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Interhemispheric Interference: An Investigation of Fluent and Dysfluent Children

by

Karen Lea Varga

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE

DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

CALGARY, ALBERTA

DECEMBER, 1993

THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

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Jan. 31. 94.
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ISBN 0-315-93995-8

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ABSTRACT

Contemporary research suggests that people who stutter exhibit a neuropsychological anomaly of "Interhemispheric Interference." The purpose of this research project was to further examine the theory of Interhemispheric Interference by comparing the performance of 16 male children who stutter and 16 male children who are fluent in dual-task finger tapping conditions. Additionally, the issue of subgroups as it relates to interhemispheric interference within the dysfluent group was also investigated.

The principal findings were that on the critical and neuropsychologically most meaningful condition of index finger tapping with the right hand (a task presumably requiring the integrity of the left hemisphere) combined with left-hand concurrent activity (i.e., drawing circles), no statistically significant differences were found between dysfluent and fluent children. Also, the data provided no support for within group variability in interhemispheric interference that relates to familial history of stuttering or severity level of speech.

Despite generally non-significant results several areas for future research were discussed.

ACKNOWLEDGEMENTS

I could not have completed this research project without the assistance and support of a great many people. They all took time from their busy schedules to help me in different ways and for this I am most grateful.

Specifically, I wish to thank the members of my committee: Dr. Walter Zwirner, and Dr. Robin Gaines who have provided encouragement and critical appraisal of this project from its conception to completion. I also want to thank Dr. Robert Van Mastrigt and Dr. Saeeda JeJe for their participation in my defense hearing.

Most especially, I want to acknowledge Dr. Robin Gaines who gave so willingly of her time to listen to my ideas and to review countless drafts of each chapter. The development of my skills as a researcher is largely attributed to her ability to assist and challenge me to critically think about theoretical and applied issues relevant to the study of interhemispheric interference.

Thanks is also extended to the following individuals: Ms. Gisela Engels at the University of Calgary, Dr. Eugene Edgington for their statistical assistance: and Mr. Frank Varga for designing and constructing the finger tapping apparatus.

I am also grateful to Dr. William Webster (Brock University) for taking the time to answer my many questions pertaining to the neuropsychological model of stuttering.

I wish to express my gratitude to Ms. Varina Russell, and the therapists at Calgary Health Services who referred the children with dysfluency problems to me. Their interest in the project and support for my search to identify subjects was most valuable. I also want to thank all the parents whose children served as subjects in the project. Without their participation this project would have never been possible.

I am sincerely grateful for my parents, Judy and Frank Varga who instilled within me a belief that all goals are obtainable if pursued.

Lastly and first, I wish to express my loving gratitude to my husband and best friend, Christopher Zahara, for his strength and unwavering belief in me.

TO ALL WHO STUTTER

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CHAPTER ONE

INTRODUCTION

The vast majority of children develop communication skills without difficulty. They understand what is said to them with no problems, they relate easily to the people and situations around them, and they speak with good articulation, comprehension and fluency. Even in the babble and the jargon of a baby, we hear continuous, changing vocal patterns, usually free of any kind of interruption. As children pass through the developmental stages of language learning, they may experience some dysfluent periods. These normal dysfluencies are characterized by the repetition of whole words and phrases with occasional interjections of "uhs," "ers," and "ahs." Whether these early repetitions, prolongations, and hesitations should be called "stuttering" and recognized as a "problem" has been a matter of some uncertainty. The uncertainty arises because a large proportion of these children, about 80 percent, stop performing these behaviours spontaneously, usually within 6 months to a year (Starkweather, 1982).

One useful way for distinguishing between normal dysfluency and stuttering is by identifying the speech unit involved in the dysfluency (Andrews et al., 1983; Perkins, 1980). For example, children with normal dysfluency are more likely to repeat whole words or phrases, such as "I want a, I want a, I want a drink." A child who is stuttering is more likely to make sound or syllable repetitions, such as "I wa-wa-wa-want a d-d-drink."

The frequency of the speech dysfluency is another good way to distinguish between normal dysfluency and stuttering. Pindzola & White (1986) suggest that if more than 5% of a child's speech is characterized by repetitions of sounds or words and more than 1% is characterized by prolongations, the communication pattern is abnormal. In addition, normal fluent speech is not effortful for the speaker, nor should the rhythm or rate of speech be noticeably different to the listener. It also appears that over time, the child who stutters may develop other tension-appearing behaviours that accompany the repetition and prolongation of sounds and syllables, such as facial contortions or excessive eye-blinking (Bloodstein, 1981; Boone, 1987; Starkweather, 1983). Various other types of speech dysfluencies may also be involved, including blocking of sounds or interjections of words or sounds. Common concomitants of dysfluency include, anxiety about and avoidance of social situations and an impending loss of speech control (Boberg & Webster, 1990).

Considerable attention has been devoted to the so called "facts" surrounding stuttering. Stuttering is primarily a childhood disorder occurring most often between the ages of three and six (Boberg & Webster, 1990). Adult onset cases are very rare although they do occur, usually following severe physical or psychological trauma. Another interesting fact is the finding that many children who begin to stutter stop stuttering before they reach adolescence. There are disagreements about how many children spontaneously recover, but according to Andrews et al., (1983) recovery in school-age children is common; the best estimate of the probability of recovery by 16 years is 78%. The prevalence of stuttering, that is, the percentage of the population actually stuttering at any one point in time is about 0.5%, which translates into approximately 125,000 people in Canada who stutter (Boberg & Webster, 1990). The lifetime risk or incidence of stuttering is about 5% (Boberg & Webster, 1990). One of the characteristics of stuttering that seems to puzzle many researchers, is the finding that three times as many boys as girls stutter and this disproportion increases with age, as more girls spontaneously recover than boys (Andrews & Harris, 1964; Bloodstein, 1981). Moreover, a genetic component of stuttering has been indicated by studies showing that the risk of onset of stuttering among first-degree relatives of stutterers is more than 3 times that of the general population (Boberg & Webster, 1990). Another interesting finding is the fact that people who stutter do not stutter when they sing, whisper, speak in chorus, talk to a child, or animal (non-threatening situation), and also, when they are alone or being totally spontaneous (Starkweather, 1983).

More has been written about stuttering than any other communication disorder (Leung & Robson, 1990). It has been the subject of books or portions of books written by psychologists, psychiatrists, philosophers, physicians, physicists, speech-language pathologists and by stutterers themselves. There have been hundreds of studies directed toward the nature of stuttering over the last half century (Boehmler & Boehmler, 1989). While researchers in the area may agree that stuttering consists of involuntary repetitions and prolongations of sounds and syllables, there is no consensus concerning the etiology of the disorder (Boone, 1987). This should not be taken to mean that we are not knowledgeable about stuttering or about the child and/or adult who stutters. Over the years, we have accumulated a considerable amount of reliable information (Brutten & Hedgé, 1984). In this respect, although we have some ideas about the variables that are causally related to stuttering, there is still no clear understanding of how or why stuttering begins.

CHAPTER TWO

LITERATURE REVIEW

Since early medical history, stuttering has received more attention than any other speech disorder (Leung & Robson, 1990). It has challenged the clinical imagination back to antiquity. Herodotus (464 - 424 B.C.), Hippocrates (450 - 375 B.C), and Aristotle (384 - 322 B.C) all mentioned the problem (Leung & Robson, 1990). In biblical times, Moses prayed, "My lord, relieve my mind and ease my task for me, and loose the knot from my tongue that they may understand my saying" (Leung & Robson, 1990).

The presence of data, as well as the desire to understand the fundamental relationships among events and to explain why things happen as they do, has lead scientists throughout the ages to theorize and test their theories. Researchers who are interested in stuttering are no different (Brutten & Hedge, 1984). One clinical area in speech-language pathology that has generated a great deal of controversy is our understanding of the causes of stuttering (Boone, 1987). The number of causative theories is remarkable and each has varied tremendously. Theories which suggest that stuttering was caused by a tongue that was either too long, too short, too wet, or too dry, seem funny to us today; but, it is clear that the disorder is still not understood and is more complex than early theorists imagined.

THEORIES OF CAUSATION

Many of the etiological theories put forth in the last half century fall into one of the following categories: environmental, psychological, biological and physiological. The ideas, concepts and subsequent research will be presented for theories in each of these categories. Theories which suggest that stuttering is caused by external variables (i.e., environmental) will be presented first, followed by etiological theories which suggest that an individual stutters as a result of physiological or internal factors. It should be noted that these categories of theories overlap somewhat, and a specific theory may fit into more than one category. Where it is considered necessary, functional descriptions of physiological mechanisms will be presented. This will enable the reader to understand how the respective physiological structure functions normally, and hence the reader will be in a position to more fully understand etiological theories suggesting abnormal physiological functioning. Following from this discussion, the theory of "Interhemispheric Interference", a neuropsychological model of stuttering, will be examined extensively. It is this theory which, in the opinion of this researcher, is in a better position to provide answers to the question of causation of stuttering.

STUTTERING: LEARNED BEHAVIOR

Perhaps the most widely embraced theory of the cause of stuttering is Wendell Johnson's diagnosogenic-semantogenic theory

(Johnson, 1942, 1961). Following from his research and interviews with parents of young stutterers and non-stuttering children, Johnson formulated a theory which states that children become stutterers because others (usually parents) wrongly labelled normal nonfluencies as stuttering. In Johnson's view, this diagnosis by the parent creates an environment of "difference" and "handicap." The child soon begins to speak abnormally in response to the parents' anxieties, pressures, help, criticisms, and corrections. Both the child and parent respond to the idea of the handicap more than to the child's actual speaking behavior. As Johnson stated so aptly, stuttering begins not in the child's mouth but in the parent's ear.

Several attempts have been made to formulate concepts about stuttering within the framework of the learning theory (Sheehan, 1953). These formulations fall into two basic categories (Andrews et al., 1983). First, there are those theories which view stuttering primarily as an avoidance response. Second, theories exist which view stuttering not as a unitary phenomenon but as the interaction of at least two distinct behavioral phenomenon. The most comprehensive form of the first category, according to Andrews et al. (1983) is that proposed by Sheehan (1953). In this theory, the stutterer is seen as vacillating between the desire to speak and the desire not to speak. The stutterer also vacillates between wanting to be silent and wanting not to be silent. When the drive to avoid talking is stronger, he is silent. When the two drives are in equilibrium, such that the gradient for avoidance crosses the gradient for approach, stuttering results. The occurrence of the stutter reduces the fear presumed to underlie the avoidance drive, thereby reducing the avoidance drive and allowing the approach motivational system to dominate. According to Sheehan, whether they choose to be silent or choose to talk, stutterers are reinforced for their choice by an immediate reduction in their anxieties.

Sheehan postulated five distinct levels which speech avoidance drives might operate. He stated that these drives might emanate from: (1) reactions to specific words; (2) reactions to threatening speech situations; (3) guilt and anxiety concerning the emotional context of speech; (4) feelings of anxiety in the stutterers' relationships with listeners; and (5) ego-defensive needs to avoid competitive endeavors posing, "threat of failure or threat of success."

The major example of the second category of theories is that proposed by Brutten and Shoemaker (1967). They suggested that the core characteristics of stuttering, namely part-word and word repetitions and sound prolongations, belong to one response class while the secondary stuttering behaviours (i.e., eye blinking, head jerking, muscle tension and facial grimaces) belong to another class. Specifically, they argue that stress may produce autonomic reactions capable of disrupting speech in some individuals. The negative emotion aroused becomes classically conditioned with concurrent stimuli, such that these stimuli become eliciting stimuli. Thus, the core characteristics of stuttering represent a behavioral failure or disintegration created by negative emotion, while the secondary symptoms are instrumentally acquired adjustive responses. These authors argue that speech disruptions, triggered by autonomic fear reactions, are classically conditioned responses to speech, to talking situations, to listeners, and so on. However, they see the secondary behaviours of stutterers (i.e., eye blinking, facial grimaces) as being operantly conditioned. These behaviours are designed to avoid stuttering or to cope with fluency failures.

Thus, while both Sheehan (1953) and Brutten and Shoemaker (1967) agree that stuttering involves learned modifications of speech behaviour, they differ in the mechanisms hypothesized to underlie the learning. Sheehan proposes a conflict-based instrumental model of approach avoidance, while Brutten and Shoemaker, propose a two factor model whereby two distinct processes operate to originate and maintain the various aspects of stuttering.

STUTTERING: PSYCHOLOGICAL

Psychoanalytic explanations for stuttering were prevalent over 40 years ago. The psychological theories focus on a number of different personality and psychological attributes of stutterers. Through observation, interviews, projective tests, and paper-and-pencil tests, attempts have been made to understand the stutterers' personality, psychodynamics, social adjustment, and inner unconscious needs. Stuttering has been viewed as satisfying oral or anal erotic needs and/or as an expression of repressed hostility, as an inhibition of threatening feelings and messages, as a fear of castration, as a device for gaining attention, and as an excuse for failure (Shames, 1986). According to these theories, stuttering can become a well-integrated, purposeful defense against some threatening idea. From a psychoanalytic point of view, stuttering acts as a mechanism to repress unwanted or threatening feelings (Abbott, 1947; Barbara, 1954; Glauber, 1958; Travis, 1957).

Research on these ideas has been very inconsistent (Shames, 1986). Formal tests given to stutterers to identify their unique personality characteristics suffer from problems of validity and reliability, while observations of behaviour suffer from the theoretical biases and subjectivity of the observers (Shames, 1986). Goodstein (1958) reviewed the large body of research literature dealing with the personalities of stutterers. He concluded that the research suffered from design and procedural problems and that the results were not conclusive.

STUTTERING: BIOLOGICAL DEFICIT

A number of well documented facts about persons who stutter and their families point to a biological component underlying the disorder. The finding that a gender ratio exists among those who stutter has been consistently uncovered in studies that have spanned time and culture (Eisenson, 1966). Evidence emerged which suggested that males were more prone to this disorder than were females. Specifically, school-age stutterers were about three times as likely to be males than females. As a result, some theorists have come to the conclusion that a sex-limited or sex-modified genetic predisposition, susceptibility, or liability exists that makes males more likely to become stutterers (Kidd, 1977; Kidd, 1983; West, 1958). Others, however, have held that the sex ratio is merely a reflection of the way society reacts to male and female children and the dysfluencies in their speech (Johnson et al., 1959; Van Riper & Emerick, 1984).

The gender ratio is not, however, the only evidence that suggests a relationship between heredity and stuttering (Brutten & Hedge, 1984). Several studies have shown that the risk of stuttering among relatives of an individual who stutters is greater than that present in the general population (Andrews & Harris, 1964; Debney & Parry-Fielder, 1988; Kidd, 1977; Kidd, 1983). The data from these investigations also have made it evident that the risk of stuttering among relatives of the female stutterer is greater than the risk among relatives of the male stutterer. Yet females are less likely than males to stutter. For example, the brother of a girl who stutters has a 23% risk of being a stutterer, while the sister of a boy who stutters has only a 3% risk (Debney & Parry-Fielder, 1988). A son of a female stutterer has a 36% risk, while a daughter of a male stutterer has only a 9% risk (Debney & Parry-Fielder, 1988). The fact that there is less likelihood of stuttering among the relatives of male than female stutterers suggests differential susceptibility. It indicates that the male is more at risk and, therefore, more prone to genetic influences than is the female (Janssen, Kraaimaat & Brutten, 1990). This inference is supported by the fact that males have a higher probability of being stutterers. Taken together, these data have lead to the conclusion that sex-modified inheritance plays a role in determining whether or not one becomes a stutterer. Specifically, it has been proposed that there is a genetically determined threshold for stuttering that is lower for males than females (Janssen, Kraaimaat & Brutten, 1990).

STUTTERING: BIOLOGY AND THE ENVIRONMENT

Overtime, the pendulum shifted from etiological theories emphasizing the organism to those that stress the environment to those that recognize the interplay between the two (Brutten & Hedge, 1984).

One impressive piece of evidence recognizing the interplay between biology and the environment can be found in the results of an investigation involving twins. In a well-controlled study, (Howie, 1981) concordance rates for stuttering of 0.73 and 0.32 for monozygotic twins (MZ) and dizygotic twins were reported, respectively. These findings suggest a strong genetic component. The fact that the concordance for MZ twins was not 1.00 illustrates that what is inherited is a predisposition, the phenotypic expression of which depends on environmental and experiential factors that have yet to be identified (Cox, Seider & Kidd, 1984).

STUTTERING: PHYSIOLOGICAL ASPECTS

Early studies in the 1920's and 1930's, began with the belief that stuttering had a physical cause. It was thought that people who stutter may be different from those who do not stutter in terms of their physiological structure and function. However, etiological theories based on physiological differences received little data-based support, and as a result they fell into disfavour following World War II (Poulos & Webster, 1991). Interest in these formulations, however, has been rekindled in the last decade (Curlee & Perkins, 1984).

A presentation of the major findings that have resulted from the study of: (1) laryngeal muscle activity; (2) neuromotor articulatory dynamics; (3) coordination between different neuromotor systems; and (4) neuropsychology will be discussed.

Laryngeal Muscle Activity

The human vocal apparatus can be divided into two major sections. The lungs, trachea, and larynx compose one segment, while all the structures or air passages above the larynx, called the vocal tract, make up the other (see Figure 1).

The human respiratory system is the major source of "power" for the production of human speech. Air is expelled from the lungs, goes up the trachea (or windpipe) and into the larynx, where it passes between two small muscular folds called the vocal folds (vocal cords). The vocal folds are a pair of thin flaps with a gap, the glottis, in between. When the vocal folds are held apart,

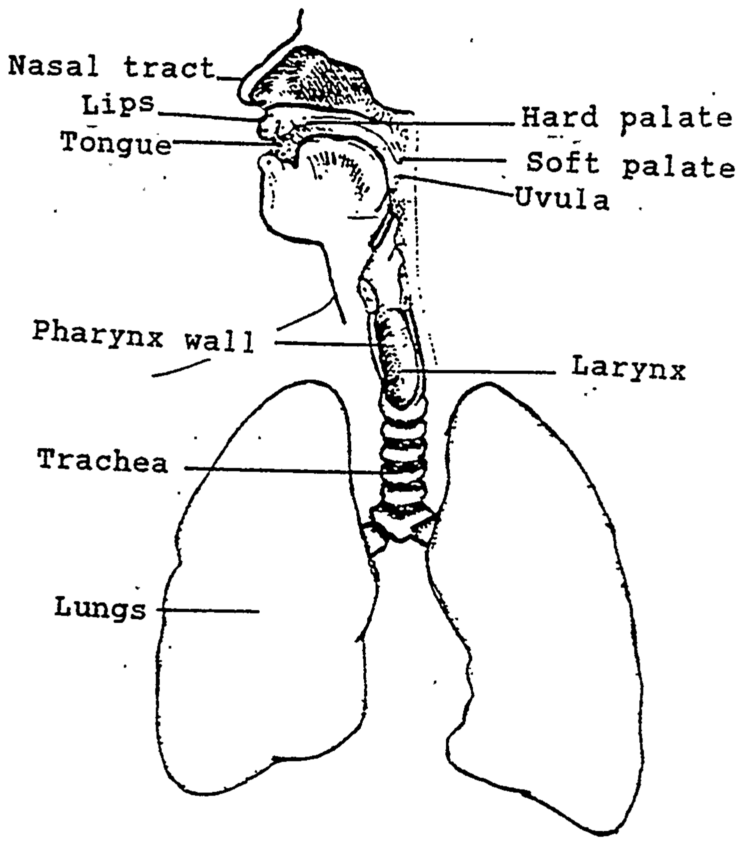


Figure 1. The Human Vocal Tract

Note. From Sensation and perception (p.379) by S. Coren; C.Porac and L.W. Ward, 1984, Florida: Academic Press.

free breathing is permitted, and air flows freely into the pharynx (throat) and mouth. Occasionally, the vocal folds are held tightly together so that air can not pass, such as when you hold your breath or prepare to cough. The most important position of the vocal folds for speech production, however, is one in which there is a restricted passage of air from the lungs to the mouth. When the vocal folds have only a narrow passage between them as air flows by, they vibrate as a result of the pressure of the air stream. The air from the lungs forces its way through the vocal folds in a series of short puffs. Before each puff, the air pressure below the folds increases until it is sufficient to force them apart to release the puff of air. After the release the pressure decreases so that the folds are able to close again. This opening and closing action, as a result of changes in air pressure across the vocal folds, contributes to the production of human voice (Coren, Porac & Ward, 1984).

The Larynx and its Role in the Etiology of Stuttering

In recent years development of sophisticated techniques, such as fibrescopy, cineradiography, and electromyography has made it possible to observe laryngeal activity. Some of the early studies have shown that stuttering is associated with irregular vocal fold vibration, inconsistent and unpredictable glottal openings, absence of voicing during glottal activity, and tight closure of the laryngeal opening (Freeman, 1974; Fujita, 1966).

Probably one of the leading exponents of the belief that stuttering may be caused by a disorder of the vocal mechanism is Schwartz (1974). He believes that the airway dilation reflex (ADR) occurs on expiration while the stutterer is speaking. Normally, the ADR is a rapid opening of the glottis during inspiration because of a rising subglottal air pressure. As the stutterer speaks, according to Schwartz, the vocal folds may reflexively open, creating the stuttering block. The lack of phonation is suddenly out of synchrony with the speaker, whose mouth is postured to say a certain word.

Another researcher, Adams (1974), began to suspect that the laryngeal participation of stutterers in the act of speaking was often out of synchrony with the other muscles used for speech. Adams & Reiss (1974) found less stuttering when individuals read a passage that was designed to have no voiceless sounds, suggesting that when the larynx was "on" without vocal fold abductions, there was better laryngeal functioning. Adams believes that in young children who are beginning to stutter, the genesis of their dysfluency may be a laryngeal discoordination with their supraglottal speech movements. As the stuttering behavior becomes more complex, Adams feels, stutterers develop "abnormal respiratory, laryngeal, and articulatory events [and] disruptions in the coordination" of the three systems (p.140).

Neuromotor Articulatory Dynamics

Neuromotor Articulatory Dynamics refers primarily to the movement of various organs and mechanisms involved in speech production. Studies of articulation (movement) have also been undertaken in order to analyze the possible neural controls, involved in such movements. When a person who stutters repeats a sound, a syllable, or even a word, or when he or she prolongs a sound, they often have difficulty in moving on to the next target sound. Therefore, several investigators have tested the hypothesis that people who stutter may be slower than the normal speaker in executing efficient movement of the articulators in rapid succession. Studies have examined stutterers' ability to produce certain speech sounds or syllables repeatedly and rapidly, and have compared their rate to that of normal speakers. The earliest study of the rapid repetitive movement, or diadochokinesis, of the stutterers' oral structures was reported by West & Nusbaum (1929). Using a measure consisting of the combined rate of movement of the jaw and eyebrow for each subject, they found that stutterers tended to make poorer scores than nonstutterers. Cross (1936) reported slower rates of movement of the tongue, jaw and diaphragm among stutterers than among normal speakers. However, Spriestersback (1940) found no differences between stutterers and nonstutterers in speed of movement of the tongue, jaw, brow and lips.

More recently, articulatory performance studies have become quite sophisticated. These studies have involved an analysis of both the movement patterns of the peripheral speech organs and the integrity of the higher neuromotor systems involved in the control of speech. Techniques such as cineradiography, which provides motion pictures of the behaviours of the speech mechanisms through, X-rays, have been used to follow complex movement patterns. One study (Zimmerman, 1980a) found that stutterers were slower than normal speakers in initiating movement of the speech organs. After the movement was initiated, they took more time to move on to the next target, resulting in longer transition times. Perhaps, as a result, stutterers showed longer steady states (lack of movement). Also, even though some speech organs had begun their motion, voice onset lagged behind. Individuals who stutter also showed lower peak velocities and smaller displacement when compared to non-stutterers. Moreover, the lip and jaw movements were uncoordinated. The magnitude of such articulatory deviations were small, but they do suggest that the spatio-temporal organization of movement necessary for speech is deviant in speakers who stutter. It has been suggested, therefore that stuttering is basically a disorder of movement (Zimmerman, 1980b).

Coordination Between Different Neuromotor Systems

Another line of physiologically oriented research has led to still a different perspective on stuttering. Some studies by Perkins and his associates have indicated that if an organic deviation does exist among stutterers, it may not be found in any particular physiological system or function (Perkins, Johnson & Stocks, 1979; Perkins, Rudas, Bell & Johnson, 1976). Rather, stuttering may be the result of a discoordination between different neuromotor systems.

The observation that stutterers are relatively fluent when they speak at a very slow rate appears to support the hypothesis that it is the rapidity with which different neuromotor systems need to be coordinated that can create problems. More specifically, Perkins and his associates have shown that when the process of speech production is systemically simplified, there is progressively greater fluency. In one study (Perkins, Rudas, Bell & Johnson, 1976) stutterers were observed under three different production conditions: normal voice, whispered speech, and articulation without phonation. In the last condition, where the stutterers simply "lipped" the words without phonation, the need to coordinate phonation with respiration was eliminated. Both whispered and "lipped" speech contained significantly less stuttering than was present in the voiced speech condition. However, the stutterers were most fluent in the lipped condition in which the simplest form of output was required. In a subsequent study, Perkins, Johnson & Stocks (1979) showed that slowing down the rate at which phones (sounds) are produced results in much greater fluency than a rate in which individual words spoken per unit of time is slowed. From results such as these, Perkins et al., (1976, 1979) have concluded that when the complexity of coordinations between different functions increases, stuttering also increases.

STUTTERING: NEUROPSYCHOLOGICAL

Contemporary research points strongly to a neuropsychological basis as the origin of stuttering. The concept of a neurological basis to stuttering is not new. More than half a century ago, Orton (1928) and Travis (1931), developed the concept of stuttering as a manifestation of incomplete hemisphere dominance for speech. While evidence available at that time was suggestive (Bryngelson, 1935, 1939; Douglass, 1943; Jasper, 1932; Lindsley, 1940), further research was unable to support this theory and interest in it subsequently dwindled. In the last two decades, however, the results of new investigatory techniques have led to renewed interest in the Orton-Travis theory. Although there is little evidence that the actual neural mechanisms are represented bilaterally in persons who stutter, as was hypothesized by Orton and Travis, there is evidence to suggest that persons who stutter exhibit a neuropsychological anomaly of "Interhemispheric Interference." This theory suggests that interhemispheric communication in stutterers may proceed in a relatively ungated or unregulated manner. The cerebral hemispheres are thought to be in a normal state of reciprocal inhibition, mediated by the corpus callosum, whereby activity in one hemisphere leads to suppression of activity in the contralateral area. Right hemisphere overactivation may reflect a dysfunction in these inhibitory mechanisms. Unregulated callosal function may also permit the effects of this overactivation to "spill over" to the left hemisphere, thus, interfering with the neural mechanisms of that hemisphere. The engaging of the right hemisphere when processing speech is an ineffective strategy in that the right hemisphere does not contain the specialized neural mechanisms required for such processing (Webster, 1987). Refer to Figure 2, illustrating the major parts of the human brain and Figure 3, illustrating the corpus callosum.

A POSSIBLE LOCUS FOR INTERFERENCE

Assuming the interference hypothesis has validity and that the interference is mediated transcallosally, at least in part, one must ask where the hypothesized interference with sequencing occurs (Webster, 1987). The results suggest that right hemisphere over activation may contribute to stuttering through interference with the left supplementary motor area (SMA) via the corpus callosum (Webster, 1988) .

The idea that the SMA is involved in the mediation of stuttering is not incompatible with the hypothesis that the corpus callosum of stutterers functions in a relatively ungated manner. There are very rich interhemispheric callosal connections between the SMA of the right and left hemispheres (Goldberg, 1985), and normally the two SMA's operate in a highly coordinated manner. This is evidenced in the bilateral SMA activation reported in regional blood flow studies (Larsen, Skinhoj & Lassen, 1978) even with unilateral movements and contralateral activation of the primary motor cortex (Roland, Meyer, Shibasaki, Yamamoto & Thompson, 1982). A dysfunctional SMA could alter these patterns

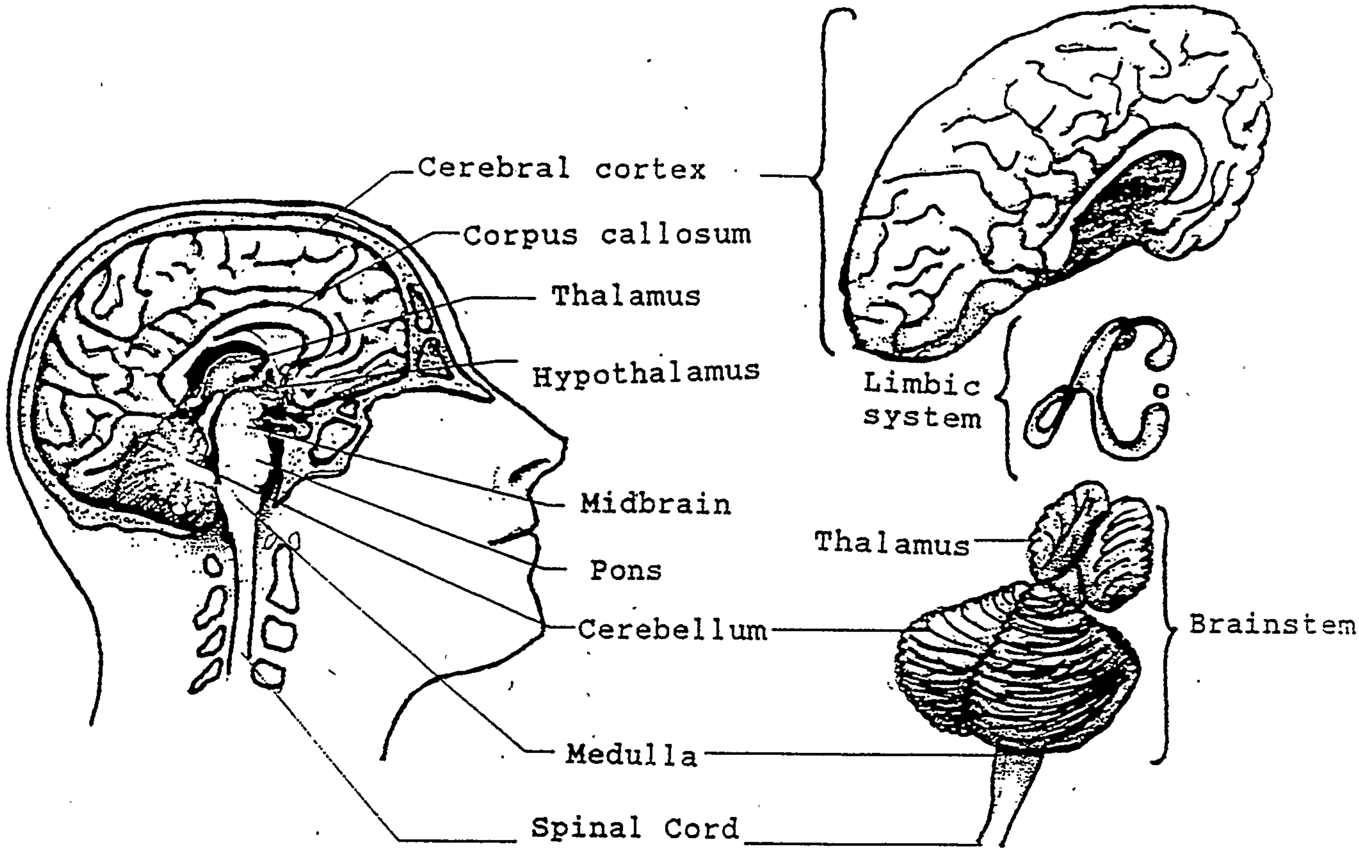


Figure 2. An exploded view of the principal brain parts

Note. From Psychology (p.41) by A.B. Crider; G.R. Goethais; R.D. Kavanaugh and P.R. Solomon, 1983, Illinois: Scott, Foresman and Company.

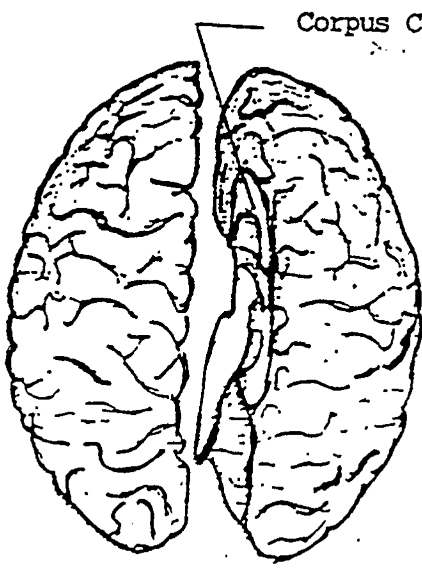


Figure 3. The corpus callosum. The corpus callosum is a large band of about 200 million axons connecting the left and right hemispheres of the cortex. In this diagram, the hemispheres have been separated so the corpus callosum is visible.

Note. From Psychology (p.65) by A.B. Crider et al., 1983, Illinois: Scott, Foresman and Company.

of interaction, or conversely, of course, ungated callosal function could produce an inefficient or dysfunctional SMA through interference effects (Webster, 1988). From this perspective, then, inefficient SMA processing and ungated interhemispheric communication could have the same underlying basis. The approximate location of the SMA on the mesial frontal surface of the human brain is illustrated in Figure 4.

SUPPLEMENTARY MOTOR AREA and SPEECH

There is a growing body of literature reviewed by Goldberg (1985) that indicates the importance of the SMA in the initiation and control of both speech and nonspeech sequential motor activities. Damage to this area, particularly in the left hemisphere, results in a number of clinical speech difficulties including the initiation of propositional speech and the suppression of nonpropositional "automatic" speech (Jonas, 1981). It also results in bimanual coordination difficulties in both human and nonhuman primates (Brinkman, 1981). These include mirror symmetric responding by the two hands, an effect that at least in nonhuman primates is partially reversed by subsequent section of the corpus callosum (Brinkman, 1982). Regional cerebral blood flow studies of the SMA in humans (Larsen, Skinhoj & Lassen, 1978) have pointed to its significance for both the mediation of propositional speech and the initiation of sequences of manual movements. These observations parallel the difficulties of stutterers. In addition to obvious speech initiation difficulties (Bloodstein, 1981),

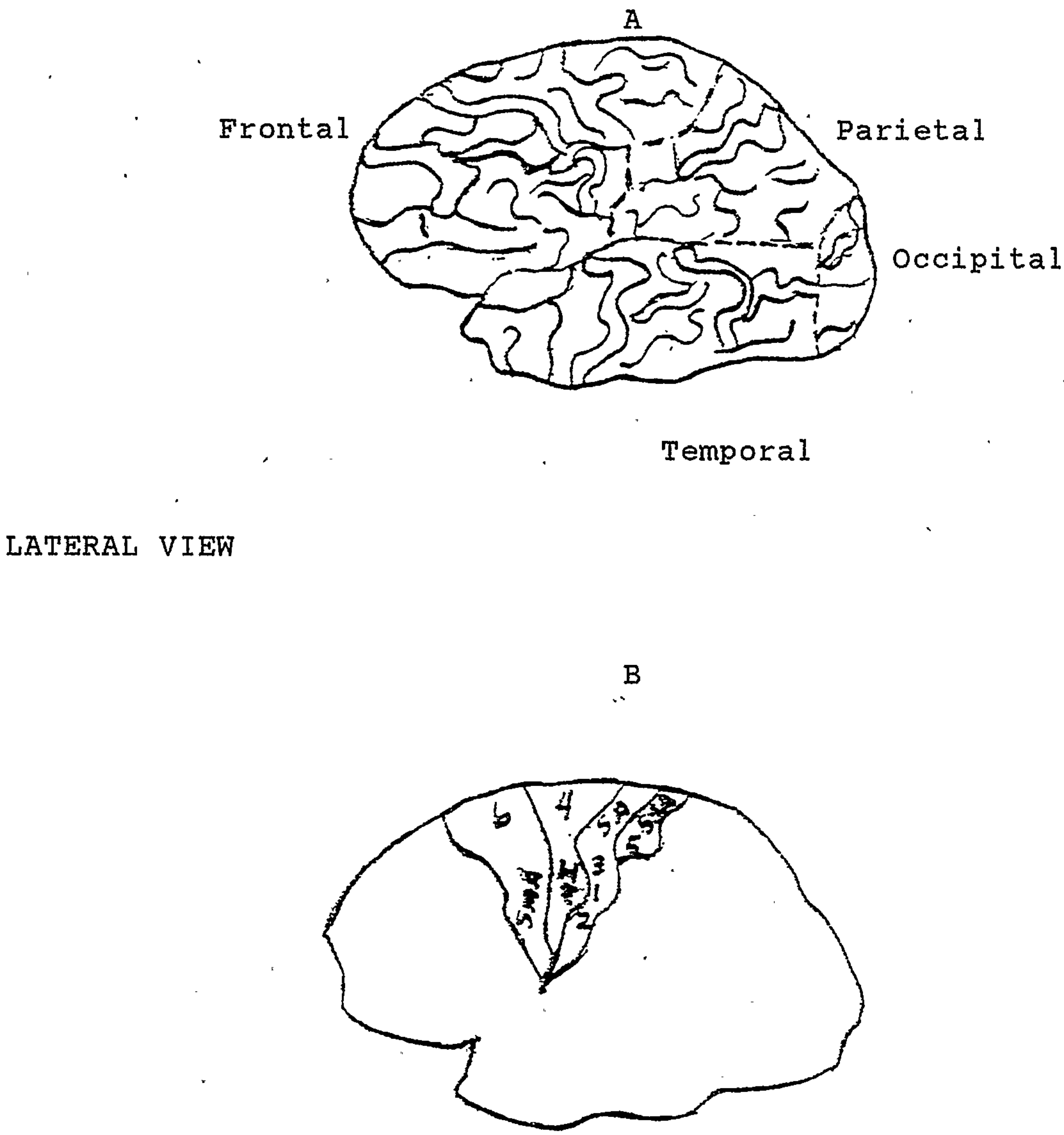


Figure 4. The localization of the frontal, parietal, occipital and temporal lobes of the brain (Diagram A). Diagram (B) shows approximate localizations of Brodmann's architectonic zones. MI: primary motor cortex; SMA: supplementary motor area; SI: primary somatosensory cortex; SSA: supplementary sensory area.

Note. From Fundamentals of neuropsychology (p.18-21) by B. Kolb and I.Q. Whishaw, 1985, New York: W.H. Freeman and Company.

stutterers have difficulty in organizing and initiating new nonspeech response sequences (Webster, 1986a). These parallels lead directly to a hypothesis that the underlying neurological basis of stuttering is to be found, at least in part, in compromised SMA integrity (Webster, 1988).

METHODS USED TO INVESTIGATE THE THEORY OF INTERHEMISPHERIC INTERFERENCE

Research methods aimed at studying the neuropsychological model of stuttering called, "Interhemispheric Interference" have varied tremendously. An examination of the research methods which support the theory of Interhemispheric Interference will be presented. The discussion will begin with a case study of an individual in which stuttering developed as a result of a right-sided stroke. Such cases, referred to as neurologically induced stuttering, are interesting in view of the possibility that impaired interhemispheric dynamics play an etiological role in stuttering (Soroker, Bar-Israel, Schechter & Solzi, 1990). Following the presentation of the case study, other sophisticated and/or creative techniques which have been utilized by researchers will be presented. These techniques are classified as: electroencephalography, dichotic listening, tachistoscopic presentation of visual stimulation, bimanual handwriting tasks and finger tapping.

Neurologically Induced Stuttering

Support for the theory of interhemispheric interference, comes from case studies (Soroker, Bar-Israel, Schechter & Solzi, 1990; Fleet & Heilman, 1985) involving right-handed individuals who suffered from a right-sided stroke. In a study by Soroker, Bar-Israel, Schechter & Solzi (1990) a 65 year old man developed stuttering, without aphasia, following a circumscribed subcortical infarction in the right hemisphere. According to these researchers, the occurrence of stuttering after right-hemispheric lesions in dextrals, and the fact that stuttering can similarly result from left-sided or bihemispheric damage, may suggest an underlying inter-hemispheric rather than intra-hemispheric problem. Moreover, synchronizing and coordinating the activities of both hemispheres during speech is probably mediated through interhemispheric callosal connections. White matter lesions in either the right or the left hemisphere might affect such connections and result in discoordinated activity manifested by stuttering. In another study, Fleet & Heilman (1985) described a patient who was similar to the patient described by Soroker et al., (1990) in that both patients had acquired stuttering as a result of an infarction in the right hemisphere. In the patient described by Fleet & Heilman (1985), the lesion had a watershed distribution between the right anterior and middle cerebral arteries, while the lesion in the patient described by Soroker et al., (1990) extended superiorly into the middle area of the centrum semiorale. In both these studies, the callosal pathways were involved. Impaired regulatory callosal transmission was proposed as a possible explanation for these cases of stuttering and is compatible with the idea of interhemispheric discoordination.

Electroencephalography (EEG)

Support for the neuropsychological theory of stuttering is found in studies of electrophysiological activity (EEG). This technique has been utilized to study the differences in relative participation of cerebral hemispheres during linguistic and nonlinguistic tasks. Most studies utilizing persons who are fluent speakers show alpha suppression over the right hemisphere for nonlinguistic activity and over the left hemisphere for linguistic activity (Dumas & Morgan, 1975; Galin & Ellis, 1975; Robbins & McAdam, 1975). Males who stutter, on the other hand, showed a different pattern than fluent persons. For example, Moore, Craven & Faber (1982) employed 36 subjects; 12 nonstuttering males, 12 nonstuttering females, and 12 stuttering males. The subjects who stuttered had varying histories of speech management. Moreover, all subjects were strongly right handed with no report of familial sinistrality. Additionally, each subject reported a negative history of cerebral pathology when asked if they had ever suffered any brain damage, concussions, epilepsy, or had ever been under the care of a neurologist. Hemispheric alpha asymmetries were obtained for all subjects for words of positive, negative, and neutral arousal values. Electroencephalographic data were gathered during the presentations of stimulus words and during the actual nonoral recall (writing down all of the words they remembered hearing) and recognition recall (circling the words they remembered). Stuttering males demonstrated right-hemispheric alpha suppression across stimulus words (positive, negative, or neutral "intensity of experience") and tasks (recall and recognition) as contrasted with left hemispheric alpha suppression for the non-stuttering males and females. Males who stuttered were also shown to recall and recognize fewer words than the non-stuttering subjects across arousal categories. The results of this investigation have demonstrated differences in the hemispheric alpha asymmetries of stuttering males compared to nonstuttering males and females for meaningful linguistic stimuli. These findings add further support to the observation that many more males who stutter in contrast to non-stuttering individuals, appear to employ right hemispheric strategies for the processing of meaningful linguistic stimuli (Curry & Gregory, 1969; Moore & Haynes, 1980; Moore & Lorendo, 1980; Sommers, Brady & Moore, 1975). The results have also shown the hemispheric alpha asymmetry ratios of male stutterers during nonoral language production task reflect greater right-than-left hemispheric involvement. This finding reinforces that of other researchers (Sussman & MacNeilage, 1975; Wood, Stump, Mckeehan, Sheldon & Proctor, 1980; Zimmerman & Knott, 1974) reporting greater right-hemispheric activation in stutterers for oral and nonoral production tasks. The interpretation for reduced recall and recognition with regard to greater hemispheric activation in the male stutterers, according to these researchers, remains elusive.

However, they do suggest that right hemispheric processing may interfere with the recall and recognition of single words due to an encoding incompatibility with task requirements.

Support for the neuropsychological theory of stuttering is also found in electrophysiological activity recorded from the right and left hemispheres of stutterers before and after treatment. A study conducted by Boberg, Yeudall, Schopflocher & Bo-Lassen (1983) found that prior to an intensive behavioral treatment program, stutterers showed greater than normal activation of the posterior frontal region of the right hemisphere during the performance of speech tasks. However, after a behavioral treatment program the stutterers showed increases in proportional alpha for most regions of the two cerebral hemispheres. This was most noticeable in the posterior frontal region of the right hemisphere for both verbal (vocabulary from the Wechsler Adult Intelligence Scale (WAIS), and Serial Sevens) and nonverbal (block design and object assembly from the WAIS) tasks. This increase resulted in a reversal of the previous right/left interhemispheric alpha relationships with the left posterior frontal region showing greater activation during speech after treatment. These results were interpreted as supporting the hypothesis of decreased inhibitory control in the posterior frontal region of the right hemisphere by the left hemisphere during speech.

Dichotic Listening

Dichotic listening is the simultaneous stimulation of both ears via stereophonic earphones, with different stimuli. The literature suggests that normal right-handed subjects exhibit a right ear preference for verbal stimuli under dichotic stimulation (Berlin & McNeil, 1976; Geffner & Hockberg, 1971; Kimura, 1961a). This has been interpreted as demonstrating a left hemisphere specialization for speech and language. In one study, Blood (1985) examined the relationship between stuttering severity and hemispheric dominance as measured by a dichotic listening task. Subjects consisted of 76 stutterers and 76 nonstutterers who were all between the ages of 7 - 15 years. Participants were asked to respond to a series of dichotically presented synthetic syllables. Results revealed: (a) a right ear preference for both stuttering and non-stuttering subjects; (b) right ear, no ear and left ear preference subgroups among the stutterers. These results, in part, suggest that some stutterers evidence atypical cerebral processing.

Rosenfield & Goodglass (1980) applied the dichotic listening paradigm to a group of right-handed male stutterers and a group of fluent subjects. Stutterers and nonstutterers were matched for age and education (age of stutterers, 26.8 years; education 14.8 grade level; nonstutterers, 26.1 years, education 14.9). Results revealed a right ear advantage for CV (Consonant-vowel) syllables and a left ear advantage for melodies, without significant differences between groups. However, a significantly greater number of stutterers than controls consistently failed to show the expected ear laterality for either type of material. According to these researchers, the finding that more individual stutterers showed deviant lateralization has special significance. It may mean that these individuals constitute a subgroup of stutterers for whom problems of cerebral dominance are related to their speech disorder.

Tachistoscopic

Studies investigating hemispheric asymmetries for visual-language processing in the stuttering population support a right-hemisphere superiority for such operations (Hand & Haynes, 1983; Moore, 1976; Rastatter & Dell, 1987). Moore (1976) compared the perceptions of nonstuttering and stuttering subjects to bilaterally presented words. Unlike the nonstutterers, who evidenced the expected right visual field advantage to the stimuli, individuals who stuttered failed to exhibit significant laterality effects. Although, the results did not reach statistical significance, the stutterers tended to respond to the words more often when presented to the left visual field. These findings were interpreted to suggest that stutterers process language in the right hemisphere. Another tachistoscopic experiment conducted by Hand & Haynes (1983) was designed to investigate linguistic processing by the left and right cerebral hemispheres in 10 adult stutterers and 10 adult nonstutterers. Subjects performed a lexical decision task in which nonword and real word stimuli were presented tachistoscopically to the right and left visual hemifields. Vocal and manual reaction times were measured to assess hemispheric participation in processing linguistic information and to determine differences between response modes. The stuttering group exhibited a left visual field efficiency or right hemisphere preference for this task and were slower in both vocal and manual reaction times than the non-stutterers. Although the nonstutterers exhibited no significant differences in their reaction times to stimuli processed by the right and left hemispheres, they tended to respond more quickly when the stimulus was processed by the left hemisphere. More recently, Rastatter & Dell (1987) further investigated the issues pertaining to cerebral organization for visual language processing in a stuttering and non-stuttering group. Employing a lexical decision task, vocal reaction times were obtained for a group of 14 stutterers and 14 non-stutterers to unilateral, tachistoscopically presented concrete (representing tangible items) and abstract (having no intrinsic form) words. The decision task was similar to that of Hand & Haynes (1983). Results showed that for both groups the concrete stimuli were processed more efficiently than the abstract stimuli in the right hemisphere. The major difference observed between the two groups lies in the right hemisphere's ability to process language. For the nonstuttering subjects, Rastatter & Dell (1987) argued that the dominant, left hemisphere was capable of inhibiting or laterally integrating the right hemisphere because both types of lexicon were analyzed most efficiently in the left hemisphere. The results obtained for the stutterers revealed that the right hemisphere was capable of more efficient language processing, albeit for concrete semantic information only. That is, the right hemisphere was superior for analyzing the concrete words while the left hemisphere was responsible for processing the abstract items. This finding concurs with those of Hand & Haynes (1983). These findings suggested that some form of verbal competition that is related to neurolinguistic organization may exist between the two hemispheres in stutterers (Rastatter & Dell, 1987).

Bimanual Handwriting Tasks

Another technique designed to explore this neuropsychological model of stuttering is based on the analogue that there is a natural tendency for the movements of one hand to be mirror-reversed with respect to those of the other (Corballis & Beale, 1982). In other words, if you turn one wrist clockwise there is a tendency for the other wrist to turn counterclockwise. The interhemispheric interference theory predicts a greater tendency among stutterers than among fluent speakers to have mirror image movements by the two hands. In order to test this hypothesis, Webster (1988) compared left and right-handed male and female stutterers with fluent speakers on a bimanual handwriting task. On each trial four words were read to each participant. After repeating the words, each subject had to write the initial letters as quickly as possible using the two hands simultaneously, and without view of their hands. Three major findings of the study bear directly on the principle of interhemispheric processing in stutterers compared to fluent speakers: (1) Stutterers as a group made significantly more mirror reversals with the nondominant hand than did fluent speakers, who were in effect mirror symmetric with respect to their right and left hands. This was the case with both right and left-handed stutterers. There was no evidence of a consistent gender difference in nondominant hand mirror reversals; (2) With both the dominant and nondominant hands, stutterers as a group had poorer quality of letter formation than did fluent speakers. This was also the case for right-and left-handers, and again there was no evidence of a gender difference; and (3) Although stutterers made more mirror reversals and formed letters more poorly than fluent speakers, this was not due to faster performance. Among males, stutterers were significantly slower to complete their writing than were fluent speakers. Among females, the data were in the same direction although not statistically significant. This highlights the difficulties of the stutterers in this bimanual coordination task and indicates clearly that a differential speed-accuracy trade off does not account for the poorer accuracy data of stutterers. The results were interpreted by Webster (1988) as supporting the idea that stutterers have normally lateralized left-hemisphere speech mechanisms, but these mechanisms are unusually susceptible to interference from other ongoing neural activities. He further suggested, as have Caruso, Abbs, & Gracco (1988) that the neural mechanisms of interference involve a functionally compromised supplementary motor area.

Finger-Tapping

The possibility that a stutterers' left hemisphere may be vulnerable to interference from on-going right hemisphere activities has been indicated by findings from sequential finger tapping studies. In one study, Webster (1986a) compared the performance of right-handed male adult stutterers and fluent speakers on repetitive sequential finger tapping with one hand while carrying out concurrent paced tasks with the other hand. Consistent with the interhemispheric interference hypothesis, right hand sequential finger tapping was more interfered with by left hand concurrent task performance in stutterers than in the fluent speakers. In other words, in a comparison with baseline performance involving only repetitive sequential finger-tapping, the stutterers showed a greater decrease in the number of correct sequences tapped when doing the concurrent task than did the fluent controls. Of critical importance for the interpretation of this effect is performance on the concurrent task. The stutterers may simply have attended more to the concurrent task at the expense of the finger tapping. Fortunately, the interpretation is simplified by the fact that results of concurrent tasks were very similar in the two groups. Overall, the data was interpreted as consistent with the neuropsychological model of stuttering that proposes a left hemisphere vulnerability to interference by concurrent right hemisphere activity.

In another study, male stutterers and fluent speakers were compared on their performance of a task requiring tapping keys as rapidly and as accurately as possible to reproduce finger movement sequences demonstrated on a visual display panel (Webster, 1986b). Although overall finger tapping rates were the same in the two groups, indicating no difficulty by stutterers in performing simple motor movements, stutterers achieved fewer correct sequences and made more errors than fluent speakers. In addition, their response initiation times were slower. Once a correct response was initiated, however, the time to execute the sequence was similar to that of fluent speakers. Replicating earlier work (Webster 1986a), the two groups were not found to differ on a repetitive sequential finger tapping task with respect to correct sequences or total presses, although the probability of error was greater for the stutterers. The data were interpreted as indicating the following: (1) In persons who stutter sequential response mechanisms are lateralized normally as they are in fluent speakers; (2) In stutterers, the left-hemisphere sequential response mechanisms appears to be unusually susceptible to interference, possibly from on-going right hemisphere activity; and (3) stutterers have special difficulty in organizing and/or initiating new response sequences, but once the sequence is initiated, they can perform the sequence as rapidly (but with greater probability of error) as do fluent speakers. These results concur with those found in a later study (Webster, 1989).

THE AIM OF THIS RESEARCH PROJECT

The aim of this research project is to further examine the theory of interhemispheric interference by studying the difference between a group of children who stutter and a group of normally fluent children when performing finger tapping tasks. As is suggested by Webster (1987), finger tapping is an interesting and relevant task in order to test this theory. Research has found (Kimura, 1977, 1982; Kinsbourne & Hiscock, 1983; Ojemann, 1983) that the neural systems underlying such sequential movement control overlap with those involved in speech and orofacial movements. Accordingly, anomalies in sequential finger tapping in stutterers may suggest something about the nature of aberrant interhemispheric relations (See Figure 5).

This study will investigate whether there is a presence of interhemispheric interference as indexed by finger tapping investigation in a group of school-aged children who stutter. More specifically, the question of whether within group variability in interhemispheric interference relates to the dysfluent subjects' characteristics such as: familial history of stuttering, and severity level of speech (mild, moderate and severe) will be explored. This information will contribute to the already growing body of literature which suggests subgroups within the population of stutterers. The collection of individual subject information is seen as important to our understanding of the etiology of stuttering, especially as it may be relevant to the issue of subgroups. Indeed, many clinicians who work with persons who

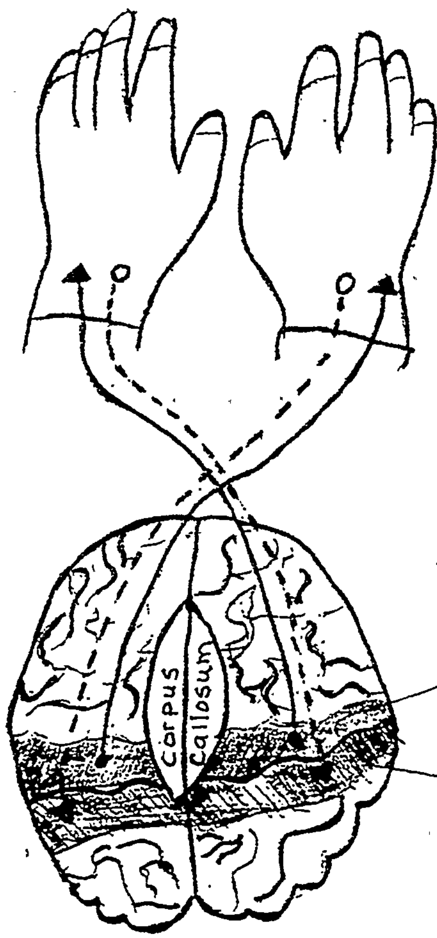


Figure 5. Motor pathways and somatosensory pathways are almost wholly crossed; each hand is served primarily by the cerebral hemisphere on the opposite side. Thus, right hand sequential finger tapping is presumably mediated by the left hemisphere, while left hand finger tapping is presumably activated by the right hemisphere (Webster, 1988).

Note. From Fundamentals of neuropsychology (p.342) by B. Kolb and I.Q. Whishaw, 1985, New York: W.H. Freeman and Company.

stutter are struck by the variation in presenting symptoms and short and long term responsiveness to treatment (Boberg, 1981). The possibility exists that if the etiology of stuttering is known to a greater extent, if the question is asked in an answerable form and if the examination of individual characteristics are explored within the framework of the theory at hand (Boehmler & Boehmler, 1989).

This study is different from many of the other previous studies which predominantly utilized adults (fluent and non-fluent) to examine this theory. Only one other study which utilized children appears in the literature, and the results are questionable as there was no control group (fluent children) with which to compare the results (Brutten & Trotter, 1985). In this respect, this research study is contributing to an area in which there has been limited and questionable findings.

THE IMPORTANCE OF RIGHT-HANDED PARTICIPANTS

In exploring the theory of interhemispheric interference only right handed fluent and dysfluent children will be selected. Such a criteria is important as research has found that speech lateralization is related to handedness. For example, Rasmussen and Milner (1977) found that out of 140 right-handed persons, 96% had speech representation in the left hemisphere, 0% had bilateral representation of speech and 4% had right hemisphere speech representation. On the other hand, of 120 left handed persons, 70% had speech representation in the left hemisphere, 15% had bilateral representation of speech and 15% had right hemisphere representation of speech. Such results suggest that we can better predict with right-handers where language will be lateralized. Given the exploratory nature of this study this is an important control.

Sequential vs. Index Finger Tapping

Due to the exploratory nature of this study, index finger tapping was selected over sequential finger tapping as a method to investigate the theory of interhemispheric interference. The rationale for this selection lies in the fact that sequential tasks may be well suited for adults, but that the same task is often too difficult for use with school age children. In other words, although sequential finger tapping may be appropriate for studying the theory of interhemispheric interference in adults, it was thought to be too demanding for use with school age children. In this respect, the question of whether a less demanding task (index finger tapping) was an effective measure of studying interhemispheric interference in children was examined.

RATIONALE FOR EXPLORING A NEUROPSYCHOLOGICAL MODEL OF STUTTERING

Exploring the cause of stuttering in the domain of neuropsychology is justified for many reasons. Namely, interest in the neuropsychological aspects of stuttering have increased dramatically in the last two decades (Boberg & Webster, 1987). This current surge of interest is partly a result of the opportunities provided by sophisticated techniques (Brutten & Hedge, 1984). As a consequence of these techniques, data have emerged which support some form of aberration or peculiarity in interhemispheric relations. More research is needed to further elucidate the nature of interhemispheric interference.

In examining a neuropsychological cause of stuttering we are examining a possible "*origin*" of stuttering. Many of the other causation theories put forth in the preceding section have examined dysfluency in terms of the dynamics, maintenance of dysfluency, with the pretense of examining origin. For example, environmental pressures have been found to contribute to the severity of stuttering in children and/or adults. In this respect, environmental factors (i.e., parental pressures) are able to account for the maintenance aspect of stuttering. There is little evidence to support the view that the actual origin of stuttering is to be found in such pressures (Andrews et al., 1983). Also, in regards to Laryngeal abnormalities, Brutten & Hedge (1984) point out that it may be more appropriate to consider them a part of the effect we call stuttering, rather than being inclined to think that laryngeal muscle activities may cause stuttering. Moreover, in terms of the research in the area of neuromotor articulatory dynamics, one must be cautious in accepting the findings, as articulatory deviations (Zimmerman, 1980a) are not necessarily the causes of stuttering. Though deviations in movement factors appear to be present it is not yet fully clear whether they are the cause of or concomitants to stuttering (Brutten & Hedge, 1984). Thus, by examining a neuropsychological theory of stuttering we are getting closer to an understanding of etiology than many of the other theories put forth. This is seen as a positive step as, theories of "possible" origin have an influence on the client and family, as well as on the clinician (Shames & Rubin, 1986). For the client and family, theories can provide much needed explanations for understanding the nature of the problem. For the clinician, they can provide a conceptual system that links origin, dynamics and therapeutic strategy.

Hypotheses

Based upon research examining the theory of interhemispheric interference the following hypothesis are put forth to be examined:

Hypothesis One: It is expected that no significant differences between dysfluent and fluent children in their ability to perform single index finger tapping with either hand will occur.

Hypothesis Two: It is expected that both dysfluent and fluent groups will perform index finger tapping significantly better with the right than with the left hand.

Hypothesis Three: It is expected that when performing index finger tapping with the right hand stutterers will experience significantly more interference (lower number of finger taps) than among fluent speakers when the concurrent task of circle drawing is performed by the left hand.

Hypothesis Four: It is expected that when performing index finger tapping with the right hand stutterers will experience significantly more interference (lower number of finger taps) than among fluent speakers when the concurrent task of bingo dabbing is performed by the left hand.

Hypothesis Five: In the condition of left hand index finger tapping and right hand concurrent activity no differences in interference are expected between the two groups.

CHAPTER THREE

METHODOLOGY

SUBJECTS

A group of children who stutter and a group of fluent children were selected for study. The stuttering children were selected from the assessment and treatment caseloads of Speech/Language Pathologists at Calgary Health Services. The control group of children were obtained in response to the investigator's announcement of the project in local newspapers, and by posted signs. A telephone interview with the parents of potential subjects was conducted to eliminate any subjects with the following problems: neurological disorder, significant motor impairment, significant visual impairment, memory difficulties, difficulties with use of arms, hands and/or fingers, developmental disorders, or behavioural disorders (i.e., conduct disorders). All subjects were right-handed as confirmed by parent report and all parent(s) stated that the child used his right hand for the following four behaviours: writing, cutting with scissors, throwing a ball, brushing their teeth (Piazza, 1977). All children in both groups came from homes in which English was the primary language spoken.

Upon receiving verbal permission from the parent to participate, a letter explaining the purpose of the research project, as well as parent and child consent forms were mailed to each parent with a return envelope (Refer to Appendix A, B and C for a copy for these documents). A testing time was scheduled during the initial phone conversation, or upon receiving the consent forms in the mail.

REFERRAL OF SUBJECTS WHO STUTTER

Sixteen male stutterers, between the ages of 6 - 13 years (mean=8.8 years) participated in this study. Two Speech/Language Pathologists at Calgary Health Services randomly selected subjects from a pool of subjects with a primary diagnosis of fluency disorder. After selection, the Speech/Language Pathologist currently in contact with the child informed the child's parent(s) of the research project. If the child's parent wished to pursue the project further, the child's name and identifying information were relayed to the investigator by the Speech/Language Pathologist.

All participants who stuttered had varying histories of speech therapy. The amount of treatment received by each child ranged from 1.5 months to six years, with a mean of 25 months. All children, however, had participated in some kind of therapy. The type of therapy received ranged from school based therapy programs to the CAFET (Computer Assisted Fluency Establishment Training) program offered through Calgary Health Services. This program utilizes computerized biofeedback to monitor breathing. At the time of testing, 11 participants were involved in speech therapy once or twice a week.

REFERRAL OF NON-STUTTERING SUBJECTS

Sixteen male non-stutterers between the ages of 7 - 13 years (mean=9.4 years) also participated in this study. The non-stuttering subjects were recruited through advertisements placed in local newspapers, word of mouth or posted announcements. During the initial phone conversation with the parent, the investigator explained the purpose of the research project and answered any questions the parents had.

All participants except one indicated no family history of any type of speech disorder, according to parental report. The parent of one child, did report that the child's father had been a stutterer from early childhood to early adulthood, but reported the father is presently fluent.

INSTRUMENTS

1) PARENT QUESTIONNAIRE

A questionnaire was administered to all the parents of dysfluent children. The questionnaire was designed to gather information about any familial history of stuttering, as well as the child's type and duration of treatment history (See Appendix D for a copy of the questionnaire).

2) THE STUTTERING SEVERITY INSTRUMENT (S.S.I.)

The Stuttering Severity Instrument (S.S.I) was utilized by two Speech/Language Pathologists at Calgary Health Services. The S.S.I was selected to measure the level of stuttering severity of the 16 dysfluent children. This instrument constructed by Riley (1972) has three subscores, one for frequency of stuttering, one for duration, and one for physical concomitants. The scale was designed to be applicable to children or adults by tallying frequency of stuttering in either reading and "job-task" descriptions or, for nonreaders, in their description of picture stories. For readers, a value of from 2 to 9 is assigned for the percentage of words stuttered in reading a 125 word passage. Reading material represented third-grade, fifth grade, or adult reading levels, according to the capability of the reader. In the reading the first 25 words are disregarded and the next 100 are used to determine percentage of stuttered words. In addition to the reading passage, the stutterer is asked to talk about a school activity. This task also is valued from 2 to 9 according to frequency of stuttering. For example, one percent of the words stuttered on either reading or school topic is scored "2"; 29 percent or greater frequency of stuttering on the school topic is rated as "9"; and 27 percent or greater frequency on the reading task in scored as "9." These two scores are added and treated as the frequency score. For non-readers (less than third-grade reading ability), frequency of stuttering in their description of picture stories is scored on a range from 4 to 18 points. The duration score is based on the estimated length of the three longest stuttering blocks in reading or conversation. The score range is from "1" for "fleeting" to "7" for more than 60-second estimated duration. Physical concomitants are rated from 0 (none) to 5 (severe and painful looking) for each of the four areas: distracting sounds, facial grimaces, head movements, and movement of extremities. The total test score (range 0 - 45) is interpreted as a severity index, and may be described as a percentile or by adjectives such as very mild, mild, moderate, severe, or very severe. (See Appendix E for a copy of the S.S.I).

PILOT STUDY

A pilot study was undertaken as very little research in the area of interhemispheric interference focused upon children. Thus, it was necessary to explore what type of concurrent tasks would be suitable to use with children.

Two male, right-handed children who were five and six years of age served as subjects for a pilot study. Different types of motoric tasks were presented to each child. These tasks included the following: hammering/nail set; turning a flashlight "on" and "off," putting money in a basket, using a bingo dabber, drawing shapes with a felt pen, printing letters of the alphabet, making holes with fingers in play dough, snapping fingers, and stacking checkers. The tasks chosen were using the bingo dabber and drawing circles with a felt pen. These tasks were chosen based on the observed level of interest, enjoyment and self report of each child. These tasks would serve as the secondary tasks.

In order to construct a finger tapper, the children's hand and finger size (length) were measured by the investigator. Moreover, the investigator experimented with a number of different tones/sounds. The sound would served as a cue for the subject to perform the concurrent task. The sounds/tones tested included the following: snapping fingers, spoon tapping a pan, running water, human voice, piano, guitar and many children's toys. The sound/tone chosen to be used in this study was produced by a child's Little Tikes® toy piano which makes different sounds as each key is depressed. This sound was chosen as it was easy to produce and had a good sound quality when recorded.

APPARATUS

The instrument used to record the number of finger taps made by all participants consisted of a lap counter mounted on a 23 cm * 40 cm solid wood base. The lap counter was made of metal and attached to it was a lever which when depressed would record the number of presses. The number of key or lever presses was visually displayed on the lap counter. The lap counter could easily be reset to zero with the turn of a knob (See Appendix F for a diagram of the finger tapper). A stop watch was used by the investigator to clock each of the single-task trials, which were 20 seconds in duration. A cassette tape in which seven, 20 second trials consisting of a 0.1 second tone heard every 2 seconds was recorded by the investigator. A panasonic mini cassette recorder was utilized for the purpose of playing this pre-recorded tape. Additional materials used in the study included: felt pens, 1 clipboard, and 1 bingo marker called, "Dab-o-Ink."

PROCEDURES

All subjects were tested in a seminar room at the University of Calgary. Testing sessions were scheduled to take place on a non-school day, and lasted approximately 45 minutes. Before any testing took place, all subjects were familiarized with all testing equipment. This involved the investigator showing each participant how to rest their right and left index fingers on the key of the counter. All subjects were also shown how to rest their hand on the solid wood base while finger tapping. There were two phases involved in this study: the pre-experimental and experimental phase.

PRE-EXPERIMENTAL PHASE

The first phase of the study called the pre-experimental phase was designed to provide each subject with an opportunity to practise both the single (index finger tapping only) and dual-task conditions (index finger tapping with one hand while carrying out a concurrent manual task with the other hand). Both single and dual-task conditions were 20 seconds in duration. The single task condition involved telling each subject to tap the key as fast as he could when the investigator said the word "start" and to stop tapping the key when the investigator said the word, "stop." The number of key presses produced by the participants was displayed on the counter. Each child practised once with his left and once with his right index fingers (trials 1 and 2). However, additional practice was granted if either the child or experimenter felt it was necessary.

Upon completion of these two finger tapping only trials, the ability of each child to perform each of the two secondary tasks (i.e., drawing circles with a felt tip marker, or using a bingo marker) was observed by the investigator. In these conditions, each child was instructed to either draw circles or use the bingo dabber on a sheet of paper with his right hand, whenever he heard the sound of a bell transmitted via a cassette recorder. The child also practised both these tasks with his left hand (trials 3-6).

All participants were also given practice with the dual-task conditions. The dual-task conditions involved the subject tapping the key with his right index finger as rapidly as possible when he heard the word "start" transmitted via a tape recorder, while drawing circles with a felt tip marker with his left hand on a sheet of paper whenever he heard the sound of a bell. The trial ended when the word "stop" was heard (trial 7). Each child was also asked to tap with his left index finger, while performing this secondary task with his right hand (trial 8). All participants were also provided with an opportunity to practice the second dual-task condition. Again, each child was asked to tap the key with his right index finger as rapidly as possible when he heard the word "start" transmitted via a tape recorder, while drawing circles with a felt tip marker with his left hand on a sheet of paper, whenever he heard the sound of a bell (trial 9). All participants were also asked to tap with their left index finger, while making ink blots using the bingo dabber with their right hand (trial 10).

Again, additional practice was granted in all dual-task conditions if the subject or investigator felt it was necessary.

Overall, each child participated in the following ten pre-experimental conditions (practice trials):

Trial 1: Right hand index finger tapping only;
Trial 2: Left hand index finger tapping only;
Trial 3: Right hand circle drawing only;
Trial 4: Left hand circle drawing only;
Trial 5: Right hand bingo dabber only;
Trial 6: Left hand only bingo dabber only;
Trial 7: Dual task: Right hand index finger tapping + left hand concurrent task (circles);
Trial 8: Dual task: Left hand index finger tapping + right hand concurrent task (circles);
Trial 9: Dual task: Right hand index finger tapping + left hand concurrent task (bingo);
Trial 10: Dual task: left hand index finger tapping + right hand concurrent task (bingo).

EXPERIMENTAL PHASE

The experimental phase of the study involved testing the finger tapping ability of all 32 participants in 14 conditions, each of 20 seconds in duration.

Using a lottery method each child was assigned to one of four conditions (R/AB, R/BA, L/AB, and L/BA). As is shown, in table 1, these four conditions are different in terms of: (1) which hand (right or left) commences testing; and/or (2) the order of secondary task presentation. Thus, some subjects started testing under the theoretically more meaningful condition of right hand index finger tapping and left hand concurrent task performance, while some subjects commenced testing under the reversed conditions of left hand index finger tapping and right hand concurrent task performance. As well, the order of task presentation (design AB or design BA) varied. In the dual task condition, "AB", participants finger tapped with the index finger of one hand, while drawing circles with their other hand whenever they heard the sound of a bell transmitted by a tape recorder. Upon completion of two trials, each subject was instructed to tap a key with the index finger of one hand, while making ink blots using a bingo dabber with the opposite hand, whenever he heard the sound of a bell transmitted by a tape recorder. The other dual-task condition, design "BA" was a reverse of design AB in terms of which concurrent task was performed first. Thus, in design BA subjects started by making ink blots using a bingo dabber, followed by the drawing of circles. Each task was performed while finger tapping with the opposite hand.

All 14 trials began by asking each child to rest his index finger on the key and instructing him to keep his wrist flat on the surface at all times. Although testing varied in terms of hand order (right or left), each child performed three trials of right and left index finger tapping only. These finger tapping only trials consisted of the investigator telling each subject to tap the key as fast as they could when the investigator said the word, "start" and to stop tapping the key when the investigator said the word, "stop." Each trial of finger tapping only was followed by the child performing a dual-task condition (i.e., finger tapping with the right index finger and drawing circles with his left hand). All dual-task conditions were performed twice and involved the subject tapping the key with his right/left index finger as rapidly as possible when he heard the word "start" transmitted via a tape recorder. While finger tapping, the subject was asked to either draw circles or use a bingo dabber with his other hand, whenever he heard the sound of a bell. The trial ended when the subject heard the word "stop." The number of finger taps displayed on the counter was recorded by the investigator on a data sheet after each trial.

After completing all required testing the investigator asked the participant to choose one dual-task condition to demonstrate to his parent(s). The parent(s) of the participant were subsequently guided into the testing room for a demonstration. Additionally, a pictorial diagram was drawn by the investigator showing the relationship between finger tapping and brain organization. Upon leaving, each child received a small prize for their participation and cooperation. In addition, parents were offered reimbursement for the parking incurred at the University of Calgary.

TABLE 1: EXPERIMENTAL CONDITIONS

	R/AB	R/BA	L/AB	L/BA
Trial 1	R.H tapping	R.H tapping	L.H. tapping	L.H. Tapping
Trial 2	R. H tapping + Circles	R.H. tapping + Bingo	L.H. tapping + Circles	L.H. Tapping + Bingo
Trial 3	R.H tapping + Circles	R.H. tapping + Bingo	L.H. tapping + Circles	L.H. Tapping + Bingo
Trial 4	R.H tapping	R.H tapping	L.H. tapping	L.H. Tapping
Trial 5	R. H tapping + Bingo	R.H. tapping + Circles	L.H. tapping + Bingo	L.H. Tapping + Circles
Trial 6	R. H tapping + Bingo	R.H. tapping + Circles	L.H. tapping + Bingo	L.H. Tapping + Circles
Trial 7	R.H tapping	R.H tapping	L.H. tapping	L.H. Tapping
Trial 8	L.H. tapping	L. H. tapping	R.H. tapping	R.H. tapping
Trial 9	L.H. tapping + Circles	L. H. tapping + Bingo	R.H. tapping + Circles	R.H. tapping + Bingo
Trial 10	L.H. tapping + Circles	L. H. tapping + Bingo	R.H. tapping + Circles	R.H. tapping + Bingo
Trial 11	L.H. tapping	L. H. tapping	R.H. tapping	R.H. tapping
Trial 12	L.H. tapping + Bingo	L. H. tapping + Circles	R.H. tapping + Bingo	R.H. tapping + Circles
Trial 13	L.H. tapping + Circles	L. H. tapping + Bingo	R.H. tapping + Circles	R.H. tapping + Bingo
Trial 14	L.H. tapping	L. H. tapping	R.H. tapping	R.H. tapping

NOTE: L.H.TAPPING=Left hand finger tapping;
R.H.TAPPING=Right hand finger tapping.

CHAPTER FOUR

RESULTS

This chapter is concerned with presenting and analyzing the data gathered in this study. The first section presents the descriptive statistics, such as age and handedness for both groups of children. Next, the mean number of finger taps performed by each group in the six different finger tapping conditions will be graphically presented. In order to determine if there were statistically significant differences between the two groups with respect to the mean number of finger taps in each of the six different finger tapping conditions, a randomization test was employed. A definition of a randomization test, as well the rationale as to why this was the chosen method of statistical analyses will be discussed. Differences within each of the two groups will be examined also.

DESCRIPTIVE STATISTICS: SUBJECT INFORMATION

The participants in this study consisted of two groups of children. The first group consisted of 16 male children who stutter, while the second group was comprised of 16 male fluent children. The subjects in the fluent group ranged in age from 7.08 to 12.03 years, with a mean age of 9.4 years. Those comprising the group of children who stutter ranged in age from 6.5 to 12.6 years, with a mean age of 8.8 years. Handedness for each participant was established by asking subjects which hand they use when they perform the following four tasks; writing, cutting with scissors, throwing a ball, and brushing their teeth. Results revealed that 14 children who were dysfluent used their right hand when performing all four tasks. Two of the children in this group, indicated they used their left hand when brushing their teeth, but otherwise use their right hand for the other three tasks. Similar results were found in the group of fluent children. In this group, 14 children reported they use their right-hand for performing all four tasks. However, one child in this group revealed he brushed his teeth with his left hand, while another child indicated no hand preference for this task. Otherwise, they also used their right hand for the three remaining tasks. Overall, both groups of children were strongly right-handed.

DESCRIPTIVE STATISTICS FOR ALL FINGER TAPPING CONDITIONS

The mean number of finger taps performed by each group of children in the six different finger tapping conditions is illustrated in Figures 6-11. As is shown, children who were fluent obtained the highest mean scores in all six finger tapping conditions, compared to children who were dysfluent.

Figure 6

Right hand finger tapping only.

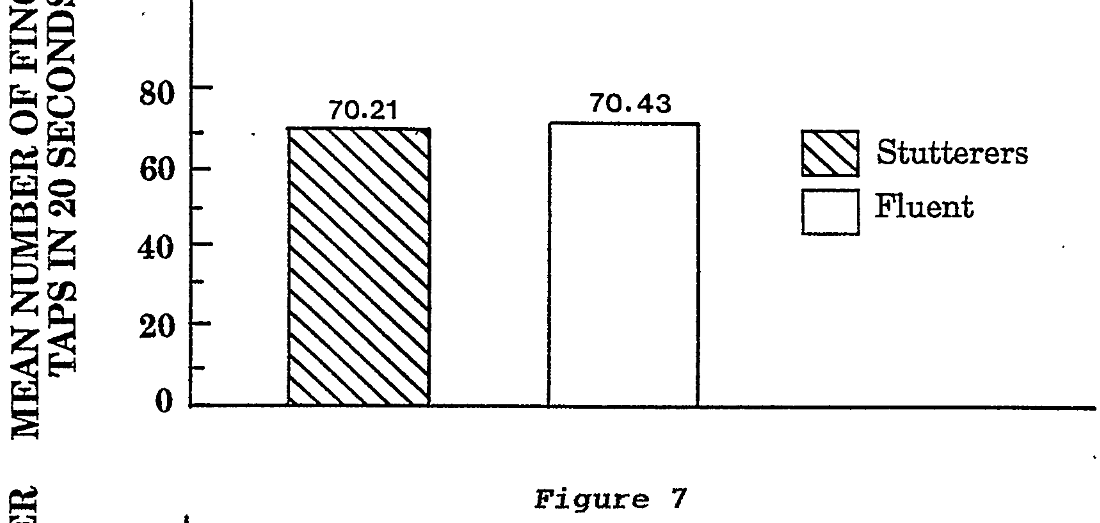


Figure 7

Left hand finger tapping only.

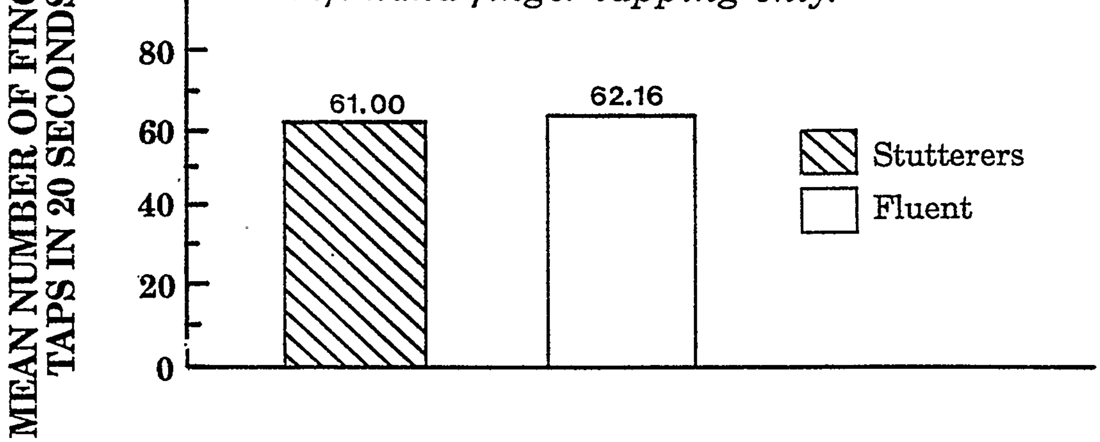
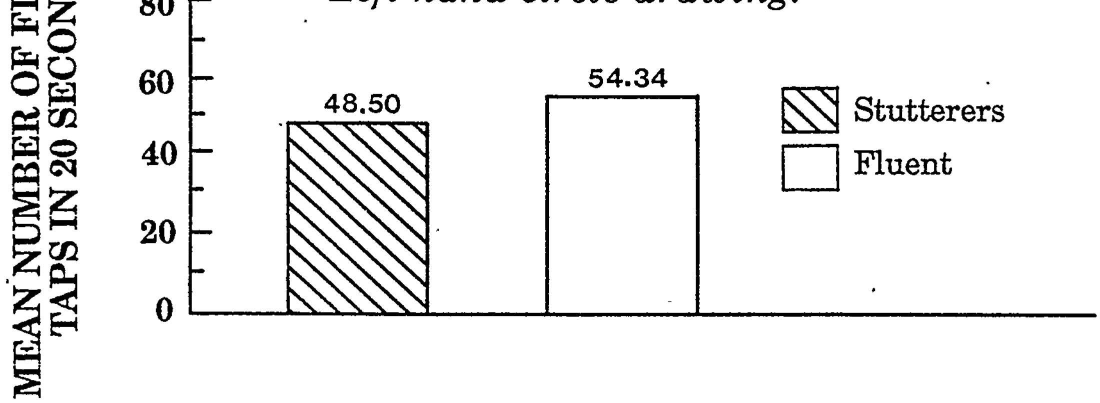


Figure 8

Right hand finger tapping and Left hand circle drawing.



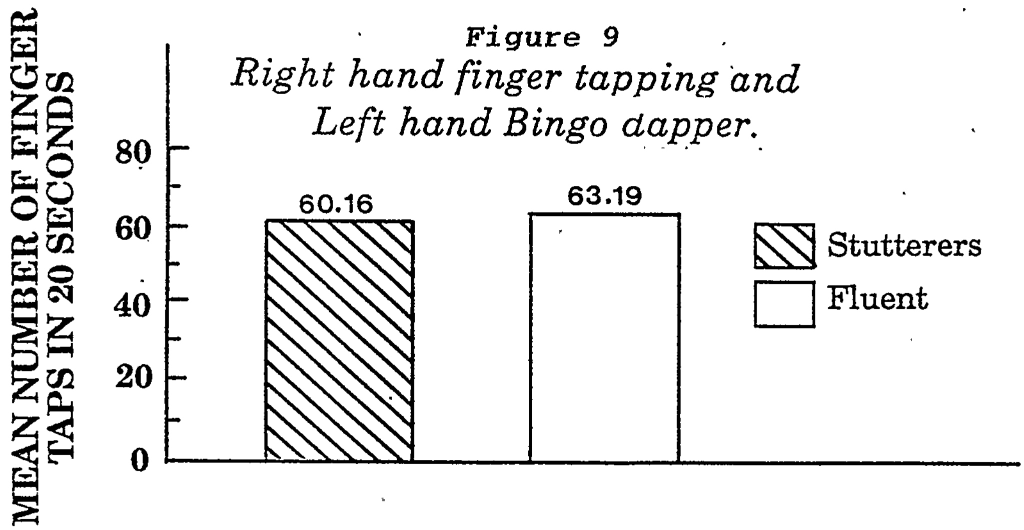


Figure 9
Right hand finger tapping and Left hand Bingo dapper.

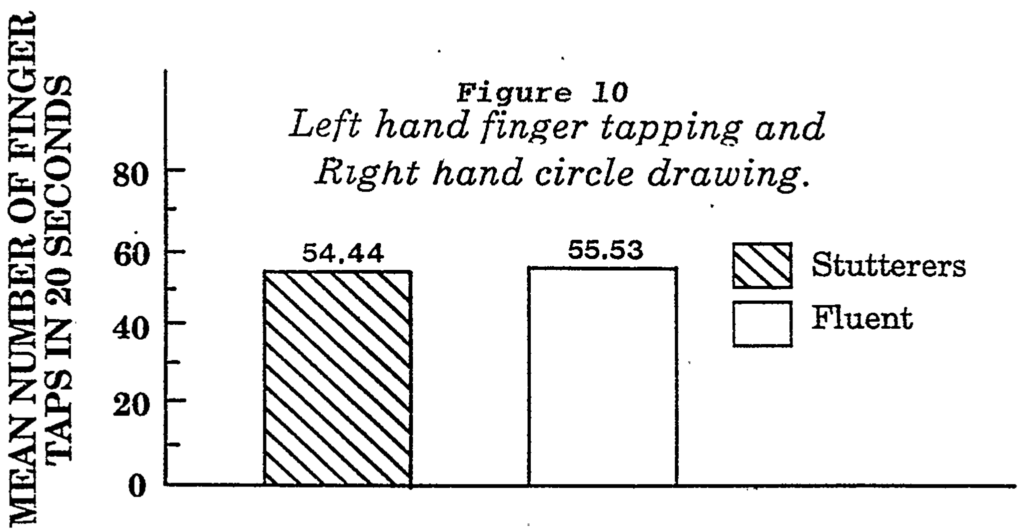


Figure 10
Left hand finger tapping and Right hand circle drawing.

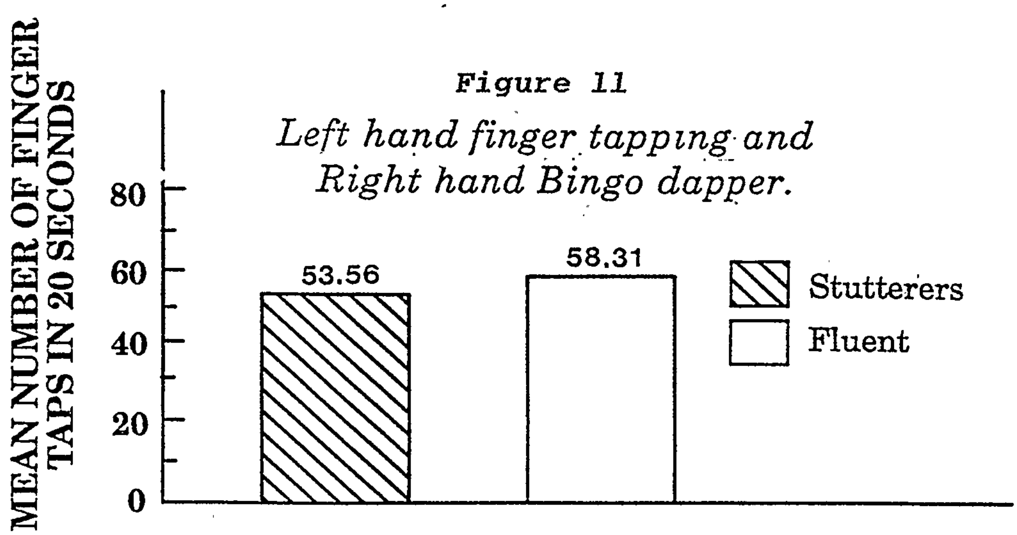


Figure 11
Left hand finger tapping and Right hand Bingo dapper.

RANDOMIZATION TESTS

The two groups of children in this study were not randomly selected from their respective populations. Instead, they were volunteers who agreed to participate. As a result, of the non-random sampling employed in this study, traditional inferential statistics were deemed not applicable. In order to analyze the data randomization tests were deemed most valid.

According to Edgington & Bland (1993) a randomization test is a statistical test for which the significance of experimental results is determined by reference to a distribution of the test statistic computed from various permutations (divisions or rearrangements) of the experimental data. A notable aspect of randomization tests is that they are tests of treatment effects that do not depend on the assumption of random sampling from any population, normal or otherwise; the experimental subjects can be selected by any means whatsoever. Moreover, when there is no random sampling of a population inferences about a population are not statistical, but random assignment in an experiment provides the random element sufficient for drawing statistical inferences on the basis of a randomization test about treatment effects for those subjects participating in the experiment (Edgington, 1987).

It should be noted that for all computations involving an independent t-test: random permutation, or repeated measures ANOVA: random permutation, the number of data permutations was 10,000 in all cases. However, in those cases where it was deemed feasible, an independent t-test; systematic permutation was conducted. In these cases the number of permutations performed varied, and are reported in the appropriate areas. Accompanying each probability statement is a decision rule to either reject or fail to reject the null hypothesis.

BETWEEN GROUP DIFFERENCES

In order to determine if there were any statistically significant differences between the two groups with respect to the observed means in the six different finger tapping conditions an independent t-test: random permutation was employed. A two-tailed probability level is stated as no direction was predicted prior to the experiment.

Finger Tapping Only Conditions

Results revealed that there were no statistically significant differences between the two groups in the right hand finger tapping only condition; $P\ (t \geq 0.05,\ \text{if Ho}) \leq 0.962$. Based on this result my decision rule is as follows: I would take a 96% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho. Results also revealed no statistically significant differences between the two groups in the left hand finger tapping only condition: $P\ (t \geq 0.35,\ \text{if Ho}) \leq 0.740$. My decision rule for this result would be to take a 74% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

<u>Dual-Task Conditions</u>

On the critical and neuropsychologically most meaningful conditions of right-hand index finger tapping (presumably engaging the left-hemisphere), combined with left-hand concurrent activity such as drawing circles, or using the bingo dabber results were not significant. Specifically, no statistically significant differences were found between the observed finger tapping means between the two groups: P ($t \geq 1.28$, if Ho) ≤ 0.212 and P ($t \geq 0.67$, if Ho} ≤ 0.510; respectively. Results also revealed no statistically significant differences between the two groups in the theoretically ambiguous condition of left-hand index finger tapping and right-hand concurrent activity of circle drawing and using the bingo dabber, P (t) ≥ 0.46, if Ho) ≤ 0.806 and P ($t \geq 1.02$, if Ho) ≤ 0.324); respectively. Again, my decision rule for these two results is as follows: I would fail to reject Ho.

<u>Concurrent Task Performance: Right vs. Left Hand Performance</u>

Accuracy in drawing circles was scored by two separate researchers. The researchers consisted of both the author and an undergraduate student enrolled in psychology. The two researchers jointly scored the results of half of the total number of participants. The inter-rater reliability was 96.4%. The remaining results were equally distributed between the two researchers. The other concurrent task, bingo dabbing, was not included in the analysis as it could not be scored for accuracy. In order to receive the maximum score for shape and completeness, each circle was scored based upon the following criteria. Firstly, the drawn figure must have complete closure. Thus, each tail of the figure must be joined to the other side. Secondly, if the length of the drawn figure exceeded twice the width, it was not a circle. Thirdly, no lines were to appear inside the drawn figure. If the circle met all criteria, it received a scored of 3/3; a perfect circle. It was also possible, for example, that a circle may satisfy criteria one and three, but not criteria two. In this case, the circle would have been given a score of 2/3. As shown in Table 2, the dysfluent group of children had an accuracy percentage of 67.4 for left hand circle drawing, while the non-stuttering children had an accuracy percentage of 61.1 for the same task. An independent t-test: random permutation revealed that this difference was not statistically significant. Alternatively, when drawing circles with their right hand, the two groups had very close percentages for accuracy with the dysfluent group obtaining 82.2%, while the non-stuttering group were 81.9% accurate in drawing circles. Again, this difference was not statistically significant (See Table 3). Of interest is the fact that both groups of children performed the concurrent task better when it was carried out with the right hand than with the left hand (Refer to Tables 4 and 5). In other words, the circles drawn with the right hand were drawn with more accuracy than circles drawn with the left hand. The differences between the mean accuracy scores for left and right hand circle drawing were statistically significant for both groups.

TABLE 2

Independent t-test: Random Permutation. Accuracy of Drawing Circles With the Left Hand While Finger Tapping With the Right Hand.

GROUP	MEAN
Dysfluent	18.2 (67.4%)
Fluent	16.5 (61.1%)

Result: P $(t \geq 1.33$, if Ho$) \leq 0.201$

Decision Rule: I would fail to reject Ho and take an unknown risk for a type II error.

TABLE 3

Independent t-test: Random Permutation. Accuracy of Drawing Circles With the Right Hand While Finger Tapping With the Left Hand.

GROUP	MEAN SCORE
Dysfluent	22.2 (82.2%)
Fluent	22.1 (81.9%)

Result: P $(t \geq 0.05$ if Ho$) \leq 0.978$

Decision Rule: I would fail to reject Ho.

TABLE 4

Repeated Measure ANOVA for Dysfluent Group: Comparing Accuracy of Left Hand Circle Drawing (A) With Accuracy of Right Hand Circle Drawing (B).

Variable	Mean score
A	$\bar{A}$=18.2 (67.4%)
B	$\bar{B}$=22.2 (82.2%)

RESULTS: P (F $\geq$ 9.13 if Ho) = 0.01

Decision rule: I would reject Ho at a risk level of 0.01.

TABLE 5

Repeated Measure ANOVA for Fluent Group: Comparing Accuracy of Left Hand Circle Drawing (A) With Accuracy of Right Hand Circle Drawing (B).

Variable	Mean score
A	$\bar{A}$=16.5 (61.1%)
B	$\bar{B}$=22.09 (81.9%)

RESULTS: P (F $\geq$ 24.85 if Ho) = 0.0002

Decision rule: I would reject Ho and take a 1/5000 chance of making a type I error.

WITHIN-GROUP DIFFERENCES

Dysfluent Children

An examination of differences in subject performance between the two concurrent tasks, drawing circles and using the bingo dabber combined with index finger tapping, was of interest in light of the non-significant results obtained in the dual-task conditions previously discussed. A repeated measures ANOVA: random permutation revealed that children who stutter performed significantly better (greater number of finger taps) when finger tapping with the right hand than with the left hand (See Table 6). Results also indicated that there were significant differences between right hand finger tapping/left hand bingo and right hand finger tapping/right hand circle drawing (See Table 7). This group performed significantly better (greater number of finger taps) in the condition of right hand finger tapping and left hand bingo dabber. Table 8 shows the results of comparing left hand finger tapping and right hand bingo dabbing with left hand finger tapping and right hand circle drawing. In this case, there were no significant differences between the number of finger taps performed in either condition.

TABLE 6

Repeated Measure ANOVA: Comparing Right Hand Finger Tapping (Y) and Left Hand Finger Tapping (Z)

Variable	Mean score
Y	$\bar{Y}=70.21$
Z	$\bar{Z}=61.00$

$F=56.15$

Probability for anova=0.0001

DECISION RULE: I would reject Ho and take a 1/10,000 chance of making a type I error.

TABLE 7

Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Circle Drawing (A) With Right Hand Finger Tapping and Left Hand Bingo Dabbing (B)

Variable	Mean score
A	$\bar{A}=48.50$
B	$\bar{B}=60.16$

RESULTS: $P\ (F \geq 47.20, \text{ if Ho}) = 0.0001$

Decision rule: I would reject Ho and take a 1/1,000 chance of making a type I error.

TABLE 8

Repeated Measure ANOVA: Comparing Left Hand Finger Tapping and Right Hand Bingo (B) With Left Hand Finger Tapping and Right Hand Circle Drawing (D)

Variable	Mean score
B	$\bar{B}$=53.56
D	$\bar{D}$=54.44

RESULTS: P (F $\geq$0.25 if Ho) = 0.646

DECISION RULE: I would take a 65% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

The results of a repeated measures: random permutation found a significant difference in the number of left hand finger taps combined with right hand circle drawing when compared to the condition of right hand finger tapping and left hand circle drawing. In this case, this group had a significantly greater number of finger taps in the case of left hand finger tapping combined with right hand circle drawing (See Table 9). However, this hand effect was not found for the concurrent task of bingo dabbing. In this case, the group had a greater number of right hand finger taps combined with left hand bingo dabbing, compared to the opposing condition of left hand finger tapping combined with right hand bingo dabbing (See Table 10).

TABLE 9

Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Circle (A) With Left Hand Finger Tapping and Right Hand Circle Drawing (C)

Variable	Mean score
A	$\bar{A}$=48.50
C	$\bar{C}$=54.44

RESULTS: P (F $\geq$ 9.74 if Ho) = 0.008

DECISION RULE: I would reject Ho and take a 1/125 chance of making a type I error.

TABLE 10

Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Bingo (A) With Left Hand Finger Tapping and Right Hand Bingo (C)

Variable	Mean score
A	$\bar{A}$=60.16
C	$\bar{C}$=53.56

RESULTS: P (F $\geq$ 9.18 if Ho) = 0.01

DECISION RULE: I would reject Ho and take a 1/100 chance of making a type I error.

Fluent Children

Children who were fluent showed the same right hand advantage when finger tapping as children who stutter (See Table 11). Results also indicated that there were significant differences between right hand finger tapping/left hand circle drawing and right hand finger tapping/left hand bingo (See Table 12). This group of children performed significantly better (greater number of finger taps) in the condition of right hand finger tapping combined with left hand bingo dabbing.

TABLE 11

A Repeated Measure ANOVA: Comparing Right Hand Finger Tapping (C) and Left Hand Finger Tapping (D)

VARIABLE	MEAN SCORE
C	$\bar{C}$=70.43
D	$\bar{D}$=62.16

RESULT: P (F $\geq$ 23.92 if Ho) = 0.0004

DECISION RULE: I would reject Ho and take a 1/2500 chance of making a type I error.

TABLE 12

A Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Circles (A) With Right Hand Finger Tapping and Left Hand Bingo Dabbing (B)

VARIABLE	MEAN SCORE
A	$\bar{A}$=54.34
B	$\bar{B}$=63.19

RESULTS: P (F $\geq$ 39.20 if Ho) = 0.0002

DECISION RULE: I would reject Ho, and take a 1/5000 chance of making a type I error.

As can be seen in Table 13, this group of children had a significantly greater number of finger taps in the case of left hand finger tapping combined with right hand bingo dabbing than in the reversed condition of left hand finger tapping combined with right hand circle drawing.

TABLE 13

A Repeated Measure ANOVA: Comparing Left Hand Finger Tapping and Right Hand Bingo (C) With Left Hand Finger Tapping and Right Hand Circle Drawing (D)

VARIABLE	MEAN SCORE
C	$\bar{C}$=58.31
D	$\bar{D}$=55.53

RESULT: P (F $\geq$ 8.60 if Ho) = 0.01

DECISION RULE: I would reject Ho and take a 1/100 chance of making a type I error.

A repeated measures ANOVA: random permutation was employed to determine if there was a difference between right hand and left hand finger tapping, while carrying out a concurrent task. The results for the group of children who were fluent appears below. As illustrated in Table 14, there were no statistically significant differences between the observed means between right hand finger tapping/left hand circle drawing and left hand finger tapping/right hand circles. Table 15, shows the results obtained when comparing right hand finger tapping/left hand bingo and left hand finger tapping/right hand bingo. In this case, there were statistically significant differences between these two conditions. This group performed better on the right hand finger tapping/left hand bingo.

TABLE 14

A Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Circle (A) With Left Hand Finger Tapping and Right Hand Circle Drawing (C)

Variable	Mean score
A	$\bar{A}=54.34$
C	$\bar{C}=55.53$

RESULTS: P ($F \geq 0.41$ if Ho) = 0.56

DECISION RULE: I would fail to reject Ho and take an unknown risk of a type II error.

TABLE 15

A Repeated Measure ANOVA: Comparing Right Hand Finger Tapping and Left Hand Bingo (B) With Left Hand Finger Tapping and Right Hand Bingo (D)

Variable	Mean score
B	$\bar{B}=63.19$
D	$\bar{D}=58.31$

RESULTS: P ($F \geq 7.41$ if Ho) = 0.005

DECISION RULE: I would reject Ho and take a 1/200 of making a type I error.

CHILDREN WHO STUTTER: SEVERITY LEVELS

The obtained severity levels of the 16 children who were dysfluent are summarized in Table 16. The instrument used to diagnose each child was called the Riley Severity Stuttering Instrument (Riley, 1972) and has been explained elsewhere in this paper.

TABLE 16

Severity ratings for the dysfluent children

VARIABLE	FREQUENCY (N)	PERCENTAGE
Very mild	1	6.25%
Mild	7	43.75%
Moderate	5	31.25%
Severe	3	18.75%
Very severe	0	0.00%
TOTAL NUMBER	16	100.00%

As is shown in Table 16, the greatest number of children were diagnosed as mild stutterers (n=7). Five children were classified as moderate stutters, and three children were categorized as severe stutterers. The very mild category only represented one child and there were no children diagnosed with a very severe stuttering problem.

Due to the low number of persons diagnosed in the very mild and very severe categories, these categories were excluded from subsequent analysis.

MILD COMPARED TO MODERATE RATINGS OF STUTTERING

An independent t-test: random permutation was employed to determine if there were statistically significant differences between the means in each of the six different finger tapping conditions between children with a mild stuttering problem and children who were diagnosed as moderate stutterers. The results which appear below in Table 17, show there were no statistically significant differences between the means in any of the six different finger tapping conditions.

TABLE 17

Results of an Independent t-test: Comparing Mild and Moderate Stutterers

Variable	Result
Right Hand Finger Tapping Only	t= 0.51 two-tail probability=0.623
DECISION RULE:	I would take a 62% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.
Left Hand Finger Tapping Only	t= 0.01 two-tail probability=.97
DECISION RULE:	I would take a 97% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.
R.Hand Tapping + Left Circles	t= 0.03 two-tail probability=0.983
DECISION RULE:	I would take a 98% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.
R.Hand Tapping + Left Bingo	t= 0.60 two-tail probability=0.569
DECISION RULE:	I would take a 57% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.
L.Hand Tapping + Right Circles	t= 0.39 two-tail probability=0.711
DECISION RULE:	I would take a 71% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.
L.Hand Tapping + Right Bingo	t= 0.48 two-tail probability=0.645
DECISION RULE:	I would take a 65% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

MODERATE COMPARED TO SEVERE RATINGS OF STUTTERING

An independent t-test: random permutation was employed to determine if there were statistically significant differences between the means in each of the six different finger tapping conditions. Differences between children with a moderate stuttering problem and children diagnosed as severe stutterers were investigated. The results which appear below in Table 18 show there were no statistically significant differences between the means in any of the six different finger tapping conditions.

TABLE 18

Results of an Independent t-test: Comparing Moderate and Severe Stutterers

Variable	Result
Right Hand Finger Tapping Only	t= 0.10 two-tail probability=0.964
DECISION RULE: I would take a 96% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
Left Hand Finger Tapping Only	t= 0.25 two-tail probability=0.855
DECISION RULE: I would take a 86% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Tapping + Left Circles	t= 0.45 two-tail probability=0.643
DECISION RULE: I would take a 64% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Tapping + Left Bingo	t= 0.08 two-tail probability=0.929
DECISION RULE: I would take a 93% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Tapping + Right Circles	t= 0.49 two-tail probability=0.663
DECISION RULE: I would take a 66% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Tapping + Right Bingo	t= 0.43 two-tail probability=0.435
DECISION RULE: I would take a 44% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	

MILD COMPARED TO SEVERE RATINGS OF STUTTERING

An independent t-test: systematic permutation was employed to determine if there were statistically significant differences between the means in the six different finger tapping conditions between children with a mild stuttering problem and children diagnosed as severe stutterers. The results appear below in table 19, show there were no statistically significant differences between the means in any of the six different finger tapping conditions. The number of data permutations in the six finger tapping conditions was 56.

TABLE 19

Results of an Independent t-test: Comparing Mild and Severe Stutterers

Variable	Result
Right Hand Finger Tapping Only	t= 0.29 two-tail probability=0.809
DECISION RULE: I would take a 81% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
Left Hand Finger Tapping Only	t= 0.32 two-tail probability=0.702
DECISION RULE: I would take a 70% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Tapping + Left Circles	t= 0.50 two-tail probability=0.65
DECISION RULE: I would take a 65% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Tapping + Left Bingo	t= 0.50 two-tail probability=0.667
DECISION RULE: I would take a 68% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Tapping + Right Circles	t= 0.22 two-tail probability=0.808
DECISION RULE: I would take a 88% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Tapping + Right Bingo	t= 0.02 two-tail probability=1.000
DECISION RULE: I would take a 100% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	

FAMILIAL VERSUS NON-FAMILIAL HISTORY OF STUTTERING

Of concern in the area of stuttering is the issue of possible sub-groups. Indeed, information gathered from the parents of children who stutter revealed that eight children in the study had a family history of stuttering, while six of the families did not. Three of the families were unable to state with certainty any familial or non-familial history of stuttering, as the parent or the child in the study were adopted. An independent t-test: random permutation was used to determine if there were differences between the observed means in the six different finger tapping conditions. As is shown in Table 20, there were no statistically significant differences between the means of the children who had a familial history of stuttering and children with no family history in any of the six different finger tapping conditions.

Table 20

Independent t-test: Familial vs. Non-familial History of Stuttering

VARIABLE	RESULT
Right Finger Tapping	t=0.13 two-tail probability=0.904

DECISION RULE: I would take a 90% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

Left Finger Tapping	t=0.71 two-tail probability=0.489

DECISION RULE: I would take a 49% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

R.Finger Tap and Left Circles	t=0.70 two-tail probability=0.505

DECISION RULE: I would take a 50% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

R.Finger Tap and Left Bingo	t=1.60 two-tail probability=0.144

DECISION RULE: I would take a 15% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

L.Finger Tap and Right Circles	t=0.98 two-tail probability=0.340

DECISION RULE: I would take a 34% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

L.Finger Tap and Right Bingo	t=1.71 two-tail probability=0.109

DECISION RULE: I would take a 11% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

FAMILIAL HISTORY OF STUTTERING

To further investigate the issue of familial history, parents were asked to indicate on their questionnaire, "WHO?" in the family stutters (besides the child in the study). The responses fell into three general categories. Three of the eight parents, stated it was an immediate family member who stutters (i.e., parent, sibs). Two of the eight parents, reported that it was an extended family member who stutters (uncle), while three families stated they had many members of the family who stuttered. This included both immediate and extended members (this category will be referred to as varied). An independent t-test: systematic permutation was used to explore any differences between the different categories.

As is evident in Table 21 there were no statistically significant differences between the means of children with an immediate familial history of stuttering and children with an extended family history of stuttering in any of the six different finger tapping conditions. The number of data permutations was 10.

TABLE 21

Results of an Independent t-test: Comparing Children With Immediate Family Histories of Stuttering and Children With Extended Family Histories of Stuttering

Variable	Result
Right Hand Finger Tapping Only	t= 1.27 two-tail probability=0.600
DECISION RULE: I would take a 60% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
Left Hand Finger Tapping Only	t= 1.37 two-tail probability=0.400
DECISION RULE: I would take a 40% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Finger Tap + Left Circles	t=0.68 two-tail probability=0.600
DECISION RULE: I would take a 60% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Finger Tap + Left Bingo	t=0.42 two-tail probability=0.400
DECISION RULE: I would take a 40% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Finger Tap + Right Circles	t=1.61 two-tail probability=0.100
DECISION RULE: I would take a 10% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Finger Tap + Right Bingo	t=1.42 two-tail probability=0.400
DECISION RULE: I would take a 40% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	

An independent t-test: systematic permutations was conducted to compared children with immediate family histories of stuttering and children with varied family histories of stuttering in all six finger tapping conditions. As is evident in table 22 there were no statistically significant differences between the means in the six different finger tapping conditions. The number of data permutations was 20 in all six conditions.

TABLE 22

Results of an Independent t-test: Comparing Children With Immediate Family Histories of Stuttering and Children With Varied Family Histories of Stuttering

VARIABLE	RESULT
Right Hand Finger Tapping Only	t= 0.17 two-tail probability=0.900
DECISION RULE: I would take a 90% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
Left Hand Finger Tapping Only	t=0.30 two-tail probability=0.801
DECISION RULE: I would take a 80% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Finger Tap + Left Circles	t=0.43 two-tail probability=0.500
DECISION RULE: I would take a 50% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
R.Hand Finger Tap + Left Bingo	t=0.68 two-tail probability=0.600
DECISION RULE: I would take a 60% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Finger Tap + Right Circles	t=0.76 two-tail probability=0.600
DECISION RULE: I would take a 60% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	
L.Hand Finger Tap + Right Bingo	t=0.55 two-tail probability=0.600
DECISION RULE: I would take a 60% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.	

An independent t-test: systematic permutation was conducted to compare children with extended family histories of stuttering and children with varied histories of stuttering in all six finger tapping conditions. As is evident in Table 23 there were no statistically significant differences between the means of children who had an extended familial history of stuttering and children with a varied family history of stuttering in any of the six different finger tapping conditions. The number of data permutations was ten in all six conditions.

TABLE 23

Results of an Independent t-test: Comparing Children With Extended Family Histories of Stuttering With Children Who Have Varied Family Histories of Stuttering

VARIABLE	RESULT
Right Hand Finger Tapping Only	t=1.35 two-tail probability=0.300

DECISION RULE: I would take a 30% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

Left Hand Finger Tapping Only	t=1.11 two-tail probability=0.300

DECISION RULE: I would take a 30% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

R.Hand Finger Tap + Left Circles	t=0.91 two-tail probability=0.500

DECISION RULE: I would take a 50% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

R.Hand Finger Tap + Left Bingo	t=0.99 two-tail probability=0.500

DECISION RULE: I would take a 50% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

L.Hand Finger Tap + Right Circles	t=1.69 two-tail probability=0.200

DECISION RULE: I would take a 20% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

L.Hand Finger Tap + Right Bingo	t=1.21 two-tail probability=0.300

DECISION RULE: I would take a 30% chance of making a type I error if Ho were rejected. Therefore, fail to reject Ho.

CHAPTER 5
DISCUSSION

The primary purpose of the present study was to examine a neuropsychological model of stuttering called "Interhemispheric Interference." An examination of differences in the finger tapping ability of a group of children who stutter and a group of fluent children was investigated. Differences within each of the two groups in terms of finger tapping ability were also explored. Additionally, the question of whether there was within group variability in interhemispheric interference in the children who stutter that relates to subject characteristics such as familial history of stuttering, and severity level of speech was examined.

This chapter will include a discussion of the results, and implications for future research.

DUAL-TASK CONDITIONS

The data failed to indicate any significant differences between stutterers and non-stutterers in the condition of right-hand index finger tapping combined with left hand concurrent task performance. Thus, hypothesis three and four were not supported by the data. This finding concurs with those of Webster (1986a) who found no statistically significant differences between a group of male stutterers and a group of male non-stutterers in their ability to perform right index finger tapping combined with left hand concurrent task performance. Although support for the theory of interhemispheric interference was not found in this study, the following are possible reasons to explain the non-significant results. Firstly, the results from the present study combined with earlier research (Webster, 1986a) suggest that the type of finger tapping may be an important variable in testing the theory of interhemispheric interference. Webster (1986a), for example, found support for the theory when sequential finger tapping was employed. More specifically, this study found a significant main effect for tapping task, with more interference for sequential finger tapping than for index finger tapping in stutterers as compared to non-stutterers. Thus, future research studies exploring the theory of interhemispheric interference as it relates to children should consider incorporating both index and sequential finger tapping tasks. Another explanation to account for the non-significant results were the type of concurrent tasks employed. To recall, these tasks have never been utilized in testing the theory of interhemispheric interference. Perhaps, the concurrent tasks in this study were not difficult enough to evoke interference in the children's finger tapping. More research aimed at employing similar tasks to test the theory of interhemispheric interference may clarify this issue.

In the theoretically ambiguous condition of left-hand finger tapping (presumably involving both hemispheres) combined with right-hand concurrent task performance, data failed to indicate any differences between stutterers and fluent speakers. Thus, hypothesis five was validated by the data. Moreover, this result is in agreement with a prior study (Webster, 1986a).

Results from this study found that children who stutter showed the same pattern of hand differences demonstrated by children who are fluent (i.e., better finger tapping performance with the right hand than with the left hand). Thus, hypothesis two was supported by the data. This hand difference is similar to that reported by others (Lomas & Kimura, 1976; Webster, 1985, 1986a). Such an advantage is usually interpreted as reflecting lateralized neural mechanisms in right handers. To the extent that these mechanisms overlap functionally with those used for speech (Mateer & Kimura, 1977) the results are consistent with previously cited studies reporting normal lateralization of speech mechanisms in stutterers (Lomas & Kimura, 1976; Wolff, Hurtwitz & Moss, 1977). This is consistent with the dichotic listening literature indicating a right ear advantage in stutterers for discrimination and recognition of phonemes and consonant-vowel (CV) syllables (Dorman & Porter, 1975; Pinsky & McAdam, 1980; Rosenfield & Goodglass, 1980). This has been interpreted as demonstrating a left hemisphere specialization for speech and language.

FINGER TAPPING ONLY CONDITIONS

Since normal speech is a neuromotor phenomenon, the hypothesis that there might be something wrong with the neuromotor mechanisms or functions of people who stutter has often been investigated (Cross & Luper, 1983; Starkweather, Franklin & Smigo, (1984); Webster, 1985; Webster & Ryan, 1991). This hypothesis has been put to test with respect to general motor performance. Although, this area was not a primary focus of this study the data obtained enables discussion of such a theory. Studies investigating stutterer's manual abilities have concerned themselves with steadiness, speed and regularity of repetitive hand movements. The results of such investigations have been contradictory. In particular, some researchers' (Snyder, 1958; Cooper & Allen, 1977) have found stutterers to be slightly inferior in tests of manual diadochokinesis (rapid finger tapping). While, in other studies examining the same ability no differences were found (Webster, 1985, 1986a, 1986b). The results from the present study indicate no significant differences between stutterers and fluent speakers in their ability to perform index finger tapping with either the right or left hand in timed trials. Thus, hypothesis one was validated based on the data obtained. These findings are consistent with earlier research (Webster, 1985, 1986b) which found that on repetitive sequential finger tapping tasks, male stutterers and fluent speakers were indistinguishable with respect to mean correct sequences tapped and total key presses in a timed trial paradigm. Results from this study support the view that there are no differences in the general motor ability (as measured by finger tapping ability) between stutterers and non-stutterers. Thus, no support was found in this study for a etiological theory of stuttering involving neuromotor dysfunction.

CONCURRENT TASK PERFORMANCE

The concurrent tasks in this study (circle drawing and using the bingo dabber) have never been used in validating the theory of interhemispheric interference. These two tasks were chosen as they proved to be enjoyable to subjects who participated in an informal pilot study. During the testing phase it was observed that children in the non-fluent and fluent groups reported both tasks to be interesting and fun. More favourable interest was expressed by the majority of children for the using the bingo dabber. This type of information is seen as important, as the concurrent tasks must be able to capture and sustain the child's interest. Based on self-reports from the children, as well as from this researcher's observations, this was accomplished.

Concurrent Task Performance: Right Vs. Left Hand Performance

In studies involving dual-task paradigms it is necessary to investigate the participant's concurrent task performance. This would have been especially important if significance between the groups were found in the condition of right hand index finger tapping and left hand concurrent task performance. In other words, had significance been found, performance of the concurrent task would have been taken into consideration because of the potential of speed-accuracy and attentional trade offs in concurrent task paradigms (Webster, 1986a). This consideration is lessened in this study because of the non-significant results found in the dual-task conditions. Nevertheless, of interest was the finding that when circles drawn by the participants were scored for accuracy both groups performed this task better when carried out with the right hand rather than with the left hand. This result does not concur with those of Webster's (1986) study who found concurrent task performance of knob turning and button pressing to be better with the left hand. These conflicting results may be an artifact of the nature of the concurrent task used, as well as the methodology used to score the concurrent task. In the present study, participants were required to draw a circle whenever they heard the sound of a bell. This task involved a greater degree of motoric skill, compared to turning a knob back and forth or pressing and releasing a button as was used in Webster's (1986a) study. The degree of motoric involvement may be a factor affecting which hand was better able to perform the concurrent task. Another factor that may account for differences is the methodology used to score the concurrent task. In the present study, circles were scored based on subjective measures while, in Webster's (1986a) study, accuracy of performance on the concurrent tasks was determined by objective methods. This involved calculating the standard deviation of complete response intervals. The lower the score, the better the performance. Overall, the nature of the concurrent task, as well as the different methodologies employed may explain the differences in results between the two studies.

Concurrent Task Performance: Low Vs. High Motoric Skill

Data indicated that within each group the mean number of finger taps performed by the right hand was dependent on which concurrent task was being performed. Both groups of children performed significantly better (greater number of finger taps) when using the bingo dabber with the left hand, compared to left hand circle drawing. In other words, results indicate that both groups found left hand circle drawing to be more difficult than left hand bingo dabbing combined with right hand finger tapping. Hence, circle drawing evoked more interference in the right hand finger tapping ability in both groups than did bingo dabbing. To recall, one of the concurrent tasks required the child to draw a circle whenever he heard the sound of a tone. A high degree of motoric skill is required in executing such a task. On the other hand, the other concurrent task, involved the child holding a bingo dabber which is the shape of a cylinder and to press it down to make an ink blot whenever he heard the sound of a tone. However, in the case of left hand finger tapping and right-hand concurrent task performance results are not as clear. For example, for the group of children who stutter the mean number of finger taps was not affected by the type of concurrent task. In this case, circle drawing and using the bingo dabber evoked the same degree of interference in the finger tapping ability in the group of non-fluent children. On the other hand, the group of fluent children had a significantly greater number of left hand finger taps when using the bingo dabber with their right hand, compared to right hand circle drawing. In this condition, circle drawing evoked more interference in the left hand finger tapping ability than did left hand bingo dabbing. Comparisons across studies can not be made, as prior studies (Webster, 1985, 1986a) did not examine differences between the two concurrent tasks with respect to the effect on the subjects finger tapping ability. Based on the preceding results, some tentative conclusions can be drawn: (1) School age children between the ages of 6-13 years of age expressed interest and found enjoyment in drawing circles and using a bingo dabber. The concurrent task of bingo dabbing was most preferred, probably because it was easier to perform; (2) Performance of right hand finger tapping appeared to be dependent on the nature of the concurrent task performed by the left hand. The more motoric the task, the greater the interference produced in finger tapping for stutterers and non-stutterers; and (3) Left hand finger tapping was not influenced by the nature of the right hand concurrent task for children who stutter. While, for fluent children, left hand finger tapping performance appeared to be dependent on the nature of the right hand concurrent task performance. The more motoric the task, the greater the interference produced in fluent children. One may speculate as to possible reasons for this unexpected result. In fluent persons a point may be reached when the task demands become so great that the left hemisphere does interfere with the right hemisphere. On the other hand, the model of interhemispheric interference assumes that in non-fluent persons the left hemisphere is functionally fragile. Taking this one step further the non-interference by the left hemisphere to the right hemisphere may reflect the inability of the fragile left hemisphere to interfere with the right hemisphere regardless of task demands. More research examining the effects of low and high motoric task demands on finger tapping ability is needed to help clarify the results found in this study.

SUBGROUPS

There is a small but growing body of research in the literature suggesting the possibility of subgroups within the stuttering population. Individual differences in performance have been cited in previous research (Poulos & Webster, 1991; Webster, 1985, 1988). For example, the data from two stutterers who had difficulty with finger tapping sequences and whose performance was better with the left than the right hand suggested that there may be a subgroup of stutterers for whom left hemisphere dysfunction forms the basis of their disorder (Webster, 1985). Unfortunately, this study did not examine the individual characteristics of these two subjects to determine if the differences in performance may have been related to individual characteristics such as speech severity, or familial history. The present study addressed the question of whether there is within group variability in interhemispheric interference in the children who stutter relating to subject characteristics of familial history of stuttering and severity level of speech. Such information was deemed important as there is the possibility that the cause of stuttering may have multiple causes. Findings indicate no significant differences in the six finger tapping conditions between children with a familial history of stuttering (n=8) and children with a non-familial history (n=6). Moreover, no differences were found in the six finger tapping conditions between children with a mild (n=7), moderate (n=5) or severe (n=3) level of speech severity. Overall, the results from this study found no evidence for within group variability in interhemispheric interference in the children who stutter relating to familial history of stuttering, or level of speech severity. Although no differences were found with respect to familial history or level of speech severity caution must be exercised in the interpretation of the results for the following reasons. Firstly, the sample of dysfluent children was not a random sample, and thus not a representative sample of children who stutter. Secondly, the number of children in all categories whether it be familial vs. non-familial history of stuttering or the categories of level of speech severity were small. In the two categories of speech severity, for example, the very mild and very severe categories were not included in the data analysis because of the very low representation. The omission of the very mild and very severe categories in data analysis is a limitation of this study.

IMPLICATIONS FOR FUTURE RESEARCH

To conclude, this study was primarily exploratory and despite generally nonsignificant results, several interesting areas for further investigation became apparent.

TYPE OF FINGER TAPPING

Tasks such as sequential finger tapping usually involve repeatedly tapping the key in the sequence 1-2-3-4 in which 1 represents the index finger and 4 represents the little finger. Index finger tapping, on the other hand, involves repeatedly tapping the same key with the index finger. Future research should focus on examining the sequential finger tapping ability of a group of children who stutter and a group of fluent children and compare it with the index finger tapping ability. This is necessary to determine which is a more effective technique to measure interhemispheric interference in children.

THE NATURE OF CONCURRENT TASKS

Not only is the type of finger tapping task important, but the nature of the concurrent tasks are equally significant. Further research is needed which incorporates concurrent tasks requiring a low degree of motoric involvement and tasks involving a high degree of motoric skills. Such information is necessary to elucidate the issue of how the degree of motoric skill involvement relates to which hand performs better. Moreover, exploring the relationship between the level of motoric involvement (low vs. high) and its influence on finger tapping ability is worthy of further investigation.

AGE OF PARTICIPANTS

Future research should consider age matching each dysfluent subject with a fluent subject. This follows from research which indicates that coordination and speed of movement increases developmentally (Denckla, 1974). This increase in coordination and speed of movement typically plateaus at approximately 8 to 10 years of age on most finger tapping tasks (Denckea, 1974). Thus, when one is trying to extrapolate from motor behavior to neuropsychological underpinnings (i.e., brain function) the subjects should be closely controlled for maturation factors.

SUBGROUPS

The non-significant results obtained in the area of subgroups should not result in abandonment of searching for multiple causes of stuttering. Researchers agree that continued study of subgroups is needed to increase our understanding of the problem (Blood, 1985; Van Riper, 1971). Specifically, research that explores what factors or individual characteristics are able to differentiate persons who stutter is required. The present study examined the individual characteristics of familial history of stuttering and level of speech severity. The idea of there being within group variability in interhemispheric interference that relates to familial history of stuttering or level of speech severity requires further testing. Such investigations need to incorporate larger sample sizes. Familial history and level of speech severity are not the only factors worthy of investigation. For example, Riley & Riley (1980) have reported success in subgroup differentiation on the basis of nonspeech and speech characteristics and have suggested that the differences reflect underlying mechanisms. More recently, Schwartz & Conture (1988) used cluster analysis techniques to differentiate a group of 43 stuttering children on the basis of speech and nonspeech behavioural characteristics. Whether these clusters differ with respect to etiology is one of the issues that needs to be investigated. It is quite possible that we will never be able to determine whether stuttering has a single or multiple causes. In many ways this situation parallels that of other human disorders such as asthma, schizophrenia, and depression. In these cases, many theories co-exist and more theories continue to be spawned by the failure of any one theory to explain everything and by differential success of various therapies (Shames & Rubin, 1986). If there are different kinds of stuttering problems (i.e., subgroups of stutterers), which lend themselves to different theoretical explanations, we may be facing the greatest challenge of all, that of differential diagnosis of individuals. This approach leads to the selection of a theoretical explanation which, in turn, binds us to a particular therapy for a particular stutterer. The implication of this is that no one theory will explain everything. No one therapy will be a panacea for all stutterers.

METHODOLOGY

Future research should also be concerned with the manner of the interview process when discussing the issue of familial history of stuttering with parent(s). An interesting finding occurred during the course of a telephone interview in which a mother indicated that no one in the family stuttered. This statement was contradicted by the father who indicated that there was a family history via an informal conversation on the testing day. Based on this small, but nevertheless important example, it is advisable to have a conversation with both parents if possible; preferably in person. This finding is in agreement with Poulos & Webster (1991) who found that variation in familial incidence estimates is related to the thoroughness with which the questions about family history are asked and answers pursued.

RESEARCH DESIGN

Further research in the area of stuttering needs to give more priority to the manner in which data is analyzed. According to Preus (1981) the use of statistical methods in research on stuttering have sometimes been questionable. Indeed, the majority of studies investigating the theory of interhemispheric interference have used parametric tests that analyze the data (Webster, 1985, 1986a, 1986b). This method is questionable as the samples in these studies do not constitute a random sample, and thus assumptions inherent in using parametric tests have not been met. In the present study, a randomization test was used. This type of test was chosen as the samples in this study were not random samples. The advantage of using such a test is that the researcher can be reasonably confident of the results, as the appropriate statistical method was used to analyze the data. In the event that a researcher used parametric tests to analyze data from non-random samples, the degree of confidence decreases. This is because statistically significant results are generally more likely to be obtained with parametric than non-parametric tests.

In conclusion, researchers need to be concerned about every aspect of the research process. This includes the type of statistics used to analyze the data.

CONCLUSION

The aim of this research project was to further examine the theory of interhemispheric interference by studying the difference between a group of children who stutter and a group of fluent children when performing finger tapping tasks. Although generally non-significant results were obtained, the data did provide some direction for future research. It is hoped that with continued research efforts the cause or causes of stuttering will be known in the not too distant future. The importance of searching for a cause or causes of stuttering can be understated. As Van Riper (1973) has pointed out, "Stuttering is not merely a speech impediment; it is an impediment to social living." Carlisle (1985) in his book states:

> Stuttering interferes with the attribute that sets human beings apart from all other animals-the aptitude for verbal communication....Speech is the basis of our culture. The inability to communicate fluently affects every moment of a stutterer's life and tends to push him or her outside society.

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Appendix A: Information Sheet for Parents of Dysfluent Children

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN BRAIN ORGANIZATION AND STUTTERING

INFORMATION SHEET

I. PURPOSE OF THE RESEARCH PROJECT

The major purpose of this research project is to examine the relationship between brain organization and a speech disorder known as stuttering. By agreeing to participate in this study you will be contributing to an area in which very little research has been done. Additionally, a better understanding of these brain-behavior relationships may assist Speech-Language Pathologists in designing more effective intervention programs.

II. GENERAL INFORMATION ABOUT STUTTERING

The majority of children speak with amazing fluency. Even in the babble and the jargon of a baby, we hear continuous, changing vocal patterns, usually free of any kind of interruption. It is not until age three or beyond that we sometimes hear and see an abrupt, observable break in the child's speech. Many children, do go through such a phase in which they might repeat words, phrases, hesitate, prolong sounds, and even struggle with some sounds but for the vast majority of children this phase is out grown. However, a small group of children (the best estimate approximately 0.7%) continue to have difficulty into their later years.

III. RESEARCH METHOD

PARENTAL PARTICIPATION:

An interview with parents would involve a brief telephone conversation about your child prior to your child's participation in the research project.

Appendix A - continued...

CHILD PARTICIPATION:

Each child will be asked to perform a number of manual tasks. This would involve each child tapping a key that is hooked up to a auditory/visual reaction timer, which simply records the number of key presses your child makes. Also, each child will be asked to press the key as fast as they can, while performing another task such as drawing circles with their other hand at the same time.

IIV. CONFIDENTIALITY

Confidentiality will be protected in that only the project researcher and her supervisors will have access to the information. All information will be stored in secure files for two years, at which time the files will be destroyed. The results of this research may be published or reported to government agencies, funding agencies, or scientific groups, but the information will be reported in such a way that no individual could be identified from the information given.

TO PARTICIPATE:

I would be most grateful for your participation in this study. Please sign the attached consent forms (2) and mail them in the enclosed stamped, self-addressed envelope. Once I have received your consent to participate in this study, I will get in touch with you to arrange times with you and your child. The actual conducting of the study will take place at the University of Calgary and will last about 45 minutes.

If you require more information prior to completing the two consent forms, please do not hesitate to contact Karen Varga.

Appendix B: Information Sheet for Parents of Fluent Children

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN BRAIN ORGANIZATION AND STUTTERING

INFORMATION SHEET

I. PURPOSE OF THE RESEARCH PROJECT

The major purpose of this research project is to examine the relationship between brain organization and a speech disorder known as stuttering. By agreeing to participate in this study you will be contributing to an area in which very little research has been done.

II. GENERAL INFORMATION ABOUT STUTTERING

The majority of children speak with amazing fluency. Even in the babble and the jargon of a baby, we hear continuous, changing vocal patterns, usually free of any kind of interruption. It is not until age three or beyond that we sometimes hear and see an abrupt, observable break in the child's speech. Many children, do go through such a phase in which they might repeat words, phrases, hesitate, prolong sounds, and even struggle with some sounds but for the vast majority of children this phase is out grown. However, a small group of children (the best estimate approximately 0.7%) continue to have difficulty into their later years.

As a parent with a child with no history of problems with speech you may be asking yourself the question: "How does my child fit into a research project about stuttering?" By allowing your child to participate in this study we can gain a better understanding of the differences in terms of brain organization between those children who have no history of a speech disorder and those who do have a speech disorder.

III. RESEARCH METHOD

PARENTAL PARTICIPATION:

An interview with parents would involve a brief telephone conversation about your child prior to your child's participation in the research.

Appendix B - continued...

CHILD PARTICIPATION:

Each child will be asked to perform a number of manual tasks. This would involve each child tapping a key that is hooked up to a auditory/visual reaction timer, which simply records the number of key presses your child makes. Also, each child will be asked to press the key as fast as they can, while performing another task such as drawing circles with their other hand at the same time.

IIV. CONFIDENTIALITY

Confidentiality will be protected in that only the project researcher and her supervisors will have access to the information. All information will be stored in secure files for two years, at which time the files will be destroyed. The results of this research may be published or reported to government agencies, funding agencies, or scientific groups, but the information will be reported in such a way that no individual could be identified from the information given.

TO PARTICIPATE:

I would be most grateful for your participation in this study. Please sign the attached consent forms (2) and mail them in the enclosed stamped, self-addressed envelope. Once I have received your consent to participate in this study, I will get in touch with you to arrange times with you and your child. The actual conducting of the study will take place at the University of Calgary and will last about 45 minutes.

If you require more information prior to completing the two consent forms, please do not hesitate to contact Karen Varga.

Appendix C: Permission Forms

CONSENT FOR RESEARCH PARTICIPATION

PARENTAL INFORMED CONSENT FORM

I, parent/guardian of ______________________________, consent to allow my child to be a participant in the research project at the University of Calgary entitled: "Interhemispheric interference: An investigation of fluent and dysfluent children." This research project is being conducted by Karen Varga, a Graduate student at the University of Calgary. Dr. Zwirner, of the department of Educational Psychology at the University of Calgary, and Dr. Gaines of the department of Speech and Language Pathology at the Alberta Children's Hospital are supervising this research project.

As a parent/guardian, I understand that:

1) My child's participation in this research project is completely voluntary, and that my child and/or I as a parent/guardian may decide freely to withdraw the child's participation in the research process;

2) My child's participation will involve performing a number of manual tasks (i.e., finger tapping, drawing circles).

3) All precautions will be taken by the researcher to ensure that the child's participation becomes a constructive experience.

4) I also understand that all information will be held in the strictest of confidence and my identify will in no way be associated with the results.

5) I also understand that if at any time I have questions, I can contact Karen Varga (Project Researcher) at xxx - xxxx or her supervisor Dr. Robin Gaines at xxx - xxxx.

______________________ DATE

______________________ (SIGNATURE, PARENT/GUARDIAN)

______________________ TELEPHONE NUMBER

______________________ WITNESS

Your signature on this form indicates that you have understood to your satisfaction the information regarding your participation in the research project.

Appendix C - continued...

CONSENT FOR RESEARCH PARTICIPATION

CHILD INFORMED CONSENT FORM

I, (child's name)______________________________ agree to participate in the research project called: "Interhemispheric Interference: An investigation of fluent and dysfluent children."

As a participant, I understand that:

1) Participation in this research project is completely voluntary and I can decide to stop participating at any time in the research process;

2) Participation in this study will involve performing a number of manual tasks (i.e., finger tapping, drawing circles).

3) All information will be held in confidence and my name will not be associated with the results.

______________________ DATE

______________________ SIGNATURE OF CHILD

______________________ WITNESS

Your signature of this form indicates that you have understand to your satisfaction the information regarding your participation in the research project.

Appendix D - Parent Questionnaire

Parents:

Below is a list of questions regarding your child's speech. It would be appreciated it if you could take the time to answer the following questions. This information is important to our understanding of Speech Disorders in children.
****

1) Could you describe at what age you first noticed something was different about your child's speech? What behaviours did he show?

____

2) What type of treatment is your child currently registered in:
-How often does your child receive speech therapy?
-What type of treatment is it? (Try to be as specific as possible).
-How long has your child been in speech therapy?

____

____

3) Familial history information:

In your family, is there another member (besides the participant in this project) who also has a stuttering problem?

(NOTE: The term family refers to both immediate (mother, father, sisters, brothers) and extended (grandparents, aunts, uncles, cousins) family members.

Yes or No (circle one);

If yes, could you describe their relationship to the participant in this study (i.e., mother, grandfather, etc):

___________________________________.

What type of a speech problem did this individual have (i.e,, stuttering, or was it something else?)

____

5) Please add any other information about your child's speech that was not addressed above:

____

*****THANK YOU FOR TAKING THE TIME TO ANSWER THESE QUESTIONS*****

APPENDIX E - Finger Tapping Apparatus