VE-MOAE	
		R	L	R	L	R	L	R	L	R	L
DL-MOCS	R	1.00	0.41 **	0.21	-0.23 *	0.28 *	-0.09	0.22	0.05	-0.00	0.15
	L		1.00	-0.04	-0.29 *	0.30 *	0.10	0.17	0.16	0.13	0.03
CE-MOCS	R			1.00	0.40 **	0.16	0.15	0.09	0.07	-0.06	0.06
	L				1.00	-0.00	0.37 **	0.04	0.14	-0.04	0.13
CE-MOAE	R					1.00	0.35 **	-0.03	0.08	0.13	0.01
	L						1.00	0.02	0.49 **	0.19	0.25 *
AE-MOAE	R							1.00	0.18	0.28 *	0.17
	L								1.00	0.21	0.71 **
VE-MOAE	R									1.00	0.15
	L										1.00

Note n=64,
* p<0.05,
** p<0.01,
R; Right,
L; Left.

The ANOVA table on DL-MOCS and CE-MOCS is presented in Table 5 and that for CE-MOAE, AE-MOAE, and VE-MOAE is shown in Table 6.

The mixed type ANOVA on the DL-MOCS indicated that a significant difference existed between trial means of right and left thumbs ($F(1,56)=13.99$, $p<0.001$). The psychometric function on DL-MOCS obtained by the right and left thumbs is presented in Figure 6. The difference limen of angular position obtained by the left thumb (1.37) was smaller than that of right thumb (1.65). However, no other significant main effects or interactions were found for DL-MOCS.

A mixed type ANOVA on CE-MOCS showed that no significant main effect existed for any independent variables. However, the interaction of sex by standard movement mode was found to be significant ($F(1,56)=7.18$, $p<0.01$). The interactive relationship between sex and standard movement mode on CE-MOCS is shown in Figure 7. The post hoc examination by the Tukey's method (Lee, 1975) on this interaction demonstrated that a significant difference ($p<0.05$) existed between responses of male and female within passive standard movement condition (Figure 7). Male showed a significant negative time error from zero ($t=-2.91$, $df=31$, $p<0.01$) while female response did not shift from zero. Other sets of comparison in this interaction did not indicate the significant difference. No other significant interaction was found for CE-MOCS.

Table 5. ANOVA Table of DL-MOCS and CE-MOCS.

Source of Variation	df	DL-MOCS F	CE-MOCS F
Sex	1	0.01	3.10
Movement Mode	1	1.00	0.66
Response Mode	1	0.50	0.08
Sex x Movement Mode	1	0.49	7.18(**)
Sex x Response Mode	1	0.76	1.21
Movement Mode x response mode	1	0.17	0.52
Sex x Movement Mode x Response Mode	1	0.95	2.54
Error (Note 1)	56		
Sidedness	1	13.99(***)	1.33
Sidedness x Sex	1	0.03	1.46
Sidedness x Movement Mode	1	0.45	0.29
Sidedness x Response Mode	1	0.16	1.29
Sidedness x Sex x Movement Mode	1	0.75	0.02
Sidedness x Sex x Response Mode	1	0.86	0.06
Sidedness x Movement Mode x Response Mode	1	0.67	0.97
Sidedness x Sex x Movement Mode x Response Mode	1	1.39	1.44
Error (Note 2)	56		
Total	127		

Note; ** $p<0.01$
*** $p<0.001$

1;The error term includes the variations of (1) Subject, (2) Sex x Subject, (3) Movement Mode x Subject, (4) Response Mode x Subject, (5) Sex x Movement Mode x Subject, (6) Sex x Response Mode x Subject, (7) Movement Mode x Response Mode x Subject, and (8) Sex x Movement Mode x Response Mode x Subject. Each variation has 7 degrees of freedom .

2;The error term includes the variations of (1) Sideness x subject, (2) Sideness x Sex x Subject, (3) Sidedness x Movement Mode x Subject,(4) Sidedness x Response Mode x Subject, (5) Sidedness x Sex x Movement Mode x Subject, (6) Sidedness x Sex x Response Mode x Subject, (7)Sidedness x Movement Mode x Response Mode x Subject, and (8) Sidedness x Sex x Movement Mode x Response Mode x Subject. Each variation has 7 degrees of freedom.

Table 6. ANOVA Table of CE-MOAE, AE-MOAE, and VE-MOAE.

Source of Variation	df	CE-MOAE F	AE-MOAE F	VE-MOAE F
Sex	1	0.40	1.24	0.14
Movement Mode	1	7.96 (**)	2.42	1.60
Sex x Movement Mode	1	6.02 (*)	0.10	0.63
Error(Note 1)	60			
Sidedness	1	0.93	0.15	0.05
Sidedness x sex x	1	0.43	1.74	2.02
Sidedness x Movement mode	1	0.07	0.09	0.78
Sidedness x sex x movement mode	1	0.00	2.89	1.94
Error (Note 2)	60			
Total	127			

Note; * p<0.05,
** p<0.01,

1;The error term includes the variations of (1) Subject, (2) Sex x Subject, (3) Movement Mode x Subject, (4) Sex x Movement Mode x Subject. The degree of freedom of each variation is 15.

2;The error term is composed of four variations of (1) Sidedness x Subject, (2) Sidedness x Sex x Subject, (3) Sidedness x Movement Mode x Subject, and (4) Sidedness x Sex x Movement Mode x Subject. each variation has 15 degrees of freedom.

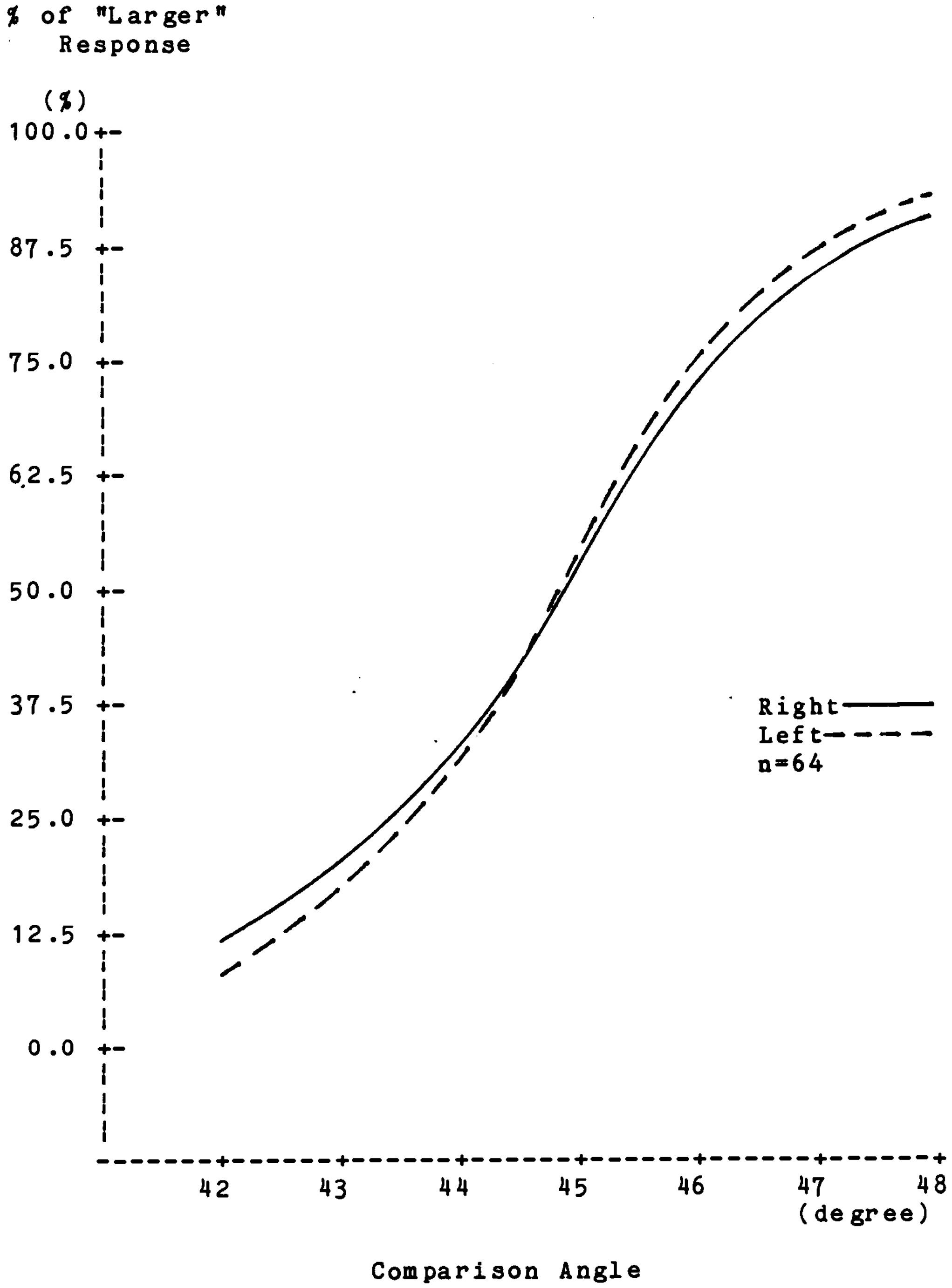


Figure 6. Psychometric function of MOCS for right and left thumb.

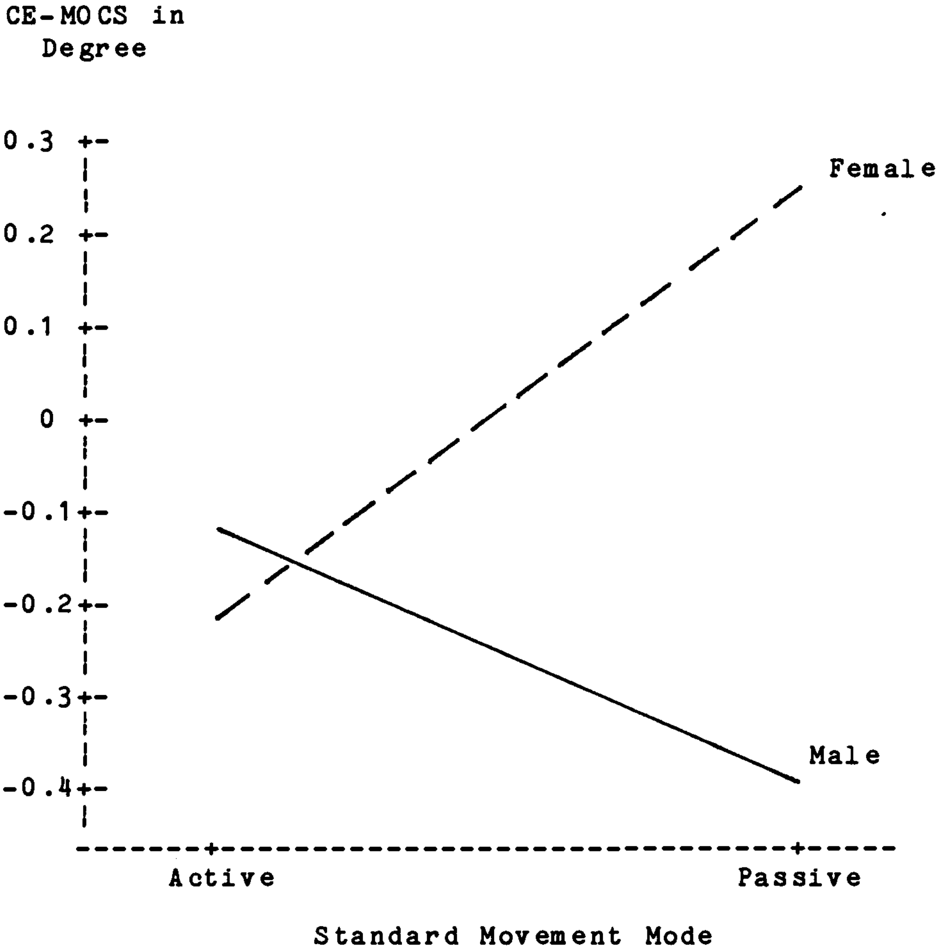


Figure 7. Interaction between sex and movement mode on CE-MOCS.

A mixed type ANOVA on CE-MOAE showed that a significantly different response was obtained between actively generated standard movement conditions and passively presented standard movement conditions. The active standard movement produced a negative time error or undershoot (-0.38°), while passive standard movement resulted in a positive time error or overshoot (+0.48°). Both negative time error ($t=-2.23$, $df=63$, $p<0.05$) and positive time error ($t=2.26$, $df=63$, $p<0.05$) shifted from zero. No other significant main effect was found. A significant interaction of sex by standard movement mode was also found on CE-MOAE (Figure 8). The post hoc examination using Tukey's method revealed that in female subjects the responses made by active and passive modes were significantly different ($p<0.05$). And both were significantly different from zero (passive, $t=3.34$, $df=31$, $p<0.01$; active, $t=-2.52$, $df=31$, $p<0.05$). No other significant difference existed for other sets of comparison in this interaction. No other significant interaction existed for CE-MOAE.

No significant main effect or interaction was found on any independent variable in the mixed type ANOVA on AE-MOAE or VE-MOAE.

The present investigation has examined four sets of hypotheses. The results mentioned above suggest conclusions to be drawn about these hypotheses (Table 7).

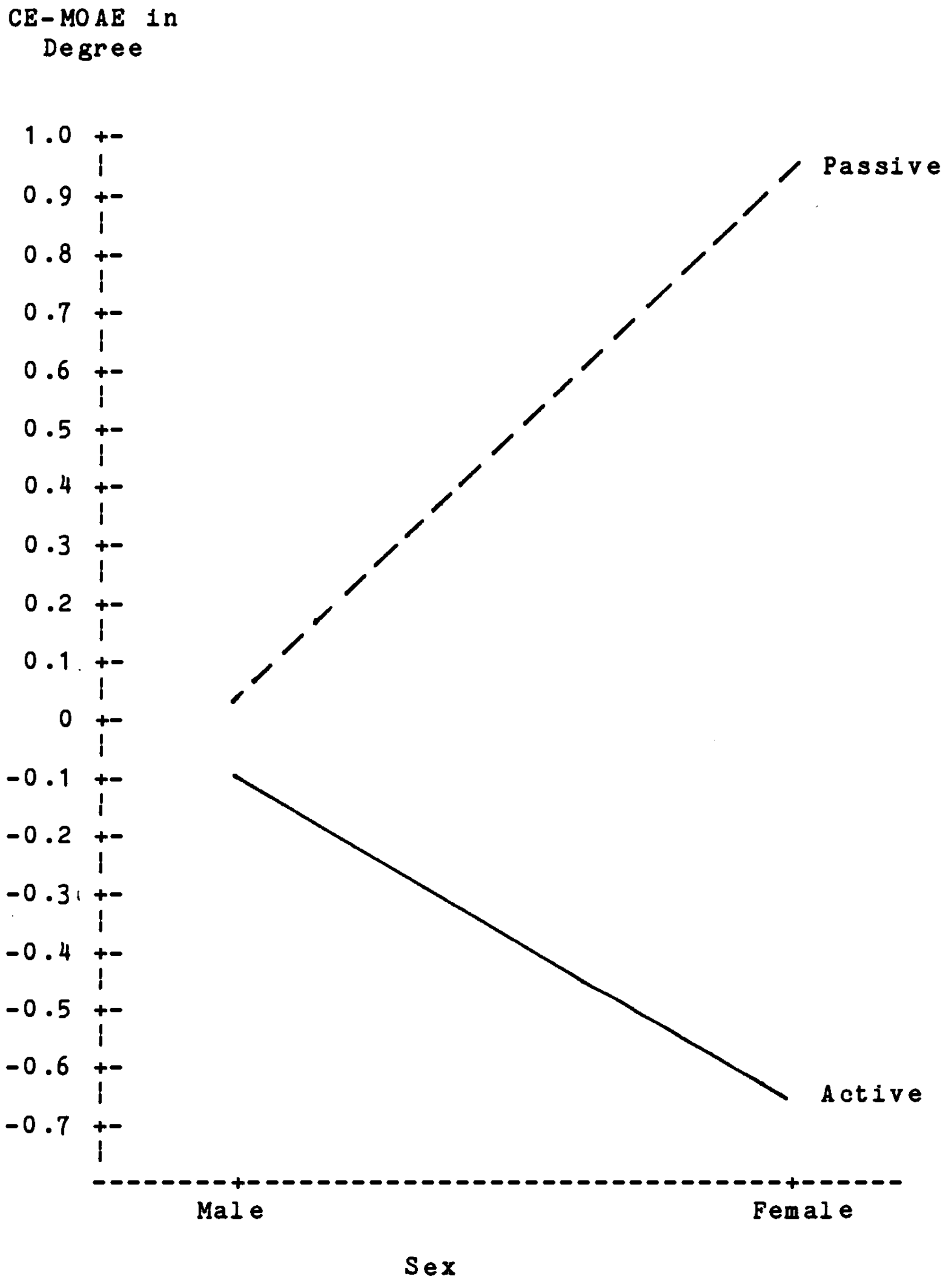


Figure 8. Interaction between sex and movement mode on CE-MOAE.

Table 7. Summary of Results of Statistical Testing of Hypotheses.

Hypotheses	1	2	3	4
Independent Variables	Sidedness	Sex	Movement Mode	Response Mode
Group Comparison	(1 through 8) vs (1 through 8)	(1 through 4) vs (5 through 8)	(1,2,5 and 6) vs (3,4,7 and 8)	(1,3,5 and 7) vs (2,4,6 and 8)
ANOVA				
Discrimination task (MOCS)				
DL-MOCS	$F=13.99$ $(p<0.001)$	$F=0.01$	$F=1.00$	$F=0.50$
CE-MOCS	$F=1.46$	$F=3.10$	$F=0.66$	$F=0.08$
Reproduction Task (MOAE)				
CE-MOAE	$F=0.93$	$F=0.40$	$F=7.96$ $(p<0.01)$	
AE-MOAE	$F=0.15$	$F=1.24$	$F=0.14$	
VE-MOAE	$F=0.05$	$F=0.14$	$F=1.60$	
Table	5, 6	5, 6	5, 6	5,

Null hypothesis one, dealing with a sidedness effect, was rejected by a criterion measure of difference limen (DL-MOCS) in the angular position discrimination task. However, both constant errors (CE-MOCS and CE-MOAE), and variable error (VE-MOAE) did not show a significant difference and hypothesis one was retained in terms of these measures.

Null hypothesis two, which required the examination of the response means made by males and females, was retained by the examination of ANOVA main effects on the five criterion measures. Although no main sex difference was found to be significant on any of five criterion measures, an ANOVA on CE-MOCS showed significant interaction of sex by standard movement mode, indicating the sex difference in the passive standard movement mode. With respect to this interaction, null hypothesis two was rejected within a limit of passive standard movement.

Null hypothesis three, which was examined by the standard movement condition, was rejected in terms of CE-MOAE. With respect to other four criterion measures, null hypothesis three was retained since no main effect was significant on any of those measures.

Null hypothesis four, examining the response made by verbal or nonverbal was retained in terms of both criterion measures of DL-MOCS and CE-MOCS.

Discussion

Overall Effect

The matrix of correlation coefficients of five criterion measures for the right and left thumbs is presented in Table 4. The small coefficient values between two types of constant errors (CE-MOCS and CE-MOAE) for both thumbs (which ranged r=-0.16 to r=0.37) suggested that constant errors elicited by the angular position discrimination task (MOCS) and the angular position reproduction task (MOAE) might be derived from different processing functions. Values of correlation coefficients on the right and left thumbs for five criterion measures were also small (r=0.15 to r=0.41) on the right and left thumbs for five criterion measures. This indicated that performances with right and left thumbs were independent within individual.

The overall average of the constant error (CE-MOCS) as measured by the angular position discrimination task showed a negative time error (-0.12°) which was significantly different from zero ($t=-1.99$, $df=127$, $p<0.05$). This indicated that the point of subjective equality (comparison angle corresponding to 50% of "Larger" response) was smaller than the standard angle. This negative time error is reported to be common in the weight discrimination task (Saslow and Watkins, 1978; Woodworth and Schlosberg, 1954).

On the other hand, the overall average of the constant error (CE-MOAE) as measured by the thumb position reproduction task did not demonstrate a significant shift from zero. Since many investigators have reported an inconsistency of direction for CE-MOAE as measured by the thumb (Colley, 1984; Roy & MacKenzie, 1978) and the arm position reproduction tasks (Gentile & Nemetz, 1978; Stelmach & Walsh, 1973; Wallace, 1977), the method of average error (MOAE) might be a less reliable test than the method of constant stimuli (MOCS). One of the reasons might be the number of trials used in the procedure, i.e., only 3 to 20 trials in MOAE, while from some tens to hundreds of trials in MOCS, since estimate based on larger samples of data are generally more reliable.

Sidedness Effect

The DL-MOCS indicated that the left thumb had more sensitive angular position discrimination than the right thumb. This laterality effect is presumably derived from different processing in the right and left cerebral hemispheres and implies the right hemispheric dominace in the thumb angle discrimination task. On the other hand, the reproduction task measured by MOAE failed to obtain significant lateralization effect. While no report has been found which employed the identical thumb position reproduction task, Colley (1984) and Roy and McKenzie (1978) reported the results of a simultaneous bilateral thumb position reproduction task. Although the present study did not yield the significant sidedness effect for a reproduction task, Roy and McKenzie (1978) demonstrated that the left thumb performed more accurately than the right thumb in terms of all three measures CE-MOAE (both thumbs undershoot), AE-MOAE, and VE-MOAE. Conversely, Colley (1984) reported that the sidedness effect was found for the CE with both overshoot, but not significant for AE-MOAE and VE-MOAE. The discrepancy was attributed by that author to a failure to control the subject's strategies, for example, the asymmetrical attention on simultaneous bimanual movement.

The main difference in experimental procedures between the previous experimenters and the present study is that they employed the bilateral standard movement presentation (in which both the right and left thumbs performed reproduction tasks simultaneously) while the present experiment used unilateral presentation (only one side of reproduction task). When comparing bilateral and unilateral stimulus presentation in the somatosensory modality, Nachshon and Carmon (1975) found that only the bimanual task revealed hand laterality. The dichaptic task, in which bilaterally presented materials were palpated simultaneously with both hands to identify the shape, revealed the hand laterality effect (Witelson, 1974, 1976). These findings emphasize the importance of employing the bilateral stimulus presentation in order to produce the laterality effects by reproduction.

However, as mentioned previously, the difference limen measured by the method of constant stimuli in the present study did indicate a laterality effect, although the task was performed unilaterally. With a weight discrimination task, in which the test weight was compared to the standard weight, Dinnerstein, Gerstein, and Michel (1967) and Saslow and Watkins (1978) found that unilaterally presented successive intrahand weight discrimination produced more sensitive discrimination than did simultanious bilateral interhand judgement. Both of these weight discrimination experiments employed the method of constant stimuli which was the method used to estimate DL in the present study.

The effects of unilateral stimulus presentation (presenting to only one hemisphere at a time) and bilateral stimulus presentation (in which interhemispheric competition should occur) has also been studied in other modalities. In the auditory system the bilateral (dichotic) presentation was reported to produce ear asymmetry (Bryden, 1969; Kimura, 1967), but also unilateral (monaural) presentation could elicit some laterality effect (Bakker, 1968). With respect to the visual system, White (1969) pointed out that the observed laterality difference depends on the material presented (verbal or nonverbal) and not on the presentation mode (unilateral or bilateral).

Another possibility of inconsistent lateralization effect in the present study is the different nature of each kinesthetic task. The difference limen obtained by the MOCS mainly depends upon the sensory processing while reproduction task emphasizes motor response, although kinesthetic information processing plays an important role in both tasks. The DL-MOCS is more sensitive measure since it is obtained with more trials than that of MOAE method. Poor correlation between DL-MOCS versus AE-MOAE and VE-MOAE indicates that either they are not measuring the same kinesthetic processing or that one measure is influenced by random error.

Sex Effect

No sex main effect was found on any criterion measures in the present study. The significant interaction effect of sex by standard movement mode for CE-MOCS indicated that male produced significantly different time error from zero while female did not. This was the only significant sex effect in the present study.

Roy and McKenzie (1978) reported no sex difference in either main or interaction effect in the thumb position reproduction task. Colley (1984) found that while there was no significant main sex effect, the interaction of sex by handedness was significant in terms of AE but not of VE. However, the sex difference within the right handed subjects, which was the same population type as the present study, was not separately described. The spatial localization task, in which the location of right index finger tip was pointed by the left pointing finger without the visual aid, showed no sex difference (Smothergill, 1973).

These findings suggest that for manual spatial task there might be no real difference in lateralization between the sexes.

Standard Movement Mode Effect

With the CE-MOAE, the active standard movement produced a negative time error (undershoot) while the passive standard movement generated a positive time error (overshoot). Both errors were significantly shifted from zero.

The topic of active or passive standard movement mode has been extensively studied by using the limb position reproduction tasks. The same results as the present study, i.e., negative time error (undershoot) by the active movement and positive time error (overshoot) by the passive movement, were reported for arm positioning (Keele and Ells, 1972) the leg positioning tasks (Lloyd and Caldwell, 1965). The negative time error had been often observed in weight lifting task and other successive discrimination tasks in which the standard stimulus is given first and the comparison stimulus follows (Woodworth and Schlosberg, 1954). Woodworth and Schlosberg (1954) presented Fechner's fading-image explanation for this negative time error. According to this explanation, the previous image or trace which was produced by the standard presentation would have faded by the time of the comparison stimulus presentation. The later image elicited by the comparison stimulus is therefore judged to be greater than the faded previous stimulus even when the comparison and standard are physically equal. The negative time error produced by the active standard movement in the present study was consistent with this explanation.

However, when the passive standard movement was presented, only kinesthetic information was coded. After fading of the kinesthesis image, not only kinesthesis but also motor efference was utilized for reproduction. It is implied that an excess of motor efference in the reproduction trial might have caused a positive time error, an underestimate of the second movement. Another positive standard movement condition, in which the weight was attached to the standard movement and the position was reproduced by only the active movement without added weight, showed less negative time error than did the active only standard movement condition (Keele and Ells, 1972). However, other studies using the arm position reproduction task did not show the difference of active and passive mode for CE-MOAE for both sexes (Jones, 1974; Kelso, 1977; Marteniuk, 1973; Marteniuk, Shields, and Campbell, 1972, Roy, 1978; and Summers, Levey, and Wrigley, 1981). These conflicting findings suggest the need for further investigation of the standard movement condition's effect on the constant error in successive tasks.

With respect to reproduction accuracy as measured by the absolute error (AE-MOAE) and variable error (VE-MOAE), the present study yielded no significantly different results between actively and passively generated standard movements.

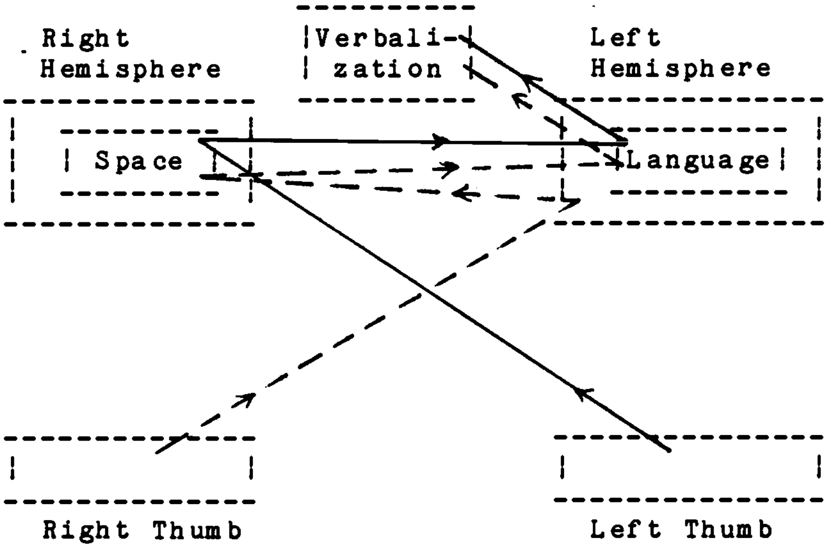
Some researchers, using the arm reproduction task, have indicated that the actively generated standard movement was reproduced more accurately than passively presented standard movement in terms of absolute error (AE) and/or variable error (VE). This has been found in studies of preselected active versus constrained passive movement (Hall & Leavitt, 1977) preselected versus constrained conditions (Kelso, 1977; Roy, 1978; Roy & Diewert, 1975); retention characteristics (Marteniuk, 1973); and movement range (Marteniuk, Shields, & Campbell, 1972). However, other studies failed to produce active presentation superiority to the passive presentation in the study of quick arm reproduction task (Jones ,1972); retention interval (Jones, 1974); retention condition of location and distance (Keel and Ells, 1974; Marteniuk & Roy, 1972); or cognitive planning and motor efferencies (Summers, Levey, & Wringly, 1981).

The majority of the studies which revealed the standard movement mode effect employed the preselective method in which the subject determined the position to stop the standard movement. On the other hand, the constrained method, in which the experimenter determined the stopping position of the standard movement, did not show the difference of reproduction between the active and passsive standard movement. The preselected condition has a cue of cognitive planning by which when or where to stop was determined prior to the initiation of movement, while the constrained condition lacks this cue. The active movement presumably depends on both the efferent discharge, a motor memory system without feedback, and kinesthesis, sensation for position, while the passive movement depends only on the kinesthesis. Among these variables, cognitive planning was reported to be crucial for the standard movement mode effect. The use of the constrained method in the present study might therefore be responsible for producing no effect of standard movement.

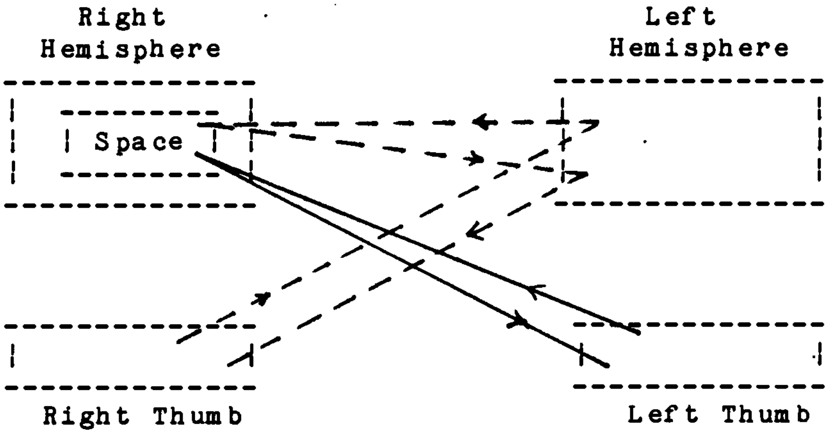
Response Mode Effect

The review of literature on the relationship between language processing and cerebral hemispheric laterality indicated that language is dominantly processed in the left hemisphere (Geschwind and Levitsky, 1968; Sperry, Gazzaniga, and Bogen, 1969). By contrast, the spatial perception was reported to be processed somewhat better in the right hemisphere (Hacaen, 1978; Nebes, 1972). The sensory information received by the thumb is projected to and the motor control of the thumb is controlled by the contralateral cerebral hemisphere. Based on these facts and an assumption that the increased number of callosal transmissions would result in a loss of information processing accuracy (Figure 9), it was predicted that the nonverbal condition would produce more accurate responses than those produced by the verbal mode in proportion to the excess callosal transmission to the left hemisphere for verbalization. Another possible prediction is that the degree of lateralization in the nonverbal responses should be greater than that in the verbal response. This reasoning stems from knowledge that the information from the left thumb crosses the corpus calosum for verbalization but did not cross in the nonverval condition, while information from the right thumb goes in the same paths in both verbal and nonverbal conditions. This prediction should be confirmed in the statistical interaction of response mode by sidedness.

However, the analysis of data showed that no significant main effect of interactions existed for the response mode on DL-MOCS. Two reasons are proposed to explain the discrepancies between the predictions and the present results. First, the capacity for simple language in the right hemisphere has been reported by some researchers (Butler & Norrsell, 1968; Gazzaniga & Hillyard, 1971). The present study employed the verbal response of "Larger" or "Smaller", which is definitely simple language. If the right hemisphere could have processed such simple language,



Verbal Response



Nonverbal Response

Figure 9. Hypothetical nervous connection in verbal and nonverbal response mode.

the results would be confounded. A second possibility comes from the observation of experimental procedure. The subject was to report his/her judgement of comparison by the thumb movement in the nonverbal condition. This thumb movement was a further abduction and return to the resting position when judged "Smaller", and adduction first and return to the resting position in the case of a "Larger" judgement. For some subjects, this manual response procedure seemed to be so complicated that remembering and self monitoring for correct manual response was necessary. When a complicated manual sequence or procedure is required, the left hemisphere is reported to be involved (Kimura and Archibald, 1974). If this is true, a confounding of the results might have been expected.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Cerebral hemispheric laterality has been observed in language processing being lataralized in the left hemisphere and in spatial perception in favor of the right hemisphere. Many spatial tasks have been investigated by using visual tasks and some have done with tactile sense. In the present study the thumb kinesthetic spatial tasks were employed.

Anatomically, efferent and afferent neural pathways to the thumb are controlled by and projected to the contralateral cerebral hemisphere.

Assuming that the right hemisphere is generally better able to process spatial perception and knowing that the thumb is controlled by the contralateral hemisphere, it was expected that the left thumb would perform a spatial task more accurately than the right. The present study was designed to investigate whether this premise was substantiated. Since the review of literature indicated that sex of subects and degree of verbalization in responding might affect the degree of hemispheric lateralization, these two variables were also manipulated in the experiment. In addition, active and passive effects were compared in a constrained standard movement presentation condition. Four sets of hypotheses were tested these variables and interactions were examined.

The kinesthetic spatial perception was measured in this research by using both the thumb position discrimination and reproduction tasks, obtaining several different measurements of discriminability and comparative judgements.

Experimental Method

Thirty two male and 32 female caucasian right-handed students without left-handed relatives served as subjects. A set of positioning apparatus for right and left thumbs were constructed by the experimenter.

A discrimination threshold (difference limen) and point of subjective equality (constant error) were obtained by the method of constant stimuli in the thumb angular position discrimination task. Three measures of reproduction deviation were obtained by the method of average error in the thumb positon reproduction task.

Analysis of Data

Data obtained by the method of constant stimuli were calculated for two criterion measures by the probit analysis. Data obtained in the reproduction task were calculated according to the their definition. A mixed type analysis of variance (ANOVA) was used to test four sets of null hypotheses. Hypotheses one through three were tested by each of five ANOVAs on dependent variable measures and hypothesis four was tested by two ANOVAs on only the two criterion measures of the discrimination task. The correlation coefficients among five criterion measures on both thumbs were also calculated.

Conclusions

The following conclusions are suggested by testing hypotheses in the present study.

1. A significant difference did exist between the difference limens of two positions made by the right and left thumbs. No significant difference existed between performances of the right and left thumbs for the rest of the four measures. Hypothesis one was rejected in terms of DL-MOCS, but retained for the rest of the four measures. Since DL-MOCS is the most sensitive measure of discriminabilities it can be concluded that the left thumb (right hemisphere) has more sensitive positional discrimination.

2. No significant difference existed between responses of male and female subjects for any of criterion measures. Hypothesis two was retained in terms of all five criterion measures. Although there was no evidence in this research for sex differences in lateralization, significant interaction of sex by standard movement mode indicated that in the passive standard movement mode sex difference existed in the subjective point of equality (CE-MOCS).

3. A significant difference did exist between responses presented by the active and passive standard movements in the reproduction task for constant error (CE-MOAE), but no significant difference for the rest of the four criterion measures. Hypothesis three was rejected in terms of CE-MOAE, but retained for the other four measures. Significant interaction between sex by standard movement mode for CE-MOAE showed that in females significant difference existed between active and passive presentation.

4. No significant difference existed between responses made verbally or nonverbally for either of the measures obtained in the discrimination task. Hypothesis four was retained in terms of all five criterion measures.

5. Small correlation coefficient values between kinesthetical spatial task procedures of the method of constant stimuli and method of average error suggested that results of the two positioning tasks might be derived from different kinesthetic processing functions.

Recommendation

The results and conclusions of the present study contribute to the research areas of cerebral hemispheric laterality and sensory-motor control systems.

Spatial perception was found to be processed more accurately with the right hemisphere in the kinesthetic spatial task. This conclusion suggests the need to study the role and possibility of left limbs in processing space related human movement.

Other measures did not show significant different lateralization. However, other standard movement presentation conditions, such as bilateral presentation and/or another kinesthetic spatial task, are recommended to amplify lateralization effects.

The verbal and nonverbal response conditions are recommended to be revised to achieve clear left hemisphric involvement in verbal response and no left hemisphere involvement in manual response in terms of motor sequencing, since the nonverbal response mode employed in the present study may not have been nonverbal.

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APPENDICES

Appendix A

OREGON STATE UNIVERSITY

Committee for Protection of Human Subjects

Chairman's Summary of Review

Title: Hemispheric Processing of Kinesthetically Oriented Spatial Perception

Program Director: Donald E. Campbell, Physical Education (Sho Nishizawa, grad. student)

Recommendation:

X Approval*

Provisional Approval

Disapproval

No Action

*The informed consent forms obtained from each subject need to be retained for the long term. Archives Division of the OSU Department of Budgets and Personnel Service is willing to receive and archive these on microfilm. At present at least, this can be done without charge to the research project. Please have the forms retained in Archives as well as in your files.

Remarks:

Date: July 25, 1983 **Signature**

If the recommendation of the committee is for provisional approval or disapproval, the program director should resubmit the application with the necessary corrections within one month.

Appendix B

A Letter of Invitation

An Invitation to the Finger Positioning Experiment

Dear Friend; A graduate student is inviting volunteer subjects who are caucasian right handers having no left handed parents or siblings. The purpose of this experiment is to investigate the relationship between the hemispheric (right or left brain) processing and spatial perception ellcited by the finger positioning task.

Your right and left thumbs will be used in the experiment. After memorizing the standard angle, the test angle will be presented. You are required to judge whether the test angle is larger or smaller than the standard angle. This procedure will be repeated (Exp. I). In another session, Exp. II, after memorizing the standard angle you are required to reproduce the same angle as the standard as exactly as possible. This will also be repeated (Exp. II). You will participate in both Exp. I and II with right and left thumbs. Sixty minutes are scheduled for the total experimental session.

If you are a right hander having no left-handed relatives and are interested in participating in this experiment, please leave your name, telephone number, and your convenient time on the experiment schedule chart posted at the entrance of room 130 Moreland Hall(Dep. of Psychology). Please shedule yourself to finish the experiment at least 15 minutes before your next commitment such as class, appointment, etc.. Please show up in <u>room</u> <u>124</u>(<u>Dr</u>. <u>Saslow</u>'<u>s</u> <u>office</u>) Moreland Hall at the appointed time.

If it is difficult for you to find an open 60 minutes, please leave your name and telephone number on the chart or by the telephone so that we can set up a convenient time for both of us.

Your participation will be greatly appreciated.

Sho Nishizawa(Doctoral student majoring in physical
education)
754-3221(Office, Langton Hall, Rm 121 B)
757-6598 (Home)

Appendix C

Informed Consent Form

Dear Participant;

Your assistance is needed for an investigation of the relationship between the hemispheric (right or left brain) processing and kinesthetically (muscle sense) oriented spatial perception.

Prior to the experiment you will be asked some questions on your conditions that might affect your performance. You reserve the right to reject to answer. This information will be treated confidentially.

In the experiment your right and left thumbs will be used. After memorizing the standard angle, the test angle will be presented. You are required to judge whether the test angle is larger or smaller than the standard angle. This procedure will be repeated (Exp.I). In another session, Exp.II, after memorizing the standard angle you are required to reproduce the same angle as the standard as exactly as possible. This will also be repeated. You will participate in both Exp.I and II with right and left thumbs. Sixty minutes are scheduled for the total experimental session.

Any questions with respect to the experimental procedure should be answered by the experimenter. The present experiment causes no physicalor mental stress that is harmful to the performer. However you will be free to withdraw your consent and to discontinue participation at any time. Your performance score will also be treated confidentially.

Your participation will be greatly appreciated. If you are willing to participate, please complete the acknowledgement form below.

ACKNOWLEDGEMENT OF WILLINGNESS TO PARTICIPATE

I give my consent to participate in this experiment. I understand that I am free to withdraw from this experiment at any time and that my information and performance score will be kept confidential.

NAME:____________________ DATE:____________________

ADDRESS:____

TELEPHONE:___________________

SIGNATURE:________________________

Appendix D

Subject Information Form

Please answer the following questions. All information will be kept srictly confidental.

1. Name____________________ 2. Age______________
3. Height________________ 4. Weight____________
5.Academic Major__________ 6. Class Status__________
7. Are you a right hander? Yes____, No_____.
8. Do you write with your right hand? Yes____ No____
9. In what situation do you use your left hand preferrably?

____

10. Are your parents both right handed? (Note including step mother or father) yes____, No_____.
11. Is (Are) your sibling(s) right handed? Yes____, No____.
12. Which handedness do your grandparents have?

Mother side	R	L	Not know
Grandmother			
Grandfather			

Father side	R	L	Not kown
Grandmother			
Grandfather			

13. Are you taking any medication regularly? Yes___, No___.
If yes, please specify the medication and it's purpose.

____.

14. Do you smoke regularly? Yes---, No____.
If yes, please check Light___, Medium___, Heavy___.
15. Do you consume alcohol regularly? Yes___, No___.
If yes, please check. Light___, Medium___, Heavy___.
16. Have you ever been diagnozed neuroiogically?
Yes___, No___.
If yes, please specify. ____________________________.

Thank you for your cooporation.

Appendix E

Recording Form 1

Name______________________________ Group#_____ Date___________
Sex; Male, Female Movement; Active, Passive
response Mode; Verbal, Nonverbal
Trial Order; (1)_______, (2)_____, (3)_____,(4)______.
( ) (MOCS R,L)

Practice

Trial #	Test Angle		
1)	47	S	L
2)	43	S	L
3)	48	S	L
4)	44	S	L
5)	45	S	L
6)	42	S	L
7)	46	S	L

Experiment

1)	45	S	L
2)	45	S	L
3)	46	S	L
4)	43	S	L
5)	42	S	L
6)	44	S	L
7)	45	S	L
8)	48	S	L
9)	47	S	L
10)	42	S	L
11)	43	S	L
12)	44	S	L
13)	43	S	L
14)	45	S	L
15)	48	S	L
16)	48	S	L
17)	43	S	L
18)	45	S	L
19)	47	S	L
20)	46	S	L
21)	43	S	L
22)	42	S	L
23)	42	S	L
24)	43	S	L
25)	46	S	L
26)	48	S	L
27)	48	S	L
28)	47	S	L
29)	46	S	L
30)	43	S	L
31)	46	S	L

Trial #	Test Angle						Experiment
32)	48	S L	47)	47	S L		1)
33)	44	S L	48)	47	S L		2)
34)	46	S L	49)	46	S L		3)
35)	44	S L	50)	47	S L		4)
36)	48	S L	51)	42	S L		5)
37)	44	S L	52)	42	S L		6)
38)	47	S L	53)	44	S L		7)
39)	48	S L	54)	42	S L		8)
40)	46	S L	55)	45	S L		9)
41)	45	S L	56)	45	S L		10)
42)	44	S L	( )	(MOAE R,L) Practice			CE
43)	44	S L	1)				AE
44)	47	S L	2)				DL
45)	46	S L	3)				
46)	42	S L					

	S Response								L Response								# of L
42	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
43	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
44	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
45	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
46	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
47	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
48	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	

APPENDIX F

Recording Form 2

Name______________________ Group#_______ Date_________
Sex; Male, Female Movement; Active, Passive
Response Mode; Verbal, Nonverbal
Trial Order; (1)_____, (2)_____, (3______, (4)_____.
( ) (MOCS R,L)

Practice

Trial #	Test Angle		
1)	43	S	L
2)	48	S	L
3)	47	S	L
4)	46	S	L
5)	44	S	L
6)	45	S	L
7)	42	S	L

Experiment

1)	43	S	L
2)	45	S	L
3)	43	S	L
4)	47	S	L
5)	45	S	L
6)	42	S	L
7)	45	S	L
8)	43	S	L
9)	46	S	L
10)	44	S	L
11)	48	S	L
12)	44	S	L
13)	45	S	L
14)	47	S	L
15)	43	S	L
16)	45	S	L
17)	43	S	L
18)	48	S	L
19)	42	S	L
20)	46	S	L
21)	46	S	L
22)	43	S	L
23)	43	S	L
24)	47	S	L
25)	44	S	L
26)	44	S	L
27)	47	S	L
28)	42	S	L

Trial #	Test Angle							() (MOAE R,L) Practice
29)	47	S	L	43)	46	S	L	1)
30)	46	S	L	44)	44	S	L	2)
31)	48	S	L	45)	44	S	L	3)
32)	44	S	L	46)	46	S	L	4)
33)	46	S	L	47)	45	S	L	5)
34)	42	S	L	48)	42	S	L	6)
35)	46	S	L	49)	48	S	L	7)
36)	47	S	L	50)	48	S	L	8)
37)	42	S	L	51)	42	S	L	9)
38)	43	S	L	52)	45	S	L	10)
39)	48	S	L	53)	48	S	L	CE
40)	48	S	L	54)	44	S	L	AE
41)	47	S	L	55)	42	S	L	DL
42)	47	S	L	56)	45	S	L	

	S Response								L Response								# of L
42	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
43	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
44	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
45	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
46	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
47	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	
48	S	S	S	S	S	S	S	S	L	L	L	L	L	L	L	L	

APPENDIX G

Probit Analysis

1; In biological assay the function of stimulus intensity and quantal response often shows the sigmoid curve, of which the typical example is the relationship between the concentration of dose and the frequency of respone produced (Tallaride and Jacob, 1979). When the frequency or portion of response is converted to the standardized normal deviate "z", the relationship between the stimulus intensity and "z" will become linear. The probit is defined as the normal equivalent deviate or standard normal deviate "z" increased by 5 so that the probit rarely shows negatibe value. Consequently, as a linear regression of stimulus intensity and probit, the median effect, by which 50% of individual respond and/or other stimulus intensity, by which specified portion respond, would be estimated. This procedure is called probit analysis (Finney, 1971a). The mathematical explanation is as follows;

For the standardized normal distribution with $\mu=0$ and $\sigma=1.0$, the reponse probability, "P", is obtained by the integration,

$$P=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y} e^{-\frac{1}{2}x^2}\,dx \qquad (1)$$

$$Y=(X-\mu)/\sigma \qquad (2)$$

where "Y" is defined as the normal equivalent deviate or standardized normal deviate "z".

The equation (1) determines either "P" or "Y" from the other and the graphical relation between them is linear except for the extreme values. The probit "Y'" is the value of "z" increased by 5.

$$Y'=5+(X-\mu)/\sigma=\ Y+5. \qquad (3)$$

2; The method of least squares is to find the estimators, "a" and "b", which minimize the sum of squared deviation, "Q", from its expected value.

$$Q=\Sigma(Y_i-(a+bX_i))^2 \qquad (4)$$

where X_i and Y_i are paired observations.

Operationally, the estimators, "a" and "b", are obtained by the equation (5) and (6) which are derived by differentiating "Q" with respect to the estimators "a" and "b", and by solving the simultaneous equations of those

(Neter and Wasserman, 1974).

$$b = \frac{\Sigma(X_i - \bar{X})(Y_i - \bar{Y})}{\Sigma(X_i - X)} \qquad (5)$$

$$a = (\Sigma Y_i - b\Sigma X_i)/n \qquad (6)$$

3; The variance, "V", of observed proportion, "P", in the binomial distribution is expressed,

$$V = P \times Q/n \qquad (7)$$

where "P" is the mean value of "P". "Q" is complement of "P" and "n" is the number of subjects.

The equation (7) shows that the variance is not constant over the observed proportion. To eliminate the unequal variance in the probit transformation, the weight, "n" times "w" (weighting coefficient), are attached to the probit. The "w" gives more emphasis to the observations producing a samller variance and does less emphasis to those of larger variance.

The wighting coeffcient "w" is expressed,

$$w = Z^2/(PQ) \qquad (8)$$

here "Z" is the ordinate to the standardized normal frequency function at the point corresponding to standardized normal deviate, z.

$$z = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}Y^2} \qquad (9)$$

4; The working probit "y" is defined as,

$$y = Y + \frac{p - P}{Z} = Y - \frac{q - Q}{Z} \qquad (10)$$

where "Y"-expected probit, "p"-empirical protion of response, "P"-expected protion on the provisional line, q-complement of "p", Q-complement of "P", and "Z"-defined by the equation (9).

5; The method of weighted least square is to find the estimators, "a'" and "b'", which minimize the quantity, Q';

$$Q' = \Sigma W_i(Y_i - (a' + b'X_i)) \qquad (11)$$

where; "W_i" -weight, "X_i" and "Y_i" - paired observation.

The wight "W_i" is expressed,

$$W_i = w_i \times n_i \qquad (12)$$

"w_i" is the weighting coefficient expressed by the equation (8).

The estimators, "a'" and "b'", are obtained in the same way as the equations (5) and (6) except that each observation is multiplied by the weights. In the probit analysis, the working probit "y" is used for Y in the equation (11).

6; The chi-square test is used to examine goodness of fit to a specified distribution. Chi-square (χ^2) is,

$$\chi^2 = \frac{(r_i - n_i P_i)}{n_i P_i (1 - P_i)} \qquad (13)$$

where; "r_i"-number of observed response, "n_i"-number of subject, and "P_i"-expected proportion.