CONCURRENT DUAL TASK PERFORMANCES OF RIGHT-HANDERS: A TEST OF KINSBOURNE'S FUNCTIONAL DISTANCE MODEL

BY

MYRON BILAK

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1981

ACKNOWLEDGMENTS

This endeavor would have been all but impossible if not for the support of many individuals too numerous to mention individually. However, there are several individuals who provided me with additional support, prodding, and that proverbial "kick in the ---" that finally made it possible.

First of all, I would like to express my gratitude to Paul Satz who came to my rescue and whose ideas were the groundwork for this doctoral dissertation. Secondly, my sincerely thanks go to Eileen Fennell who willingly took over my committee after Paul left and who had subsequently put up with my diversions, distractions, and seemingly endless streams of delays. I also extend my thanks to Hugh Davis and Warren Rice, who throughout this have waited patiently for the outcome of my dissertation and who, on more than one occasion, have presented me with the proper perspective and attitude to continue forth. Special thanks are also extended to Nathan Perry who initially gave me the opportunity to develop my research skills, and who was instrumental in my decision to attend the University of Florida. One final member of my committee who deserves extra special thanks is Frank Sieka. Over the years he has become a close and lasting friend. His role as teacher, mentor and friend made the demands of graduate school easier to cope with. Also, the countless dinners at his home kept me from starving when funds were tight.

One other person who deserves more than just honorable mention is Cynthia Belar. As both a teacher and friend, she provided me with support throughout the program. Respectfully, I would like to take this opportunity to thank all of you collectively for being my role models, supporters, mentors, and friends.

Lastly, I thank my parents, Wolodymyr and Jaroslawa Bilak, for not giving me a first name as long as theirs. Otherwise, I might still be filling out applications for graduate school.

TABLE OF CONTENTS

Abstract of Dissertation Presented to the
Graduate Council of the University of Florida
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

CONCURRENT DUAL TASK PERFORMANCES OF RIGHT-HANDERS:
A TEST OF KINSBOURNE'S FUNCTIONAL DISTANCE MODEL

By

Myron Bilak

December 1981

Chairman: Eileen B. Fennell
Major Department: Clinical Psychology

The present study examines dual task performances for both verbal and motor tasks. Specifically, the verbal task required the subject to say as many words as he/she could think of beginning with a specific target letter. The two motor tasks consisted of a foot tapping and a finger tapping task during which the subject was asked to tap a foot or finger counter. The dual task condition required the subject to perform one of the motor tasks simultaneously with the verbal fluency task.

The following questions were addressed in the study: (1) According to Kinsbourne's model, one would predict a drop in finger tapping under conditions of concurrent verbalizations but not a drop in foot tapping which is mediated by areas more distant from language centers; (2) In contrast, an attentional or priming model would predict a drop in both finger and foot tapping performances under concurrent verbalizations; (3) One might also predict that under conditions of concurrent foot tapping and verbalization, verbal fluency

would be improved over baseline rates; (4) Finally, one could also predict a relatively greater increment over baseline for verbal fluency under foot tapping than under finger tapping conditions.

Expected results were not clearly obtained. Decreases in the respective rates occurred for the two motor tasks, but they were smaller for the foot tapping task than for the finger tapping task. The obtained results support the premise of less interference between them as a function of their distance. The verbal fluency data showed no significant change in performance as a function of hand or task condition. It is surprising in that research on concurrent dual tasks shows a decrement in performance in both tasks when the tasks are performed simultaneously. The current results suggest that there is a unidirectional inhibitory effect with verbal processing showing little or no inhibition, whereas motor tasks are inhibited. Finally, one can also partly invoke an attentional priming model in that the verbal nature of the instruction may have primed the language hemisphere and guaranteed the verbal over motor priority on output.

CHAPTER I
INTRODUCTION

Overview of the Problem

Research in the area of the brain and its functions has diversified into many branches of science. It has united many diversely unrelated researchers in joining their endeavors and tackle its secrets with a variety of methods and approaches. From the humble beginnings and early days of phrenology when every mother probed her son's scalp to see if he was presidential material, to today's complicated, highly technological bioassays of brain tissue, the brain has been poked, probed, dissected, timed, and stimulated by countless researchers. Thus it is not unusual to find various methods employed in its study ranging from anatomical dissection to radiographic analysis of x-rays.

The present study will center around the brain and its different functions. Specifically it will focus on the topic of hemispheric specialization and lateralization. Research over the past century has supported the notion of dichotomous functioning of the two cerebral hemispheres (Geschwind, 1970). Various researchers have shown that in general the left hemisphere processes linguistic stimuli better, whereas the right hemisphere processes various nonlinguistic visuospatial stimuli better.

Within the past twenty-five years, the development of various lateral perceptual stimulation techniques, i.e., dichotic listening tasks, visual half field procedures, and dichotomous tactile stimulation, has allowed researchers to better address the problem of laterality of function in normal subjects. Prior to that, notions of cerebral laterality were based on the study of patients with known cerebral lesions to either the left or right side of the hemisphere. Observed deficits in behavior functions were attributed to the site of the lesion and became in theory localized centers for specific functions. This "classical" lesion approach had its limitations, however, in that it did not directly assess the function of the lesioned area, but, in fact, inferred its function from the resulting observed behavior which was mediated by the remaining intact brain. Further complications to the "lesion" approach were recently identified by Whitaker (1978). In a series of topographical studies done on epileptics with long-standing seizure foci, Whitaker showed that these patients had grossly deviant arrangements of sensory, motor, and language areas within the left hemisphere. The observed cortical reorganizations of functional space in these patients suggest a rather poor subject population from which to base and develop models of "normal" brain functioning and then generalize and attribute them to a normal nonlesioned population.

Previously mentioned laterality tasks developed originally by and borrowed from the area of cognitive psychology have helped solve the inferential problems of the "lesion" approach and allowed researchers to study brain functions in normal populations. In a typical laterality task, the subject is presented with some sensory stimulus to either lateral side or both sides of the body and asked to make some discriminatory decision about its occurrence. Thus in a dichotic listening task, auditory stimuli are simultaneously presented to each ear via stereo headphones and the subject is asked to recall the stimuli (usually words). In a visual half field stimulation procedure, the subject is presented tachistoscopically with visual stimuli to one or both visual half-fields and asked to identify or recall the stimuli. Similarly, dichotomous tactile tasks require the subject to manually manipulate different three-dimensional shapes or letters by the left or right hands and identify them later.

Results of experimental studies utilizing the above described procedures have shown that perceptual asymmetries exist between the two cerebral hemispheres (Kimura, 1961; Hilliard, 1973; Berlucchi et al., 1974; Braine, 1968; Bryden & Rainey, 1963). Two differing models have been proposed to account for these perceptual asymmetries. Kimura (1966) presented an input transmission model which postulates that sensory input is better processed by the shorter direct pathways of the various sensory projections. For this reason, verbal material is perceived better in the right half visual field, and verbal right ear input is better perceived than left ear input in the dichotic presentation. Kinsbourne (1970), in contrast, states that observed differences in perceptual asymmetries are the result of attentional biases related to preponderant activation of one hemisphere over the other as a function of the nature of the subject's task. Thus in Kinsbourne's model, perceptual asymmetries result when the presentation of verbal material in a dichotic listening task creates an attentional bias to the right, as this is congruent with the basic orientational bias of the left hemisphere, allowing the subject to more consistently attend to the right ear and thereby optimize performance to the right side.

Recent research efforts have centered on the functional organization of the brain and its relationship to concurrent and competitive performance in simultaneous dual tasks (Kinsbourne, 1978). Thus, the scope of this proposal will be to address Kinsbourne's model of functional space as it relates to cerebral organization and laterality. First, however, a brief literature review will be presented encompassing past and current research perspectives in the areas of laterality and cerebral organization.

Laterality of Cerebral Functioning: Historical Perspective

A multitude of functions have been attributed to the organ known as the human brain. Generally, it acts as a huge clearing-house and processor of incoming information.

Similar to a computer, it has the capacity to not only codify, analyze, and integrate data, but it can also act on it seemingly instantaneously. What significantly distinguishes the human brain from that of the lower primates is the relative massive size and area of the cerebral cortex with its accompanying vast number of neural cells. Rough estimates place a minimum of five million neural cells beneath each square centimeter of surface cortex (Geschwind, 1974). Photographs of human cortex show a highly convoluted, many times folded, deeply fissured mantel that covers the underlying deep brain structures in the cranium. The many fissures themselves act to subdivide the cortex into lobes with the predominant mid-brain fissure dividing the cortex into two cerebral hemispheres.

The presence of two cerebral hemispheres in the brain has brought forth the concept of cerebral dominance. Cerebral dominance can best be defined by Geschwind (1974) as follows: "One hemisphere may be said to be dominant for a given function when it is more important for the performance of that function than the other hemisphere" (p. 174). Evidence for the phenomenon of cerebral dominance was first shown by Broca (Lenneberg, 1967), who, in 1865, made the discovery that a form of aphasia was the result of left unilateral lesions. Wernicke (Lenneberg, 1967), in 1874, gave further credence to the concept when he showed that forms of aphasia in which loss of auditory comprehension were a prominant feature were also the result of left unilateral lesions. Again in 1891, Dejerdine (Lenneberg, 1967) implicated left unilateral lesions for the loss of reading and writing comprehension. Concurrent with this, observation of massive damage to the right hemisphere showed no impairment in the language functions. This consequently lead most people to believe that the left hemisphere was the dominant one, primarily in terms of language functions, whereas the right hemisphere was thought of as the silent or minor hemisphere, dominant for nothing.

This concept of unilateral cerebral dominance has recently been replaced, however, by one in which dominance is more material specific, i.e., it differs according to different functions. Thus dominance can be attributed to one hemisphere for one function (i.e., left for language) and concurrently be attributed to another hemisphere for another function (e.g., right for visual spatial ability). As a result, various significant differences have been observed in terms of dominant function. Meyer and Yates (1955) showed that recall of verbal material presented in associative learning tasks is impaired with lesions of the left temporal lobe. Likewise, difficulty with verbal memory has been shown by Milner (1954) to occur in patients with epileptogenic lesions of the left temporal lobe. The right hemisphere in contrast has been identified as dominant for spatial perception. Lesions within the right hemisphere have resulted in various spatial deficits (Hebb, 1939; Patterson & Zangwill, 1944; Piercy & Smyth, 1962; Warrington & James, 1967) as well as deficits in constructional capacities (Griffith & Davidson,1966).

Evidence indicates that the right hemisphere is also dominant for certain intellectual abilities such as music. Luria (1963) presents a case study of a composer whose best work was done after he became aphasic with a massive stroke to the left hemisphere. Similarly, Milner (1962) reported that following right temporal lobectomies, patients exhibit marked deficits on musical and nonverbal auditory tests with pronounced difficulties in comparison with tonal patterns and judgment quality. Thus evidence for a bilateral theory of cerebral dominance based on function organization rather than unilateral dominance prompted Hecean (1962) to say:

> The facts so far generated suggest that there exists a specific symptomatology for each hemisphere, without so far having the right to infer from that the existence of particular functions. It is a fact that the symptomatology is different according to the hemisphere disturbed thus obliging us to consider a certain functional organization of the cortex that would be different for each hemisphere.

<u>Anatomical Asymmetry within the Brain</u>

Researchers having observed the functional differences between hemispheres in man sought corresponding anatomic asymmetries in the brain. Early researchers, namely Eberstaller, Conningham, Shellshear, and Connally, noted that the Sylvian fissure was longer in the left than in the right hemisphere (Witelson, 1977). This was taken to indicate that some region within the fissure was asymmetric. Later researchers such as Pfeifer, von Economo, and Horn

(Witelson, 1977) identified the plan temporale located within the Sylvian fissure as being larger in the left than the right hemisphere. Von Bonin (1962) disclaimed, however, these anatomical differences as being too trivial and of insufficient magnitude to account for the marked functional differences between the hemispheres and stated that no anatomical differences were in evidence. Recent research efforts by Geschwind and Levitsky (1968), using more refined surgical techniques and anatomic measurements, showed that in a sample of 100 brains, 65% showed a longer planum in the left hemisphere, whereas only 11% had a longer right planum. Teszner et al. (1972), using a different method of measurement than Geschwind, in which they made molds of the temporal plane and then obtained area measurements of the two-dimensional projected planes of the molds, found similar results. Likewise, Witelson and Paille (1972) observed a larger left planum than right planum in the series of adult brains that they examined. LeMay and Culebras (1972) looked at the corresponding vasculature of the brain in the Sylvian fissure and found that the middle cerebral artery angled more sharply on the left than it did on the right. The observed differences in arteriographic asymmetries in the whole brain specimens showed a more highly developed parietal operculum (considered to be part of the central language area) on the left than on the right.

In a review of the literature on anatomical asymmetry in infants, Witelson (1977) notes that all of the studies done showed a greater number of infant brains with a larger left planum than the right. The overall percentage of specimens having a larger left planum was 75%, which is comparable to the 69% that is observed in studies of adult brains. In light of the above data, she hypothesizes that there may be a preprogrammed neural substrate for the left hemisphere to be later specialized for linguistic functions.

Whether structural asymmetries within the brain lead to later functional asymmetries in performance is a question that is beyond the scope of this proposal to answer. However, the data do present strong inferential evidence that the structural anatomical organization of the brain may account for later functional asymmetry.

Current Research Directives in Cerebral Organization

The most clear-cut evidence for lateralization and specialization of function and organization is seen in persons who have suffered certain forms of brain lesions. Damage localized to the left side of the brain often results in some loss of language functions, whereas similar damage to the right side leaves the functions of language intact. According to Lenneberg (1967), time of onset of injury is very important as a prognostic indicator of recovery of function. For lesions occurring in the very young, either during or immediately after the age in which language is acquired, full recovery of function is obtained. In a review of clinical cases, Lenneberg maintains that if language had developed before the onset of the disease, and if the lesion is confined to a single hemisphere, language function will return if the child is nine years old or younger at the time of onset. However, if onset of brain injury, or if recovery of function is not yet obtained by the age of puberty, aphasic symptoms will remain and continue into adulthood. Basser (1962) looked at children who sustained lesions during the first two years of life, either to the left or right side of the head, and found that in half of them the onset of speech was delayed, whereas in the other half, language developed normally. This distribution held true regardless which side of the head the lesion was incurred. It seems that before the onset of speech, both hemipsheres are equipotential in sustaining language. This equipotentiality is apparently lost after the onset of speech. Basser notes that after language acquisition begins, and up to the age of ten, left-sided lesions result in speech distrubance 45% of the time. Other researchers, namely Sperry (1966) and Zangwill (1960), likewise hypothesize that both cerebral hemispheres possess equal potentials for language at least until four to five years of age.

Evidence for lateralization of speech functions has been found by others. Studies involving dichotic listening tasks show that verbal or linguistic stimuli such as words, digits, single syllables or nonsense syllables are reported more accurately when presented to the right ear and hence transmitted to the left hemisphere (Kimura, 1961; Shankweiller & Studdert-Kennedy, 1967). In contrast to this, nonverbal or nonlinguistic stimuli, i.e., steady state vowels, melodies, environmental sounds, tend to be processed more efficiently by the left ear--right hemisphere circuit (Chaney & Webster, 1966; Kimura, 1964; Milner, 1962).

Hemispheric lateralization has also been demonstrated utilizing dichoptic visual techniques. Kimura (1969, 1973) found that verbal material is more readily identified in the left hemiretinas--(i.e., right visual fields in either eye) left hemisphere circuit, while the right hemiretinas--(i.e., left visual fields in either eye) right hemisphere system is more specialized to process nonverbal stimuli, e.g., geometric forms. Kimura postulates that right hemisphere mediates those functions involving a spatial-nonverbal component.

Further evidence for support of Kimura's hypothesis was presented by Hilliard (1973) and Berlucchi et al. (1974). Hilliard reported significant differences in recognition and recall between verbal material (i.e., trigrams) and nonverbal material (i.e., faces) when presented to subjects' right and left visual fields. Left visual field superiority was found for faces, whereas right visual field superiority was found for the trigrams. Berlucchi et al. modified the above paradigm and looked at reaction times to the presentation of verbal and nonverbal material to the left and right visual fields. They reported a differential increase in reaction times to letter and face stimuli dependent on the visual field in which it was presented. A superiority of the right visual field was found for letters, while a superiority of the left visual field was observed for faces. Reaction times to a patch of light did not exhibit any interfield differences between left and right visual fields.

Various researchers have attempted to establish electrophysiological measures as correlates of hemispheric lateralization. Buchsbaum and Fedio (1969) studied averaged evoked potentials of verbal and nonverbal stimuli from left and right hemispheres in normal subjects. They found that the averaged evoked response waveforms for both sets of stimuli were different from the left hemisphere than those from the right. Averaged evoked responses to verbal stimuli were also found to have shorter latencies when recorded from the left hemisphere. Morrell and Salamy (1971) were able to differentiate between evoked potentials produced by phonemic sounds and pure tones. Amplitudes to the pure tones were larger on the right side, particularly over the parietal region. In contrast to this, the evoked potentials produced by phonemic sounds were larger and more stable over the left parietal region.

Task demands in regard to processing complexity can enhance asymmetry between hemispheres as reported by Poon et al. (1976). They reported an increased positive P_2

component in the right hemisphere as compared to the left hemisphere during a simple recognition task of tachistoscopically presented letters. This asymmetry was further enhanced when task demands required more complex processing.

Gallin and Ellis (1975) compared the asymmetry of averaged evoked potentials and the electroencephalography (EEG) alpha function as indicators of lateralized cognitive functions. They engaged the subjects in spatial and verbal tasks while simultaneously presenting light flashes. Results showed that the alpha ratio was lowered in the task engaged hemisphere, i.e., spatial tasks lowered alpha frequency in the right hemisphere, whereas verbal tasks lowered alpha in the left hemisphere. Similar results were obtained by Dumas and Morgan (1975) who compared a population of engineers and artists on different tasks. They found no differences between occupations in terms of alpha asymmetry nor were there differences as a function of task difficulty. However, differences were observed in amount of alpha present within the hemisphere that is dominant for a particular task. Thus, alpha suppression was observed in the right hemisphere for right hemisphere tasks, i.e., facial recognition and Nebes ring test, along with alpha suppression being observed within the left hemisphere for left hemisphere tasks, i.e., linguistic and verbal material.

Recent empirical data have cast some doubt, however, as to whether the lateralization of speech is as simplistic as described previously. Whereas it is fairly well established that the left cerebral hemisphere is usually especialized for language functions in right-handed persons, left-handers show far more variability for language to be lateralized in the left hemisphere. Results of studies of left-handers have been contradictory. Some studies have found that strongly left-handed subjects can be divided into two groups: one having left hemisphere language and the other having right hemisphere language (Lishman & McMeekan, 1977; Satz, Achenbach, & Fennell, 1967). Likewise, Dee (1971) reported that in performance on dichotic listening tasks, strongly left-handed subjects showed left hemisphere language control and weak left-handers displayed variable language lateralization. In contrast, however, Knox and Boone (1970) found that when the dichotic listening task was made more difficult, performance of strong left-handers was under right hemisphere language control.

Other confounding variables related to handedness and cerebral organization that have been identified are the presence of a positive history of familial sinistrality and sex. Clinical and experimental studies of subjects having a positive history of familial sinistrality show less dependence upon the left hemisphere for language processing (Hecean & Sauget, 1971; Hines & Satz, 1971; Subirana, 1964, Zuriff & Bryden, 1969). In a study done by Luria (1969), he reports that recovery of language in aphasics is likely to be more improved, regardless of the patient's own handedness, if there is a left-hander in the immediate family of the patient. In contrast, Briggs et al. (1975) found that familial sinistrality has no outcome on language processing, whereas others have shown that a positive history of familial sinistrality may indicate more dependence rather than less on the left hemisphere for language processing (Newcomber & Ratcliffe, 1973; Warrington & Pratt, 1973).

Further confusion and contradiction have been found in the few studies that have addressed sex as a significant variable in performance differences related to hemispheric asymmetry. However, in a review of the dichotic listening literature, Lake and Bryden (1976) concluded that "studies dealing with sex differences in dichotic listening are virtually unanimous in showing greater laterality effects in men than in women" (p. 144). Visual half tachistoscopic studies by Bradshaw, Gates, and Nettleton (1977), and Hannay and Malone (1976) show that females tend to be less lateralized than their male counterparts. Contrary to this, a significant sex effect was found by McKeever and Van Deventer (1977) who reported females having left hemispheric superiority in visual and auditory processing of verbal stimuli, whereas males failed to show any hemispheric asymmetry.

It appears then that several variables may affect or mediate cerebral organization and performance asymmetry, namely, handedness, familial sinistrality, and sex. As a consequence, further research endeavors need to incorporate these salient factors and allow for control of their effects as they cannot be neglected.

Cerebral Organization and Interhemispheric Competition

To this point the review of the literature has centered on research studies examining subjects' performances of singular tasks and their relationship to cerebral organization. However, researchers have also focussed on subjects' performances on dual tasks to study the effects of cerebral competition and facilitation. Studies have shown that a subject, when working at full capacity, will lose efficiency if he is required to simultaneously perform a second task. Usually the performance of both tasks is altered (Taylor, Lindsay, & Forbes, 1967). Kinsbourne and Cook (1971) reported that subjects engaged in verbal activity had lower balancing times with the right hand, whereas the left hand balancing times were higher and enhanced. Kinsbourne thus proposed a model for this asymmetrical phenomenon which incorporates the following: In a dual task paradigm, the dual task performance decreases to the extent that cerebral programs controlling the two tasks share the same functional space. In this situation, the functional distance or space between any two cerebral control centers decreases or increases according to the extent to which they collaborate on concordant tasks and to the extent they compete on discordant tasks. According to this model, if effector A can be paired with either effector B (functionally close) or effector C (functionally distant), then the AB combination will more efficiently perform concordant tasks, whereas the AC combination will more effectively perform discordant tasks. Within the framework of this model, right balancing times were depressed because the left hemisphere had to simultaneously program both speech and motor movement of the contralateral hand (functionally close--discordant task), whereas left hand balancing times were increased because motor movements (discordant tasks) are programmed in the right hemisphere (functionally distant).

Data for support of Kinsbourne's model were provided by Hicks (1975) who found that increased phonetic difficulty of the verbalized material increased the interference in right hand performance. In contrast, performance of the left hand was unaffected by the difficulty level of the verbalizations. Likewise, Hicks also showed that when humming was substituted for the speech tasks, similar deficits appeared in the right hand whereas no interference effects were found for the left hand. In another experiment by Briggs (1975), it was demonstrated that in a bimanual step tracking task with a concurrent verbal task, the right hand made more errors than the left hand. Hicks, Provenzano, and Rybstein (1975) combined a motor sequencing task with a verbal task and found an asymmetrical interference in the motor task with the right hand showing more deficits than the left.

In contrast, however, Lomas and Kimura (1976) failed to replicate the results obtained by Kinsbourne and Hicks for either speech or humming tasks. Instead they found symmetrical bilateral interference for both hands when combined with the verbal and humming tasks. In an experiment done by Bowers et al. (1978) in which a visuospatial task was combined with a finger tapping task, performance on the motor task was equally depressed for both hands with no asymmetry in evidence. However, results from the simultaneous verbal tasks and concurrent finger tapping showed asymmetrical interference in tapping performance with the right hand being more depressed than the left.

In general then it appears that concurrent motor activity performed simultaneously with varied verbal tasks results in an asymmetrical performance deficit in the right hand. However, extending Kinsbourne's theory further, one can also hypothesize that some performance deficit would occur in the verbal tasks when the subject was engaged in right sided - motoric activity. One can assume this on the premise that discordant tasks performed by functionally close effector centers would compete for locus control and have an inhibiting effect requiring certain "time sharing" of neural space. Some evidence has been shown that this in effect does happen as Hicks et al. (1975) reported that finger tapping depressed performance on a verbal memory task. However, recently Bowers et al. (1978) found no decrements on three different verbal tasks of varying cognitive difficulty.

The evidence to date implies that in a dual task involving a cognitive verbal component combined with a motoric activity, a one-sided interference effect is observed with an asymmetrical depression of the motor performance. This is not accounted for, however, by Kinsbourne's model of functional distance, as it instead implies a mutual interference for tasks functionally close. This question consequently needs further examination and will be hopefully addressed by this study.

Statement of the Problem

Kinsbourne's functional distance model predicts that a concurrent verbal task will interfere with right-handed performance more than with left-handed performance in those subjects with left hemisphere speech. This prediction is based on the premise that the right hand control center is functionally closer to the left hemisphere speech center than the left hand control which is contralaterally located in the right hemisphere motor strip. Studies of hemispheric connections likewise show that motor control for the feet follows a similar contralateral pairing, i.e., motor control of the left foot is found within the right motor cortex and motor control for the right foot is centered within the left motor cortex. Specifically, the motor control center for the right foot is located more medially along the motor cortex than the motor control center for the right hand which is closer to the speech center. Extrapolating Kinsbourne's model further, the functional distance between the left-sided speech center and motor control for the right foot would be greater than the functional distance between the left-sided speech center and the right hand. Likewise, one could predict then that because of the greater functional distance between the two control centers, less interference in motor performance would be observed for the right foot than for the right hand.

In order to test the above hypothesis a study will be designed that will first attempt to replicate the previously reported results of right hand performance deficits. Secondly, a paradigm will be designed that will effectively test the hypothesis that the functional distance between the speech center and effector control for the right foot is greater (i.e., less decrement) than that of the speech center and right hand.

Since the above results are expected to occur in right-handers with speech lateralized to the left side, a dichotic listening task originally developed by Satz and associates (Fennell et al., 1978) will be employed to identify subjects with left-sided speech centers. A handedness inventory will also be used in conjunction to help in further identification of subjects. This will help insure that only subjects with a strong right hand preference and speech localized to the left hemisphere will be selected.

A foot tapping device has been developed that will be used to test the motor performance of the subject's foot tapping skills. This task has been chosen as being the most effective in activating that part of the motor cortex that controls the foot. Likewise, it will allow us to measure performance differences, if any, between the two contralateral homologous limbs (left foot/right foot), and ipsilateral limbs (right foot/right hand).

Specific Hypothesis

In this experiment subjects were asked to perform simultaneously a verbal fluency task while either tapping a finger board or a foot board. The hypothesis that was tested included the following: First, according to Kinsbourne's model, one could predict a decrease in finger tapping under conditions of concurrent verbalizations but not a decrease in foot tapping which is mediated by areas more distant from language centers. Secondly, one would predict that under conditions of finger tapping and verbalization, verbal fluency rates would be larger for the left hand than the right hand as there would be less interference effects from the contralateral left-sided motor centers. Similarly, comparison of verbal fluency rates for foot and finger tapping conditions would predict a relatively greater increment over baseline for verbal fluency under foot tapping conditions than under finger tapping conditions. Finally, and in contrast to the above, an attentional or priming model would predict a drop in both finger and foot tapping performances under the premise that verbal instructions presented by the examiner wouldprime the subject's left hemisphere to action at the expense of adjacent functional areas.

CHAPTER II
METHOD

Subjects

The subjects were 40 right-handed college students, 20 males and 20 females, with ages ranging from 18 to 25 years. Subjects were selected on the basis of having the following qualifications: a) no family history of sinistrality, and b) a positive right-hand preference score +9, (range -24 to +24) on the Briggs and Nebes Handedness Inventory (1975). Subjects were obtained from a pool of undergraduates at the University of Florida, Psychology 201 students, whose participation in this study partially fulfilled the requirements of this Psychology 201 coursework.

Apparatus

Two different apparati were used in this experiment: the finger tapping board and the foot tapping pedal. The finger tapping apparatus consisted of a metal level 3.75 cm. long mounted in the upper center quadrant of a 20.3 x 17.5 cm. board. This lever was suspended approximately 2.54 cm. above the board and was attached to a decimal counter that mechanically advanced each time the lever was depressed. Similarly, the second apparatus, the foot tapping pedal, consisted of a pedal in the shape of a shoe attached at its base by a hinge to a board 450 x 330 cm. with a spring on the underside of its toe raising it approximately 6.0 cm. From the side of the pedal a 9 cm. dowel extended to and came in contact with a metal level 3.75 cm. long mounted to the left of the foot pedal. This lever was suspended 2.54 cm. above the board and attached to a decimal counter. Whenever the pedal was depressed, the dowel likewise depressed the lever and the counter was advanced.

Procedure

Dichotic Listening Task

Each subject was presented with a dichotic listening task on two separate days approximately one week apart, in which he was asked to recall groups for one syllable concrete words presented simultaneously to each ear. This task had been developed by Satz and associates in preliminary pilot work done at the Neuropsychology Lab at the University of Florida. Forty-five different pairs of one syllable concrete words, e.g., pipe/cone, were used as stimuli. The 45 pairs of words were grouped into 15 test trials, with each trial consisting of three pairs of words being presented one to each ear at the rate of 500 msec. per pair. Each trial, from onset to offset, lasted 1.5 sec. followed by a 10 sec. intertrial interval. Stimuli, recorded earlier on Scotch Mylar Tape, were played on a Tannberg Stereophonic tape recorder and presented via Stennheiser

Stereophonic headphones to the subject. The subject was seated at a table facing a blank wall. The subject's task at the end of each trial was to say aloud to the examiner as many words as he could remember from that trial without regard for order of presentation or ear. At the end of 15 trials, the headphones were reversed and the 15 trials repeated so that words previously heard in the right ear were heard in the left ear and vice versa. Prior to the testing session, each subject was presented with five practice trials to familiarize himself with the task. Scores were the total number of words correctly recalled on each trial from each ear.

Dual Task Paradigm I

An experimental task developed by Bowers et al. (1978) was used as the first dual task. Each subject was given a preliminary finger tapping task consisting of four 10 sec. trials using first the right hand and then repeated with the left hand. Subjects were shown and instructed to tap the lever as rapidly as possible with their index finger, restricting movement to the proximal joint. The subjects were asked to keep the wrist and remaining fingers still while positioned on the finger tapping board. This was done to familiarize the subject with the task. Following this, the experimental session consisted of two baseline and one dual task condition including the following tasks: a) finger tapping alone (FT), b) verbal fluency alone (VF), and c) finger tapping and verbal fluency performed simultaneously (FF).

The baseline FT condition will consist of four 30 sec. finger tapping trials as described above, alternating between right and left hands (RLRL or LRLR). Intertrial intervals were 10 sec. long.

The baseline verbal fluency consisted of four 30 sec. trials in which the subject was asked to say as many words as possible beginning with a specified target letter identified by the experimenter. One of 12 letters (A, D, F, T, B, P, etc.) was used for each of the four trials. Proper names and their derivatives were not allowed. Each trial began with the announcement of a specified target letter by the experimenter and ended 30 sec. later. A tape recorder was used to record the subject's responses for later scoring.

The dual task condition required the above described finger tapping task and verbal fluency task to be performed together. Each trial began with the experimenter presenting a target letter at which time the subject was asked to begin tapping and generating words. Four trials were done, alternating hands (RLRL or LRLR). Subjects were asked to divide their attention equally between the two simultaneous tasks.

The Dual Task Paradigm I consisted of a total of 12 trials per subject, four per condition. Half of the baseline trials (two FT and VF) were done at the beginning of the session and the remainder at the end. Hand and letter order were balanced across subjects and condition.

Dual Task Paradigm II

The second dual task was similar to the procedure described above for Dual Task Paradigm I. Foot tapping (FtT) was substituted, however, for the FT task. Likewise, each subject was given a preliminary foot tapping task consisting of four 10 sec. trials using first the right foot and then repeated using the left foot (RLRL). Subjects were shown and instructed to tap the pedal as rapidly as possible with their foot, restricting movement to the tibial tarsal joint. Following this, the experimental session consisted of one dual task condition including the following tasks: a) foot tapping alone (FtT) and b) foot tapping and verbal fluency performed simultaneously (FtF). Verbal fluency baseline data were used from data obtained in Dual Task Paradigm I.

The baseline FtT condition consisted of four 30 sec. foot tapping trials as described above, alternating between right and left foot (RLRL). Intertrial intervals were 10 sec. long.

In the dual task condition, the subjects were asked to perform the FtT described above and VF task previously described simultaneously. Four trials were done alternating feet (RLRL). Concurrently, each subject was asked to generate concrete words to a specific target letter. Throughout the session, subjects were asked to divide their attention equally between the two tasks. A tape recorder was used to record the subjects' responses.

Dual Task Paradigm II consisted of a total of eight trials per subject, four per condition. Half of the baseline trials (two FtT) were done at the beginning of this part of the session and the remainder at the end. Foot and letter order were balanced across subjects and conditions.

Analyses

The proposed analyses were three-fold. First, test-retest reliability were assessed for the dichotic listening task over two sessions using Pearson Correlations of right ear scores, left ear scores, and a difference score (R-L/R+L). High correlation coefficients were added support to the reliability of the dichotic listening task as a measure of speech laterlaity.

Secondly, separate analyses of variance were performed with verbal fluency scores and respective motor tapping scores as the dependent variables for both previously described test paradigms I and II. Within subject factors in Paradigm I were hand (R or L) and condition (baseline or dual task). Similar analyses were performed for results obtained on verbal fluency scores and foot tappings in Paradigm II using foot (R and L) and condition (baseline or dual task) as within subject factors.

Thirdly and lastly, comparisons were made between the two Dual Task Paradigms I and II using R-L difference scores for each condition. Mean test scores were examined for each paradigm and T-tests run to check for significant differences.

CHAPTER III
RESULTS

The obtained results are presented in four sections. The first section will primarily deal with evaluating the reliability of the subjects' performances on the individual tasks from Day 1 to Day 2. The second and third sections concern themselves with motor performance data obtained on test Paradigm I and test Paradigm II. These sections address themselves to evaluating Kinsbourne's functional distance model which predicts that a concurrent task will interfere with right-sided performance more than with left-sided performance in those subjects with left hemisphere speech. The fourth and final section will present the verbal fluency data and address itself to answering the questions of whether motor performance finger tapping vs. foot tapping has a reciprocal effect on verbal fluency as expected by extrapolating Kinsbourne's model.

Preliminary Analysis

Three different sets of correlation measures were obtained, one for each performance measure (ear, hand, and foot) comparing Day 1 and Day 2. These were done to evaluate the reliability of the test data from Day 1 to Day 2.

Table 1 presents the r-values for the dichotic listening task for both ears (R and L) and Days (1 and 2). A correlation coefficient of r = .77 was obtained for the right ear between Day 1 and Day 2 with a p value of .0001. Overall means for the R Ear Day 1 = 57.39 with a standard deviation (S. D.) = 9.42. Overall means for the R Ear Day 2 were 62.47 with an S. D. = 9.93. A higher correlation was obtained for the left ear from Day 1 and Day 2 with an r-value .84 and a p value of .0001. The overall means for the L Ear Day 2 were 37.71 with an S. D. = 9.52. The mean for L Ear Day 2 was 43.61 with an S. D. = 13.37. It is assumed that the increased means for both ears on the second day of the experiment were due to practice effects and increased familiarity with the task by the subjects. The above data indicate, however, that the dichotic listening task was a reliable measure and indicator of right ear dominance.

Table 2 shows the correlation coefficients for the finger tapping practice trials on both hands between Days 1 and 2. A correlation coefficient of .72 was obtained for right-handed finger taps between Day 1 and Day 2 with a p value of .0001. The overall means for right finger taps on Day 1 were 100.66 with an S. D. of 17.43. The overall mean obtained for right finger taps on Day 2 was 102.58 with an S. D. of 13.97.

Correlation coefficients for the left hand on Days 1 and 2 were observed to be somewhat higher with an r-value of .84 statistically significant at the p = .0001 level.

Table 1
Correlations for Ears: Day 1 vs. Day 2

	Right Ear Day 1	Right Ear Day 2
Right Ear Day 1	1.0000	0.7704 (p=.0001)
Right Ear Day 2	0.7704 (p=.0001)	1.0000

	Left Ear Day 1	Left Ear Day 2
Left Ear Day 1	1.0000	0.8399 (p=.0001)
Left Ear Day 2	0.83990 (p=.0001)	1.0000

Table 2
Correlations for Finger Taps: Day 1 vs. Day 2

	Right Finger Taps Day 1	Right Finger Taps Day 2
Right Finger Taps Day 1	1.0000	0.7164 (p=.0001)
Right Finger Taps Day 2	0.7164 (p=.0001)	1.0000

	Left Finger Taps Day 1	Left Finger Taps Day 2
Left Finger Taps Day 1	1.0000	0.8404 (p=.0001)
Left Finger Taps Day 2	0.8404 (p=.0001)	1.0000

The overall means for left finger taps on Day 1 were91.03 with an S. D. of 14.02. The overall means obtained for left finger taps on Day 2 were $\overline{M}$ = 95.05 with an S. D. of 12.53 Once again the observed slight increase in finger tap scores from Day 1 to Day 2 on both hands can be attributed to practice effects and familiarity with the task by the subject along with individual subject differences. Despite these observed variances in the data, the relatively high r-values suggest that the finger tapping task is a reliable measure over time.

Analysis of the Dual Task Paradigm I

An analysis of variance was performed on the finger tap performances from Day 1 and Day 2 which was collapsed into one data pool. Four conditions were analyzed: Right Hand alone (RH), Left Hand alone (LH), Right Hand combined with Verbal Fluency (RHVF), and Left Hand combined with Verbal Fluency (LHVF).

Significant differences were found to exist between all four different experimental conditions with an obtained F value = 72.27 and p = .001. Table 3 presents the results of the analysis for the Finger Tap data. The means for these conditions are presented in Table 4. Rate of finger tapping was greatest for the RH alone conditions with an obtained $\overline{M}$ of 288.30. The largest difference in observed rates of performance was between the RH alone and the LH combined with Verbal Fluency. The mean rate of performance

Table 3
Analysis of Variance for Finger Taps

Source	DF	F Value	Pr F
Condition	3	72.27	0.0001
Sex	1	136.36	0.0001
Subject (sex)	36	23.21	0.0001
Day	1	12.14	0.0006

Table 4
Mean Finger Taps per Trial

Condition	Number of Finger Taps
RH	288.30
RHVF	262.21
LH	254.50
LHVF	238.88

Sex	Number of Finger Taps
Male	275.15
Female	246.80

Day	Number of Finger Taps
1	256.74
2	265.20

for the LHVF condition was found to be 238.88 which, using Duncan's Multiple Range Test, was significantly different at the .05 level.

Smaller absolute differences were found for the other two conditions with the overall mean for RHVF (M = 262.21) being greater than the overall mean of the LH alone condition (M = 254.50). Figure 1 shows the actual results for the finger tap data drawn from research on concurrent tasks. As one can see, both the actual data and expected data are congruent with each other. Subjects performed better with their RH's alone than with their LH's alone. These results were as expected and reflect the subject pool of all right-handers. Similarly, their performance dropped for both hands when a concurrent task was added, namely, verbal fluency.

Analysis of the Dual Task Paradigm II

A similar analysis of variance was done on the foot tapping performance from Day 1 and Day 2 as was done on the finger tap data. Four conditions were analyzed also: Right Foot alone (RF), Left Foot alone (LF), Right Foot combined with Verbal Fluency (RFVF), and Left Foot combined with Verbal Fluency (LFVF). Significant differences were observed between three of the four conditions. The F-value obtained was 18.66 with p = .0001. Table 5 presents the results of the analysis of variance for the Foot Tap data. Differences were obtained between both alone

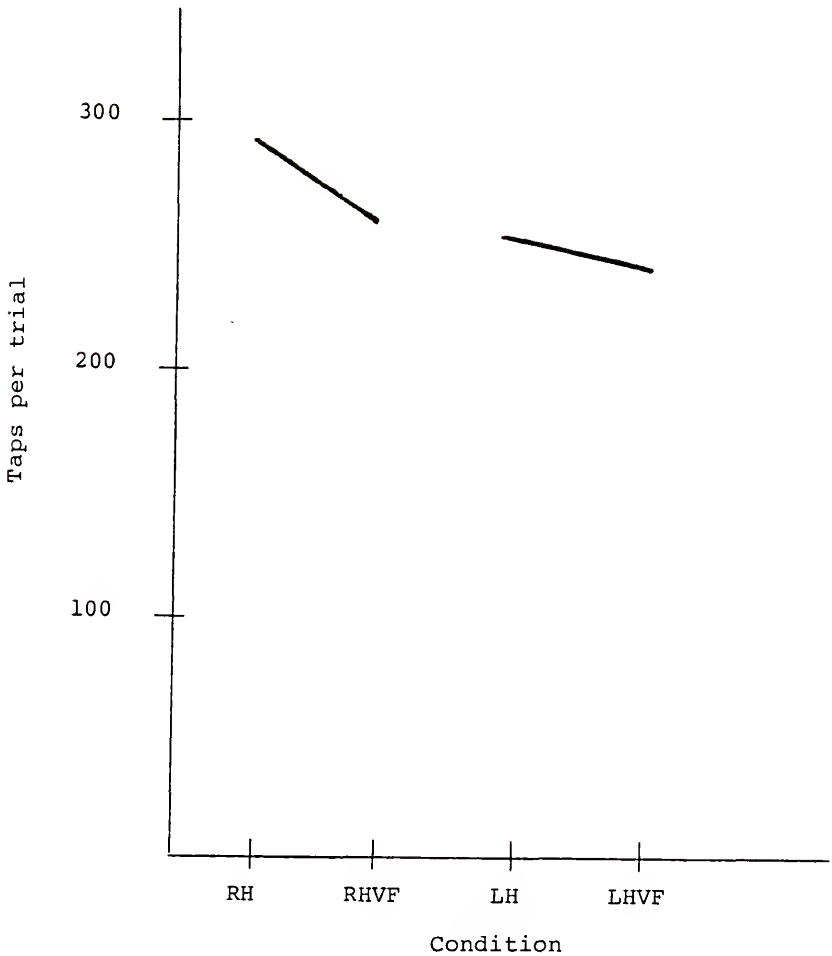

Figure 1. Finger Tap Rates

Table 5
Analysis of Variance for Foot Taps

Source	DF	F Value	Pr > F
Condition	3	18.66	0.0001
Sex	1	24.75	0.0001
Subject (sex)	36	8.14	0.0001
Day	1	2.85	0.0001

conditions which were also significantly different from the combined tasks conditions. There were no differences between the tasks conditions for either the left or right foot. Table 6 presents the means for the four different conditions. As one can see, rate of foot tapping was greatest for the RF alone condition with a mean of 230.89. Foot taps dropped significantly when the nonpreferred foot was used alone with an observed mean of 211.02. When a verbal task was added, foot rates for the right foot were lowered further to an observed mean of 199.56. Foot tap rates dropped for the left foot also when a verbal task was added, but the obtained results were not statistically different from those for the RFVF condition. Figure 2 shows the means plotted out for the different conditions. Subjects performed better with their preferred foot when engaged in one task, but there were no differences between feet when another task was added. These results are somewhat different from those obtained for the figer tap data where all four conditions were statistically different.

Analysis of the Verbal Fluency Data

An analysis of variance was performed on the verbal fluency data for both the hand and foot conditions. No significant differences were found in verbal fluency rates across the different conditions. An obtained F-value of .97 was found which was nonsignificant at the .05 level. This is seen in Table 7 which shows the analysis of variance

Table 6
Mean Foot Taps per Trial

Condition	Mean Response
RFt	230.89
RFtVF	199.56
LFt	211.03
LFtVF	198.37

Sex	Mean Response
Male	275.15
Female	246.80

Day	Mean Response
1	256.74
2	265.20

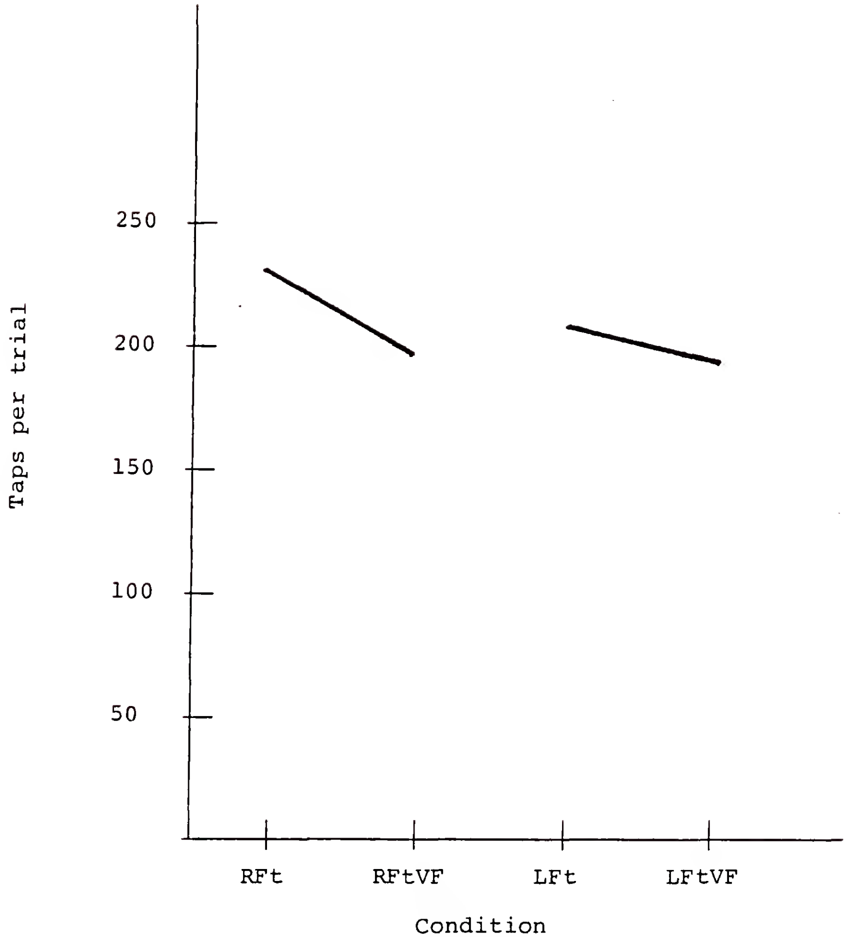

Figure 2. Foot Tap Rates

Table 7
Analysis of Variance for Verbal Fluency

Source	DF	F Value	P < F
Condition	4	0.97	0.4246
Sex	1	0.10	0.7473
Subject (sex)	36	26.01	0.0001
Day	1	30.73	0.0001

results that were obtained. Significant differences were observed between Days I and II, but these are likely due to practice effects that the individual experienced. Mean values for the different conditions are given in Table 8 and presented graphically in Figure 3. The greatest drop in VF rates is when the right-handed motor task is added. The VF rate drops from 20.19 words/trial to 19.27 words/trial.

Table 8
Mean Verbal Fluency Rates

Condition	Mean Response
VF	20.20
RHVF	19.28
LHVF	19.80
RFtVF	20.16
LFtVF	20.03

Sex	Mean Response
Male	19.84
Female	19.95

Day	Mean Response
1	18.94
2	20.84

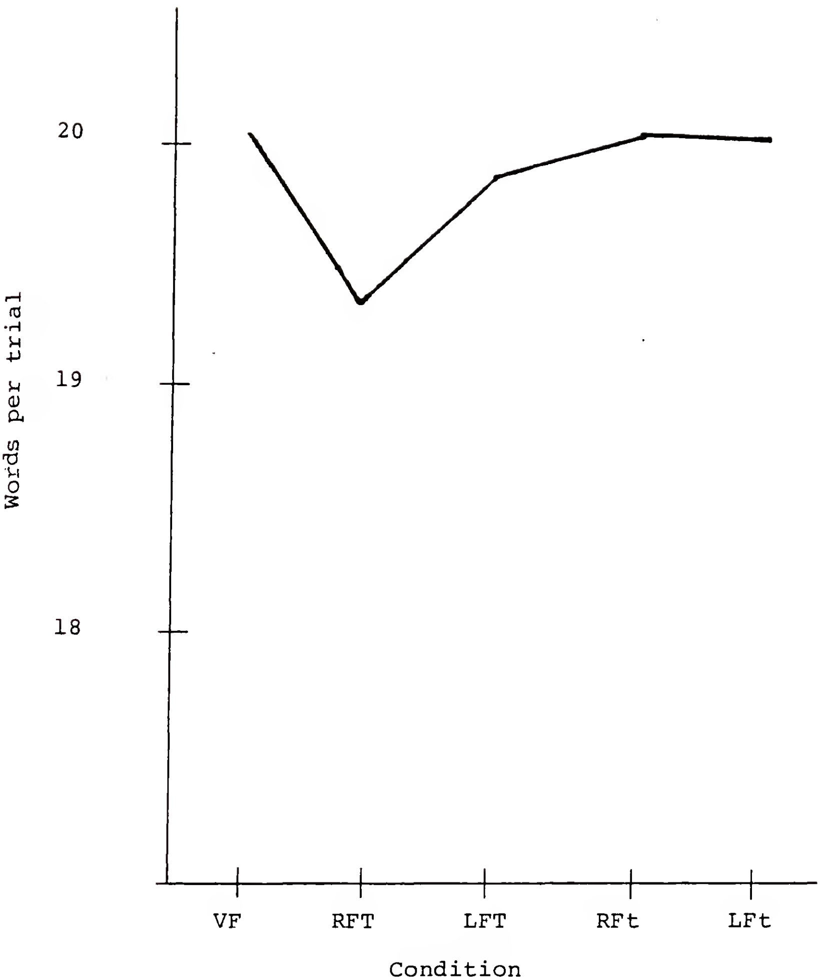

Figure 3. Verbal Fluency Rates

CHAPTER IV
DISCUSSION

According to Kinsbourne's theory of functional distance and shared space, it was expected that respective rates of performance for concurrent tasks would not decrease as their respective loci of control became more distant from each other. Specifically, the model predicts a decrease in overall finger tapping performance under conditions of concurrent verbalization but not necessarily a decrease in foot tapping performance whose control is mediated by areas more distant from language center than those controlling finger tapping performance. In conjunction with this, the model further predicts a greater decrease in finger tapping performance for the right hand over baseline rates than that of the left hand with concurrent verbalization. This is based on the premise that the loci of control for the left hand are contralaterally located and more distant from the language centers than the control centers of the right hand which are ipsilateral to the speech control areas. Likewise, a similar effect would be predicted for foot tapping rates under conditions of concurrent verbalization with right foot tapping performance being more adversely affected than left foot tapping.

Further extrapolation of Kinsbourne's model allows us to predict that verbal fluency rates will be better when the subject is engaged in a motor task involving either the left hand or foot as there will be less interference between the two control centers with the contralaterally located speech center. In contrast, verbal fluency rates for subjects will be lower when the subjects are engaged in right-sided motor tasks as their loci of control are more adjacent and ipsilateral to the language center.

Expected results were not completely obtained, however. Specifically, decreases in the respective rates of performance did occur within motor tasks under concurrent motor and verbal task conditions, but there was no significant change in rates for the verbal component of the dual task paradigm. Partial support of Kinsbourne's theory was illustrated in the differences from baseline rates for left hemisphere controlled motor tasks (i.e., right finger and foot tapping) were larger than those for right hemisphere controlled motor tasks (i.e., left finger and foot tapping) under dual task conditions (see Figure 4). One would expect this according to Kinsbourne's model in that motor areas of control for left-sided motor tasks are located in the right hemisphere and are functionally distant from their counterparts in the left hemisphere. Subsequently, when the two hemispheres are engaged in separate competing tasks, there is less interference from the activation of the left hemisphere in its performing a verbal task while the right hemisphere is engaged a competing motor activity.

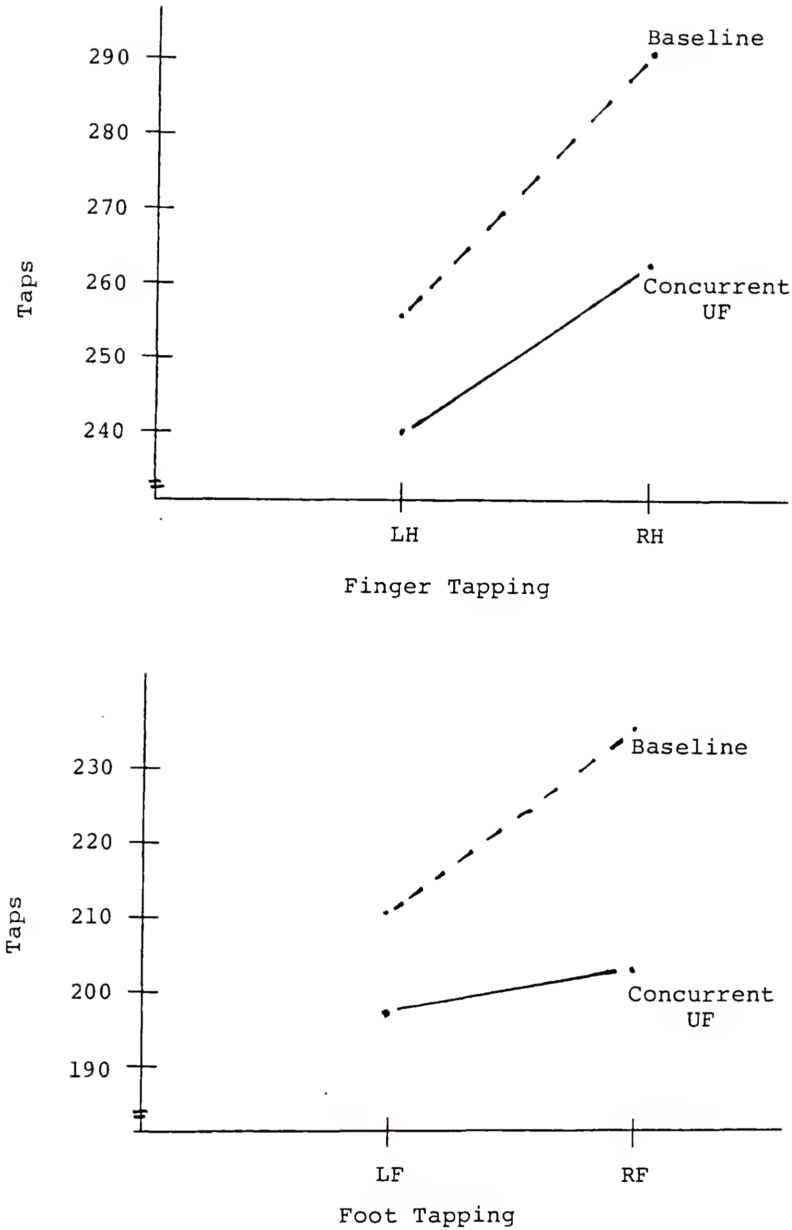

Figure 4. Finger and Foot Tap Rates

Similarly, the argument can be put forth that the observed large deficits in right-sided performance from baseline rates were the function of having two competing tasks originating from or controlled by neural areas that are nearer to each other, i.e., within the same hemisphere. In this case, both the verbal task and right-sided motor tasks have their loci of control in the left hemisphere. The nearness of the two loci of control results in interference effects between them whenever either of the two centers is activated for function. Support for this hypothesis is presented from EEG studies.

When a subject is about to perform a unilateral manual movement, a slow negative potential shift is observed which is maximally recorded over the contralateral motor cortex (McAdam & Seales, 1969; Vaughn, Costa, & Ritter, 1968). Likewise, McAdam and Whitaker (1971), who recorded surface potentials from the left and right motor cortex (precentral gyri) as well as the left and right inferior frontal regions (Broca's area), found that during speech production, greater electrical activity occurred over Broca's area than in the corresponding area of the right hemisphere. In conjunction with this, they also found more electrical activity in the left precentral gyrus than in the contralateral right precentral gyrus. The latter finding suggests that activation of the speech system (Broca's area) is associated with concurrent activation of adjacent motor systems in the left hemisphere which may induce interference in that neural area.

Although it appears that related research lends itself to Kinsbourne's model, the results obtained in this study do not completely support it. If Kinsbourne's model was accurate, one would expect an improvement in verbal fluency rates when the subject was engaged in motor tasks which were controlled by motor centers more distant from the language center. Thus, whenever a subject was engaged in using either the left hand or foot which are both controlled by right hemisphere motor centers, less interference would be expected between the two functional areas with a resultant increase in verbal fluency performance levels. This effect was not observed, however, as verbal fluency rates remained constant under all concurrent conditions and were statistically nonsignificant (see Figure 5).

Why then do the obtained results lend only partial support to the theory proposed by Kinsbourne? One answer that immediately comes to mind is sampling error due to individual subject differences. In this particular study, subjects were all strongly right-handed, exhibited right ear dominance, and had no history of immediate familial left-handedness, i.e., neither parent was left-handed. Studies have shown that left-handers exhibit more varied and different decrements than do right-handers in both unimanual and concurrent tasks (Lomas & Kimura, 1976; Hicks, 1975). Furthermore, left-handers showed less difference between the ears for dichotic listening tasks that employ verbal stimuli which include words, consonants, and digits

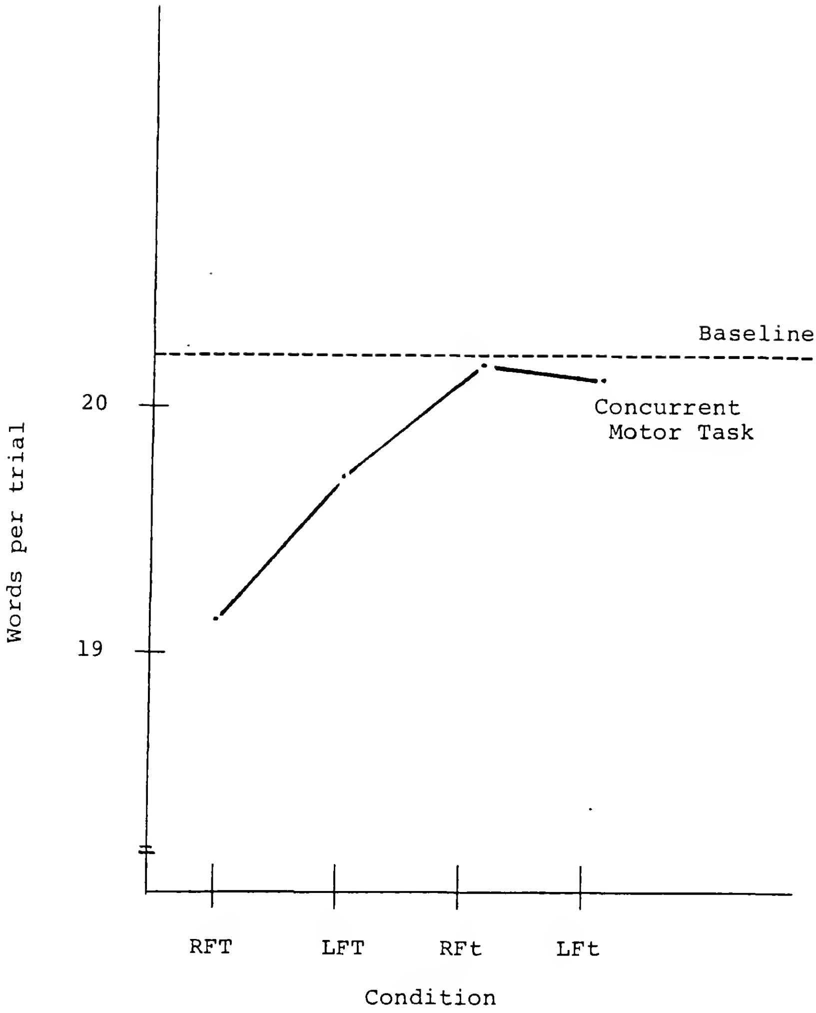

Figure 5. Verbal Fluency Rates

(Bryden, 1970; Curry, 1967; Satz, Achenbach, & Fennell, 1967). In contrast to this, right-handers exhibit greater right ear superiority for the same stimuli (Kimura, 1967; Shankweiler & Studdert-Kennedy, 1967; Spellacy & Blumstein, 1970). If support for the model cannot be found in the simplest design paradigm in which subjects are carefully selected to maximize right/left differences, another explanation must be sought.

A more probable explanation for the lack of support of Kinsbourne's model is that which is proposed by Bowers et al. (1978). In a test of Kinsbourne's model, in which they presented subjects with a dual task requiring them to simultaneously perform a motor task and verbally articulate words, they found that the verbal articulation task exerted a bilateral asymmetrical interference on the motor task. They also found that the motor task had no apparent reciprocal effect on the verbal articulation task. According to Kinsbourne's model, however, one would expect a reciprocal inhibitory effect on verbal articulation when the right hand was engaged in a motor task. No such effect would be expected, however, when the left hand was engaged in a motor task as its motor control strip is in the contralateral, more distant, hemisphere from that of the left hemisphere speech center. If, in fact, observed interference effects for concurrent dual tasks are due to the overlap of functionally adjacent neural areas, the nearness of the right-sided controlling motor strip to the language center would adversely affect the performance of a verbal articulation task. No such effect was observed, however, by Bowers et al. (1978). They consequently proposed that under dual task conditions in which a simple motor task is in competition with a verbal task, a "one-way street" phenomenon is present where priority is given to the language component of the dual task.

This one-sided interference effect, in which motor and cognitive tasks do not mutually interfere with each other, but instead cognitive tasks have priority over motor tasks, does not fit within the framework of Kinsbourne's model. Such a proposition is tenable only if one assumes a hierarchical structuring of systems in which higher order functions, i.e., speech, interfere with lower order functions, i.e., motoric movement, and there is no reciprocal interference flowing the other way.

Hicks (1975) reported, however, a study supporting Kinsbourne's model. In a series of experiments in which subjects were asked to balance a dowel rod on either their left or right index finger while simultaneously repeating phrases, results indicated that concurrent verbalization had a decremental effect on right hand balancing times. He further showed that increased phonetic difficulty of the phrases had a greater decremental effect on right hand balancing. In contrast to the results of Bowers et al. (1978), increase phonetic difficulty caused more verbalization errors on trials of the right hand but not with trials of the left hand. In other words, a mutually reciprocating inhibitory effect was observed with increased difficulty of the verbal task.

Studies reporting effects of increased task difficulty under concurrent task conditions show mixed and varied results. Hicks, Provenzano, and Rybstein (1975) requested their subjects to perform a sequential tapping task that required either bilateral or unilateral synchronized movements alone and concurrently while rehearsing verbal lists of varying redundancy silently or vocally. The results indicated support for an intrahemispheric competition interpretation à la Kinsbourne in that the right hand leading bimanual performance and right hand unimanual performance were interfered with greater than their left hand counterparts under conditions of concurrent verbal rehearsal. They also found some left-handed interference which was not predicted within the framework of the intrahemispheric competition model. They subsequently proposed that obtained results reflected the inherent difference of the tasks. Whereas in the previous study (Hicks, 1975), dowel balancing and simple phrase repetition were the two concurrent tasks, their inherent cognitive demands were rather simple and not as taxing as those in the latter study. They consequently attributed the interference effects that were generalized across hands to the increased cognitive demands inherent within the tasks of sequential tapping and verbal rehearsal. In the earlier study (Hicks, 1975), in which the interference effects were lateralized as task difficulty increased, the difficulty factor reflected a phonetic or speech production component. In the latter study, however, increased difficulty appears to be due primarily to an increased cognitive component which is inherent in the rehearsal of verbal lists and in which a greater amount of cognitive processing is involved than in the continuous repetition of short phrases. Similarly, they surmised that sequential finger movements require greater cognitive demands in that correct sequencing involves a mediating memory component that is not present in a simple dowel balancing task.

Other studies do not show, however, that increasing cognitive demands of the concurrent task will necessarily result in a generalized though asymmetrical decrement in hand performance. In fact, Lomas and Kimura (1976) showed that a bilateral interference effect was seen in simple finger tapping and concurrent verbalization, whereas on a more complex finger sequencing task combined with verbalization, only right-sided interference effects were observed. They further showed that right hand performance was also disrupted not only by sequential taps but also by a sequential arm tapping task, where only gross motor movements were required to change the location of the arm from one location to another. They differentiated their sequential tapping task into more than just a repetition of the same discrete movement as one sees in a straightforward finger tapping task. In their finger tapping sequencing, the subject was required to use different fingers on different key locations and all done in rapid sequence. Since the same lateralized effect in right hand performance was seen in both the sequential finger tapping and sequential arm tapping, they proposed that the effects are due to the rapid positioning of a limb, or parts of a limb, in which there is minimal visual guidance. They went on to hypothesize that the observed effect is not merely the result of concurrent processing within the same hemisphere but rather it is the result of the degree of functional similarity of the different competing systems within the hemisphere. Thus, it is the degree of congruency of two competing motor systems within the same hemisphere than produce lateralized performance effects.

Lomas (1980) repeated in part his previous experiment (Lomas & Kimura, 1976) and added the independent variable of varying visual feedback of the subject's performance. His results showed that right hand interference effects were only seen when the subjects did not receive any visual feedback and could not rely on visually guiding their limb or digit positioning. In contrast, when subjects had recourse to visual feedback, speaking failed to selectively disrupt right hand activity and, in fact, disrupted left hand performance. Although Lomas failed to account for the disruption to left hand performance when visual control was present, he nevertheless hypothesized that intrahemispheric competition is only present for certain motor tasks and only when these tasks are under the control of a specific cerebral motor system.

Other researchers, in trying to test Kinsbourne's model of intrahemispheric competition, devised experiments that utilized tasks specific to and presumably localized to the right hemisphere. McFarland and Ashton (1978b) utilized a visuospatial concurrent task (i.e., right hemisphere controlled) to test whether the obtained results would be reversed from those obtained with a concurrent verbal task (i.e., left hemisphere controlled). They hypothesized that if verbal tasks lead to a right-handed performance decrement, then a visuospatial task should cause a decrement in left hand performance. They found that, in fact, such an effect was observed. When subjects were asked to perform a memory task involving shapes in conjunction with a finger tapping task, left hand performance was disrupted, whereas right hand performance was not disrupted. Although such results tend to support Kinsbourne's intrahemispheric competition model, McFarland and Ashton instead chose to interpret it in terms of an attentional bias model also proposed by Kinsbourne (1970). An attentional model suggests that lateralized cerebral activity biases attention to the contralateral side of the body and would consequently interfere with a task performed on that side. Consequently, it is expected that a concurrent verbal task would bias attention to the right side and disrupt right-handed performance. Likewise, the visuospatial task would bias attention to the left and subsequently disrupt left hand performance.

Another experiment utilzing a visuospatial concurrent task was performed by Hellige and Longstreth (1981). They asked their subjects to simultaneously tap a telegraph key while solving a block design problem from the Weschler Intelligence Scale for Children-Revised (WISC-R) using the hand. Results indicated that decrements in performance were greater for the left hand than for the right hand. The obtained effect was opposite of that in which the concurrent task was a verbal one. They summarily concluded that when the concurrent activity is primarily known to involve the right cerebral hemisphere, observed interference is greater for the left hand than for the right hand on a unimanual task.

This effect is not as clear or consistent, however, when a verbal component is employed in the solution of the visual spatial task. Bowers et al. (1978) looked at the effects of a recognition task believed to be subserved by the right hemipshere and is nonverbal in nature on concurrent tapping. They found that both right- and left-sided tapping were bilaterally and symmetrically disrupted with concurrent visuospatial processing. They suggested that despite the nonverbal nature of the task, subjects may have nevertheless verbally tagged the faces resulting in bilateral processing of the task. Similarly, even if the faces were processed by the right hemisphere, their processing need not necessarily overlap with the motoric programs of the same hemisphere for control of the left hand.

Contradictory results were also obtained by Johnson and Kozman (1977) who failed to find lateralized effects on finger tapping when employing a musical task which likewise is allegedly subserved by the right hemisphere.

It is apparent that previous studies have provided numerous explanations for the varied and conflicting results obtained from experiments on concurrent tasks. The fact that no reciprocal inhibitory effect was found in this study does not necessarily refute Kinsbourne's theory. If one accepts the hypothesis of a hierarchical structuring of control in which interference effects are one-way, the present obtained results lend themselves to that interpretation. However, if one examines the trend of the data across all four concurrent tasks, one sees that even if significance was not attained, the greatest disruption in verbal fluency occurs for the right finger tapping condition. Furthermore, the trend in the data shows that the further the motor control center is from the left speech center, verbal fluency approaches baseline rates.

A reciprocal inhibitory effect may not have been obtained due to the lack of a significant demand component in the verbal task. Although the verbal fluency task used in this study is inherently more difficult than the repetition of a simple phrase, it is not as difficult as that of a task requiring a memory component. Subsequently, if the task demand was not cognitively stringent enough, no reciprocal inhibitory effect would be expected.

The results obtained on the concurrent foot tapping and verbal fluency task are somewhat surprising. A bilateral though asymmetrical interference effect was observed on foot taps. It was expected that left-sided foot tapping would not be adversely affected by a concurrent verbal task as the motor control for left-sided foot tapping is furthest removed from the speech center. An argument can be put forth that the motor control center for feet is less lateralized than that of the speech center, and subsequently the left hemisphere exerts bilateral control over the neuromusculature system for the left and right feet. Such an explanation is tenable if one assumes that the task demands were harder for the foot tapping task and concurrent verbal processing than those for either task alone.

The verbal articulation task required the subject to use a specific target letter and generate a list of words, all of which required the subject to begin with that target letter. The demands for the particular task require not only a simple vocalization of a word but also require the subjects to actively scan and sort out targeted words from their preexisting vocabulary source. In terms of the attentional model, this implies that both hemispheres are being used to process the concurrent task. Subsequently there would be no left or right attentional biases that would cause a differential disruption of manual performance. This assumes then that the biasing characteristics are not due to the characteristics inherent in the task as the task was kept constant but more likely on the strategy employed by the subjects to perform the task. In this case, the degree of the memory load for the verbal fluency task caused the subjects to focus their attention to that task and thereby neglect or decrease the involvement of the right hemisphere in the left foot tapping. The fact that the left foot tapping was not disrupted, however, as greatly as that of right foot tapping can also be explained via a functional distance model. This implies that the right hemisphere motor control center for the left foot was less adversely affected than that of the more adjacent left hemisphere motor control center of the right foot.

Another interpretation for the obtained results may be that of Lomas and Kimura (1976) who proposed a motor theory of disruption. They propose that performance of a verbal task may make use of neural mechanisms that overlap with those neural mechanisms of the left hemispheres which are associated with controlling rapid repositioning of the limbs. Consequently, a verbal task is likely to disrupt concurrent foot performance because the neural units for controlling right foot positioning and speech are closer than those controlling left foot positioning and speech. However, with the increased memory for the verbal task, the resulting verbal output is likely to involve more diffuse neural activity and thereby overlap with the neural system controlling the rapid repositioning of both left and right feet.

Summary and Conclusion

In summary, one can see that the results of this study do not entirely lend support to Kinsbourne's model of functional distance and shared space. If, in fact, the model was completely accurate, two different main effects would have been clearly obtained. First, an asymmetrical decrease from baseline rates would be seen in right-sided finger and foot tapping tasks during concurrent verbalization. Secondly, verbal fluency rates, in turn, would be asymmetrically decreased by motor task conditions, specifically more so when control of those tasks is centered in the left hemisphere. The first main effect was obtained and found to be statistically significant. The second effect, however, was not found although a trend in the data suggests that further research and refinement in techniques may lend support to its basic premise. A plausible explanation that may account for the results of this study can be presented as follows.

The two hemispheres of the brain are structurally programmed for differential activation dependent on stimulus input and task demands. Thus, a task requiring a subject to tap a keyboard with the left index finger activates the motor strip in the right hemisphere. Similarly, a verbal stimulus activates the language center within the left hemisphere. In conjunction with this, activation of a functional neural system may cause activation of other adjacent neural system may cause activation of other adjacent neural systems because of their proximity. Since neural efficiency is somewhat dependent and limited by the availability of information storage and processing capabilities, priority for a given task is likely to be allocated when two separate tasks are performed simultaneously. This allocation of priority may be preprogrammed and based on a hierarchical organization of neural systems in which higher cortical functions (i.e., language) subsume simpler cortical functions (i.e., digit tapping). This inherent supremacy of higher cortical functions, however, can be modified by such variables as the complexity of specific task demands, a subject's cognitive set, and stimulus specific attentional biases. In the present study, verbal fluency rates did not significantly change as a function of motor task conditions, as was predicted. One possible explanation is that there was greater activation of the left hemsiphere due to the verbal nature of the task. This allowed and resulted in the language center controlling a greater percentage of the total neural efficiency of the brain and thereby allocating greater attention to, and better performance of, the verbal task.

Although the above explanation presents an alternative to Kinsbourne's model, the reason for lack of support of his model may have been due, in part, to various intangible factors, some of which are methodological in nature. Laterality studies have always been plagued by poor psychological methodology as well as lack of specification or standardization of treatment parameters. Laterality research has failed to make a distinction between direction and degree of laterality. Both imply similar constructs but are vastly different when used in the literature. Similarly, there is no unambiguous description of what is meant by the term "bilateral representation." If valid research is to be done in the area of neuropsychology, these issues need to be addressed in future research studies or otherwise our research efforts will be similar to that of the all too familiar parable of the four blind men standing around an elephant and basing their separate "views" of what the object is in front of them on their own tactile sensing experience.

REFERENCES

Basser, L. Hemiplegia of early onset and faculty of speech with special reference to the effects of hemispherectomy. Brain, 1962, 85, 427-460.

Berlucchi, G., Brizzolara, D., Marzi, D., Rizzolatti, G., & Umilta, C. Can lateral asymmetries in attention explain interfield differences in visual perception? Cortex, 1974, 10, 177-185.

Botkin, A, Schmaltz, L, & Lamb, D. Overloading the left hemisphere in right-handed subjects with verbal and motor tasks. Neuropsychologia, 1977, 15, 591-596.

Bowers, D., Heilman, K., Satz, P., & Altman, A. Simultaneous performance on verbal, nonverbal and motor tasks by R. H. adults. Cortex, 1978, 14, 540-556.

Bradshaw, J., Gates, A., & Nettelson, A. Bihemispheric involvement in lexical decisions; handedness and a possible sex difference. Neuropsychologia, 1977, 15 277-286.

Braine, L. G. Asymmetries of pattern perception observed in Israelis. Neuropsychologia, 1968, 6, 73-88.

Briggs, G. A comparison of attentional and control shift models of the performance of concurrent tasks. Acta Psychologia, 1975, 39, 183-191.

Briggs, G., Nebes, R., & Kinsbourne, M. Intellectual differences in relation to personal and family handedness. Quarterly Journal of Experimental Psychology, 1975, 28, 591-602.

Bryden, M. Laterality effects in dichotic listening: Relations with handedness and reading ability in children. Neuropsychologia, 1970, 8, 443-450.

Bryden, M., & Rainey, C. Left-right differences in tachistoscopic recognition. Journal of Experimental Psychology, 1963, 66, 568-571.

Buschbaum, M., & Fedio, P. Visual information and evoked responses from the left and right hemispheres. EEG & Clinical Neurophysiology, 1969, 26, 266-272.

Chaney, R. & Webster, J. Information in certain multi-dimensional signals. U.S. Navy Electronic Laboratory Report No. 1339, San Diego, Calif., 1966.

Curry, F. A comparison of left-handed and right-handed subjects on verbal and nonverbal dichotic listening tasks. Cortex, 1967, 3, 342-352.

Dee, H. Auditory asymmetry and manual performance. Cortex, 1971, 7, 236-245.

Dumas, R., & Morgan, A. EEG asymmetry as a function of occupation, task, and task difficulty. Neuropsychologia, 1975, 13, 219-228.

Eling, P. On the theory and measurement of laterality. Neuropsychologia, 1981, 19, 321-324.

Fennell, E., Satz, P., Van Den Abell, T., Powers, D., & Thomas, R. Visuospatial competency, handedness, and verbal dominance. Brain and Language, 1978, 5, 206-214.

Galin, D., & Ellis, R. Asymmetry in evoked potentials as an index of lateralized cognitive processes: Relation to EEG alpha asymmetry. Neuropsychologia, 1975, 15, 45-50.

Geschwind, N. The organization of language and the brain. Science, 1970, 190, 940-944.

Geschwind, N. The anatomical basis of hemispheric differentiation. In Dimond & Beaumount (Eds.), Hemispheric Function in the Human Brain. New York: Halstead, 1974.

Geschwind, N., & Levitsky, W. Human brain; right left asymmetries in temporal speech regions. Science, 1968, 161, 186-187.

Griffith, H., & Davidson, M. Long term changes in intellect and behavior after hemispherectomy. Journal of Neurology, Neurosurgery & Psychiatry, 1966, 29, 571-576.

Hannay, J. & Malone, D. Visual field effects and short term memory for verbal material. Neuropsychologia, 1976, 14, 203-209.

Hebb, D. Intelligence in man after large removals of cerebral tissue defects following right temporal lobectomy. Journal of General Psychology, 1939, 21, 437-446.

Hecean, H. Clinical symptomatology in right and left hemisperic lesions. In V. Mountcastle (Ed.), Interhemispheric Relations and Cerebral Dominance. Baltimore: Johns Hopkins Press, 1962.

Hecean, H., & Sauget, J. Cerebral dominance in left-handed subjects. Cortex, 1971, 7, 19-48.

Hellige, J., & Longstreth, L. Effects of concurrent hemisphere-specific activity on unimanual tapping rate. Neuropsychologia, 1981, 19, 395-405.

Hicks, R. E. Intrahemispheric response competition between vocal and unimanual performance in normal adult human males. Journal of Comparative Physiological Psychology, 1975, 98, 50-60.

Hicks, R., Provenzano, F., & Rybstein, E. Generalized and lateralized effects on concurrent verbal rehearsal upon performance of sequential movements of the fingers by the left and right hands. Acta Psychologia, 1975, 39, 119-130.

Hilliard, R. Hemispheric laterality effects on a facial recognition task in normal subjects. Cortex, 1973, 9, 246-258.

Hines, D., & Satz, P. Superiority of right visual half-fields in right-handers for recall of digits presented at varying rates. Neuropsychologia, 1971, 9(1), 21-26.

Hiscock, M., & Kinsbourne, M. Asymmetry of verbal-manual time sharing in children: A followup study. Neuropsychologia, 1980, 18, 151-162.

Johnson, D., & Kozman, A. Effects of concurrent verbal and musical tasks on a unimanual task. Cortex, 1977, 13, 11-16.

Lenneberg, E. Biological Foundations of Language. New York: Wiley, 1967.

Kimura, D. Cerebral dominance and perception of verbal stimuli. Canadian Journal of Psychology, 1961, 15, 166-171.

Kimura, D. Left-right differences in the perception of melodies. Quarterly Journal of Experimental Psychology, 1964, 16, 355-358.

Kimura, D. Dual functional asymmetry of the brain in visual perception. Neuropsychologia, 1966, 4, 275-285.

Kimura, D. Spatial localization in left and right visual fields. Canadian Journal of Psychology, 1969, 23, 445-458.

Kimura, D. The asymmetry of the human brain. Scientific American, 1973, 228, 70-78.

Kinsbourne, M. The cerebral basis of lateral asymmetrics in attention. Acta Psychologia, 1970, 33, 193-201.

Kinsbourne, M. Asymmetrical Function of the Brain. Cambridge: Cambridge University Press, 1978.

Kinsbourne, M., & Cook, J. Generalized and lateralized effects of concurrent verbalization on a unimanual skill. Quarterly Journal of Psychology, 1971, 23, 341-345.

Kinsbourne, M., & Hicks, R. Mapping cerebral functional space: Competition and collaboration in human performance. In M. Kinsbourne (Ed.), Asymmetrical Function of the Brain. Cambridge: Cambridge University Press, 1978.

Knox, A., & Boone, D. Auditory laterality and test handedness. Cortex, 1970, 7, 164-173.

Lake, D., & Bryden, M. Handedness and sex differences in hemispheric asymmetry. Brain and Language, 1976, 3, 266-282.

LeMay, M., & Culebras, A. Human brain: Morphologic differences in the hemisphere demonstrable by carotid arteriography. New England Journal of Medicine, 1972, 278, 168-170.

Lenneberg, E. Biological Foundations of Language. New York: Wiley, 1967.

Lishman, W., & McMeekan, E. Handedness in relation to direction and degree and degree of cerebral dominance for language. Cortex, 1977, 13, 30-43.

Lomas, J. Competition within the left hemisphere between speaking and unimanual tasks performed without visual guidance. Neuropsychologia, 1980, 18, 141-149.

Lomas, J., & Kimura, D. Intrahemispheric interaction between speaking and sequential manual activity. Neuropsychologia, 1976, 14, 23-33.

Luria, A. Restoration of Function after Brain Injury. Oxford: Pergamon Press, 1963.

Luria, A. Traumatic Aphasia. The Hague: Montow, 1969.

McAdam, D., & Seales, D. Bereitschafts-potential enhancement with increased level of motivation. Electroencephalography and Clinical Neurophysiology, 1969, 27, 73-74.

McAdam, D., & Whitaker, H. Language production: Electroencephalographic localization in the normal human brain. Science, 1971, 172, 499-502.

McFarland, K., & Ashton, R. The lateralized effects of concurrent cognitive activity on a unimanual skill. Cortex, 1975, 11, 283-390.

McFarland, K., & Ashton, R. The influence of brain lateralization of function on a manual skill. Cortex, 1978, 14, 102-111. (a)

McFarland, K., & Ashton, R. The influence of concurrent task difficulty on manual performance. Neuropsychologia, 1978, 16, 735-741. (b)

McKeever, W., & Van Deventer. Familial sinistrality and degree of left-handedness. British Journal of Psychology, 1977, 68(4), 469-471.

Meyer, V., & Yates, H. Intellectual changes following temporal lobectomy for psychomotor epilepsy. Journal of Neurology, Neurosurgical & Psychiatry, 1955, 18, 44-52.

Milner, B. Intellectual functions of the temporal lobes. Psychological Bulletin, 1954, 51, 44-52.

Milner, B. Laterality effects in audition. In V. Mountcastel (Ed.), Interhemispheric Relations and Cerebral Dominance. Baltimore: Johns Hopkins Press, 1962.

Morrell, L., & Salamy, J. Hemispheric asymmetry of electrocortical responses to speech stimuli. Science, 1971, 174, 164-166.

Newcomber, F., & Ratcliffe, G. Handedness, speech lateralization and ability. Neuropsychologia, 1973, 11, 399-407.

Patterson, A., & Zangwill, O. Disorders of visual space perception associated with lesions of the right cerebral hemisphere. Brain, 1944, 67, 331-358.

Piercy, M., & Smyth, V. Right hemisphere dominance for certain nonverbal intellectual skills. British Journal of Psychiatry, 1962, 83, 777-790.

Poon, L., Thompson, L., & Marsh, G. Average evoked potential changes as a function of processing complexity. Psychophysiology, 1976, 13, 43-49.

Rizzolatti, G., Bertolini, G., & Buchtel, H. Interference of concomitant motor and verbal tasks on simple reaction time: A Hemispheric difference. Neuropsychologia, 1979, 17, 323-330.

Satz, P., Achenbach, K., & Fennell, E. Correlations between assessed manual laterality and predicted speech laterality in a normal population. Neuropsychologia, 1967, 5, 295-310.

Schankweiler, A., & Studdert-Kennedy, M. Identification of consonants and vowels presented to left and right ears. Quarterly Journal of Experimental Psychology, 1967, 19, 59-63.

Spellacy, F., & Blumstein, S. The influence of language set on ear preference in phoneme recognition. Cortex, 1970, 6, 340-349.

Sperry, R. Brain bisection and mechanisms of consciousness. In J. Eccles (Ed.), Brain and Conscious Experience. New York: Springer Verlag, 1966.

Subirana, A. The relationship between handedness and cerebral dominance. International Journal of Neurology, 1964, 4, 215-234.

Summers, J., & Sharp, C. Bilateral effects of concurrent verbal and spatial rehearsal on complex motor sequencing. Neuropsychologia, 1979, 17, 331-343.

Taylor, M. M., Lindsay, P., & Forbes, S. Quantification of shared visual capacity processing in auditory and visual discriminations. Acta Psychologia, 1967, 27, 223-229.

Teszner, D., Tzavaras, A., Gruner, J., & Hecean, H. L'aymetric diocti-gauche du planum temporale: A propos de l'etude anatomique de 100 cervaux. Revieux Neurologique, 1972, 126, 444-449.

Vaughn, H., Costa, K., & Ritter, W. Topography of the human motor potential. Electroencephalography and Clinical Neurophysiology, 1968, 25, 1-10.

Von Bonin, G. Anatomical asymmetries of the cerebral hemispheres. In V. Mountcastle (Ed.), Interhemispheric Relations and Cerebral Dominance. Baltimore: Johns Hopkins Press, 1962.

Warrington, E., & James, M. An experimental investigation of facial recognition in patients with unilateral cerebral lesions. Cortex, 1967, 3, 317-326.

Warrington, E., & Pratt, R. Language laterality in left-handers assessed by unilateral ECT. Neuropsychologia, 1973, 11, 423-428.

Whitaker, H. Electrical stimulation mapping of language and memory in the cerebral cortex. Paper presented at the International Neuropsychology Society, Minneapolis, 1978.

Witelson, S. Anatomic asymmetry in the temporal lobes: Its documentation, phylogenesis and relationship to functional asymmetry. Annals of the New York Academy of Sciences, 1977, 299, 328-354.

Witelson, S., & Paille, W. Left hemisphere specialization for language in the newborn: Neuroanatomical evidence of asymmetry. Brain, 1973, 96, 641-646.

Zangwill, O. Cerebral Dominance and Its Relations to Psychological Function. Springfield, Ill.: Thomas, 1960.

Zurif, E., & Bryden, M. Familial handedness and left-right differences in auditory and visual perception. Neuropsychologia, 1969, 7, 179-188.

BIOGRAPHICAL SKETCH

Myron Bilak was born on September 23, 1951, in Lorain, Ohio, and subsequently spent the next 17 years of his life there doing what most little boys do while they are growing up. He experienced the usual traumas: getting his first kiss from a girl other than his mother, his first day in kindergarten, and the day he struck out in the bottom of the ninth inning with the tying run on third base. Somehow he survived all of this, made it through adolescence, and successfully completed high school. He went on to college, attending Case-Western Reserve University, from which he successfully graduated in 1973 with honors in psychology. For a year he explored other avenues other than school and became involved in the world of full-time employment as a research assistant, part-time waiter, and part-time child care worker.

After a year of soul searching and exploring career options, he left cold and cloudy northeastern Ohio for the warm and sunny climate of north central Florida to pursue his degree in clinical psychology. Little did he know then that it would take more time than he expected to successfully complete what he had started. Finally after some seven years, he is ready to begin on a new direction. What that will be is yet unbeknownst to him, yet he is sure that it will be as exciting and challenging as the years before.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Eileen B. Fennell, Chairman
Assistant Professor of
Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Hugh C. Davis, Jr.
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Nathan W. Perry, Jr.
Professor of Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Warren J. Rice

Warren J. Rice
Associate Professor of
Clinical Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Frank L. Sieka
Associate Professor of
Rehabilitation Counseling

This dissertation was submitted to the Graduate Faculty of the Department of Clinical Psychology in the College of Health Related Professions and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1981

Dean, College of Health
Related Professions

Dean for Graduate Studies and
Research