CHAPTER II

REVIEW OF LITERATURE
The present study aims to understand the nature of hemispheric processing in stutterers. Verbal and visuospatial functions were studied in stutterers and a matched group of controls (nonstutterers) using dual task procedures. The study also aims to test the hypothesis that stuttering is caused by aberrant interhemispheric relations. In addition, it was hoped to find out whether stutterers can be divided into subgroups according to presence or absence of family history, age of onset and severity levels based upon their performance in the tasks.

The theory that stuttering has a neurophysiological basis was first put forward by Orton (1927) and Travis (1931). They proposed that stutterers lack unilateral cerebral dominance for speech. At that time, however, the theory could not be directly put to the test. Today, rapid advances in technology have aided researchers considerably in their search for the brain mechanisms that underlie stuttering.

Hemispheric processing differences in stutterers has been studied using a variety of techniques. These include dichotic listening, tachistoscopic presentation, electroencephalographic techniques, averaged evoked potentials and dual task techniques. These will be reviewed below.
The dichotic listening task is a technique employed for investigating hemispheric laterality differences. First used by Kimura (1961a, 1961b), the dichotic listening task requires that a subject be presented simultaneously with two different auditory signals of equal intensity and onset times to the two ears. The subject has to recall the material that is presented. Normal subjects tend to recall more items from the right ear than the left since the vast majority of normal adults are known to be left hemispheric dominant for speech.

Although there are both crossed and uncrossed pathways from the ear to the cortex, Kimura (1967) cited evidence to indicate that the crossed pathways were dominant over the uncrossed ones and that information passing along the contralateral pathways would block or occlude information ascending the ipsilateral paths. Thus right-ear information would have direct access to the left auditory cortex whereas left-ear information would be forced to the right hemisphere and then have to be passed transcallosally before it could be analysed by the speech centres of the left hemisphere. Left ear information would therefore take longer to reach the speech centres and/or degraded by the longer transmission route.

The dichotic listening task has been the most popular procedure used to test hemispheric processing differences between stutterers and nonstutterers.
A considerable number of these studies have found that stutterers, unlike nonstutterers, present with higher left ear scores.

As early as 1969, Curry & Gregory studied 20 stutterers and 20 nonstutterers, using one monotic verbal listening task and three dichotic listening tasks—verbal as well as nonverbal. Stutterers had smaller difference scores between ears on the dichotic verbal task than did nonstutterers. 75% of the nonstutterers had higher right ear scores indicating left hemisphere activation for the verbal task. In contrast only 45% of the stutterers had higher right ear scores.

In a dichotic listening task utilizing nonsense syllables, a greater proportion of stutterers reported a left ear preference (Brady & Berson, 1975).

Sommers et al. (1975) used meaningful linguistic stimuli and reported a significantly larger proportion of stutterers with a left ear preference.

Sussman and MacNeilage (1975) tested stutterers and non-stutterers for laterality in relation to speech perception and speech production. The former was tested using a dichotic listening task while for the latter, a tracking paradigm was used. In the tracking paradigm, the subject had to match the frequency of a variable tone in one ear.
with the frequency of an externally varied tone in the other ear. The frequency of the former tone could be varied by the subject by moving his tongue or jaw. The authors found a right ear advantage for both the groups on the dichotic listening task. On the tracking task however, while normals showed a right ear advantage, stutterers did not.

Barret et al (1979) found significant differences between 10 stutterers and 10 nonstutterers on a dichotic consonant-vowel identification test.

In a study utilizing dichotic word and digit listening tasks, Davenport (1979) demonstrated significantly weaker right ear preference in stutterers. An interesting finding was that the right ear preference weakened as the severity level of stuttering increased.

A stop consonant-vowel dichotic listening task was used by Cimorell-Strong et al (1983) to compare dichotic speech perception between stuttering and nonstuttering children. Two and a half times as many stutterers as nonstutterers were found to display either a left ear advantage or no ear advantage. They interpreted their findings as suggesting a greater tendency on the part of stutterers as opposed to nonstutterers for reversed or bilateral representation of the auditory speech areas of the brain.
Laterality changes were investigated in young stuttering and nonstuttering children. Results suggest that younger stutterers present fewer right ear advantages than nonstuttering subjects (Blood et al., 1987).

Blood and Blood (1989) determined the difference among 18 male and 18 female stutterers and matched control groups on a meaningful, linguistic dichotic word task. A significant difference was found between stuttering and nonstuttering groups in the magnitude of ear preferences with the stutterers showing a left ear preference.

A number of studies have been reported which contradict the above findings.

In a method similar to that of Curry and Gregory (1969), Quinn (1972) investigated dichotic listening in 60 right-handed stutterers and matched controls. He did not find any difference between the two groups.

Two studies used dichotic digit pairs on child stutterers and failed to find significant inter-ear differences between the stuttering and the nonstuttering groups. (Slorach and Noehr 1973; Gruber and Powell 1974).

Dorman and Porter (1975) used a dichotic nonsense syllable test and found the performance of stutterers to be similar to that of nonstutterers. Similar findings were reported by Pinsky and McAdam (1980) using dichotic listening
with consonant-vowel pairs on 5 stutterers and 5 controls. Liebetrau and Daly (1981) also used consonant-vowel syllables in a dichotic listening task and found no difference between stutterers and nonstutterers.

Blood and Blood (1986) administered a dichotic digits test under conditions of free recall and directed attention. Analysis indicated right ear preference for both groups and no difference between the free recall and directed listening conditions.

The findings of the dichotic listening tasks appear to be equivocal. This may be due to a number of reasons. Some of the studies did not use stringent criteria in the selection of subjects with regard to handedness (Quinn 1972; Pinsky & McAdam, 1980). Since laterality is the issue in question, handedness is a factor that needs to be controlled. Piazza (1980) studied the influence of handedness in relation to dichotic listening tasks. She found left-handedness to be associated with atypical or bilateral hemispheric specialization. Galaburda et al (1990) report that there are anatomical differences in the brain between left-handers and right-handers. For instance, left-handers are more likely to have anatomically symmetric brain areas related to language than right-handers.
Investigators in the past have also not studied males and females as separate groups, (Curry and Gregory, 1969; Quinn, 1972). Significantly different patterns of anatomical asymmetry have been reported between the sexes, (McClone, 1980; Galaburda et al, 1990; Geschwind and Galaburda, 1985). With regard to functional differences, Piazza (1980) using verbal and non-verbal dichotic listening tasks found that males were more strongly lateralized for speech processing, whereas right-handed females were more strongly lateralized for processing nonspeech auditory stimuli. Also, the prevalence of stuttering is known to be different in the two groups. It has been found to be three times higher in boys than in girls (Andrews et al, 1983).

Rosenfield and Goodglass (1980) attempted to overcome these limitations and evaluated only strongly right-handed male stutterers on a dichotic consonant-vowel paradigm and on a melody paradigm. Results showed more stutterers to have a left ear advantage for verbal material. In addition, fewer stutterers had a left ear advantage for melodies.

Another reason for the contradictory findings may be due to the fact that the studies tested different variables and used different stimuli. Some investigators have employed nonsense syllables (Dorman and Porter, 1975; Brady and Berson, 1975), others have used words (Blood and Blood, 1989; Sommers et al, 1975) or digits (Davenport, 1979; Slorach and Noehr
If this factor is kept in mind a clearer picture emerges. When Moore (1984), for instance, examined studies which utilized only meaningful stimuli, he found that these studies generally reported a left ear preference in stutterers.

**ELECTROPHYSIOLOGICAL STUDIES**

Electrophysiological procedures permit researchers to study electrophysiological activity in both hemispheres simultaneously during information processing. Two such procedures, namely, electroencephalographic techniques and averaged evoked responses have been used with stutterers.

**Electroencephalographic (EEG) Techniques:**

In recent years, the EEG has gained popularity in the study of hemispheric processing and specialization. The alpha component of the EEG is reported to be suppressed during active processing. Cerebral asymmetry is studied by comparing the alpha components between hemispheres. Studies with normal subjects have revealed alpha suppression in the left hemisphere during the performance of verbal tasks (Galin and Ornstein, 1972; Doyle et al, 1974).

Moore has used spontaneous EEG procedures to study hemispheric activation differences in stutterers and nonstutterers. He measured alpha wave suppression in the two groups under various conditions by manipulating stimulus,
task and electrode placement variables. The stimulus material included single words of high and low imagery (Moore and Lorendo, 1980), words with different arousal values (Moore, Craven and Faber, 1982), connected reading passages (Moore, 1986), as well as words and sentences varying in complexity and syntactic structure (Moore, 1984). The tasks performed by the subjects were those of listening (Moore, 1986), formulation (Moore, 1986), production (Moore, 1984), recall and recognition (Moore and Lorendo, 1980; Moore, Craven and Faber, 1982).

In all the above conditions, greater right hemispheric alpha suppression has been consistently observed in the posterior electrodes for stuttering subjects. In contrast, alpha wave suppression in nonstuttering subjects varied according to stimulus and task conditions. In three of these studies (Moore, Craven and Faber, 1982; Moore and Lorendo, 1980; Moore, 1986), stutterers were found to recall and recognize significantly fewer words than nonstutterers.

The results of Moore and his co workers agree with those of Boberg et al (1983) who found greater alpha suppression in the right posterior frontal areas of stutterers during the processing of verbal information.

Hemispheric activation differences appear to have an effect on fluency as well. Moore (1986) studied the relationships between stuttering severity and alpha ratios
and found a significant correlation between the two. Results showed that as stuttering frequency increased, alpha ratios decreased indicating greater right hemisphere activation. In another study, he used electromyographic (EMG) biofeedback to reduce the dysfluent behaviour of a right-handed male stutterer. He also collected EEG alpha data during baseline as well as pre-treatment and post-treatment sessions. It was found that high dysfluency percentages were associated with greater right hemisphere alpha suppression, while a decrease in dysfluency was accompanied by increased left hemisphere alpha suppression (Moore, 1984). Similarly, Boberg et al (1983) reported greater alpha suppression in the right posterior frontal areas of stutterers. When stuttering was reduced after three weeks of therapy, a significant left hemisphere alpha suppression was observed during the performance of verbal tasks.

Based on his findings, Moore put forward a "segmentation dysfunction hypothesis" of stuttering wherein he suggests that stutterers use different processing strategies compared to nonstutterers. Specifically, they may be using the right hemisphere which is essentially a nonsegmental and time-independent processor (Moscovitch, 1977; Gordon, 1979) for linguistic-motor planning tasks. Such a processing strategy can disrupt motor speech fluency and speed of processing (Moore, 1990). Thus, the reported shifts in
alpha suppression from right to left with increased fluency (Moore, 1984,; Moore, 1986) could be because ". . . . . . compliance with task demands (increased verbal fluency) may have required the stutterers to draw primarily from the resource compositions of the left hemisphere" (Moore, 1990).

Boberg et al (1983), whose findings agree with those of Moore propose that right hemisphere activation during speech in stutterers may be due to "an inability of the left hemisphere to maintain stable inhibitory control over its homologous regions in the right hemisphere (and/or subcortical regions) of the brain during speech would be consistent with studies which indicate that stutterers have reduced ability to recall words (Moore, Craven and Faber, 1982; Moore and Lorendo, 1980) and also with studies which have found that patients with left frontal brain damage have significantly poorer verbal fluency than right frontal and left temporal lobe patients (Benton, 1968; Milner, 1964).

Averaged Evoked Response (AER) Studies:

An evoked potential (EP) is the electrical manifestation of the brain's reception of and response to an external stimulus. The evoked potentials cannot be seen in routine EEG recordings as their amplitude is low and they are lost against the background EEG activity. Separation of the EPs from the waveforms of the electrical activity of the brain
can be achieved by signal averaging. Since the electrical response of the brain to the stimulus always comes at the same interval of time after the stimulus, simple computers can be used to extract the desired signal from the temporally random background activity. Stimuli are given repeatedly and the computer averages the new data acquired after each stimulus with the averaged results from previous stimuli. This is continued till the desired waveform becomes sufficiently prominent (Chiappa, 1983).

Ponsford et al (1975) studied AER potentials with meaningful words embedded in phrases. Stutterers' responses were accompanied by greater AER changes in the right hemisphere unlike the nonstutterers who showed greater left hemisphere changes.

Shenker et al (1980) used AER techniques with stutterers and nonstutterers while they performed a single fluent word reading task. Nonstutterers showed significantly larger AER amplitudes in the left hemisphere than in the right. In contrast, stutterers did not show any significant left hemisphere advantage.

The contingent negative variation (CNV) is a slow potential shift in the EEG baseline which typically occurs on the association (contingency) of successive stimuli. It develops between the warning signal and the imperative signal in a constant foreperiod reaction time task. It appears
within the interstimulus interval as a surface negative shift in the EEG activity with respect to a mastoid reference. It is not readily seen in the raw EEG traces and hence averaging techniques are used to enhance the CNV amplitude relative to the background EEG. The maximum negative voltage, compared to the isoelectric direct current prestimulus baseline ranges from 10 µV to 50 µV. (Haider, Groll-Knapp and Ganglberger, 1981).

Zimmerman and Knott (1974) used a contingent negative variation (CNV) paradigm to investigate the relationships between slow potential shifts measured at the vertex and over inferior frontal positions in relation to speech onset. Verbal conditions were included. The verbal conditions consisted of a nonspeech expectancy condition and a speech condition. Differences were seen at the lateral electrodes in the verbal conditions between the two groups. Unlike the normal speakers who showed a larger shift in the left hemisphere than in the right, 88% of stutterers showed a right greater than left asymmetry. They concluded that the left and right inferior frontal areas of stutterers and non-stutterers performed differently even when no overt motor speech was required (the expectancy condition).

Pinsky and McAdam (1980) also used the CNV technique with stutterers. They however, did not find enough evidence to support hemispheric differences between stutterers and
nonstutterers. Similarly, Prescott and Andrews (1984) in a CNV study found greater late CNV over the right hemisphere prior to speech responses in both stutterers and nonstutterers. Reviewing AER research, Moore (1990) suggested that the different results obtained in these studies may be due to the differences in procedures and the nature of the tasks performed.

At present, the data available from electrophysiological research supports the findings of other procedures that stutterers use processing strategies for verbal tasks which are different from those of nonstutterers. Verbal tasks appear to be processed in the right hemisphere of significantly more stutterers than nonstutterers. With the exception of Boberg's study (1983) which implicated the right posterior frontal area in stutterers, the studies so far have not provided specific information regarding localization of activation and processing. Hence, further work is required in this area.

**TACHISTOSCOPIC STUDIES**

Studies on visual hemispheric asymmetry have generally used the tachistoscope which allows rapid controlled visual exposure of stimuli. Stimuli can be presented unilaterally or bilaterally. In the unilateral mode of presentation, subjects are required to fixate a central fixation point
after which lateralized stimuli are presented to one or the other visual field. The dependent measure commonly used for these procedures is the latency of vocal or manual reaction time as well as errors in recognition. Both the procedures have reported a right visual field superiority for verbal material and a left-field superiority for some types of nonverbal material (Bryden, 1982). Work with stutterers however, has not produced similar results.

In a bilateral tachistoscopic study of 15 stutterers and 15 normal controls, a significantly larger proportion of stutterers compared to controls demonstrated a left visual half-field preference. The results were interpreted as indicating reversed cerebral processing for the stuttering group (Moore, 1976).

Hand and Haynes (1983) measured normal and vocal reaction times of stutterers and nonstutterers to tachistoscopically presented meaningful and nonmeaningful stimuli. The reaction times of stutterers were slower for stimuli presented to the right visual field.

Using a unilateral tachistoscopic procedure, Johannsen and Victor (1986) found that two and a half times as many stutterers showed a right hemisphere superiority when processing verbal material than did nonstutterers.
Rastatter and his coworkers conducted a series of tachistoscopic studies aimed at exploring visual-language processing in stutterers. They measured vocal and manual reaction times to various linguistic stimuli (Rastatter and Dell, 1987a; 1987b; 1988; Rastatter, Loren and Colcord, 1987; Rastatter and Loren, 1988). In all the studies, stutterers exhibited a right hemispheric superiority for visual language processing, unlike nonstutterers. It is known that in normal speakers, the neurological structures underlying language processing are larger in the left hemisphere. Hence, the left hemisphere processes language and inhibits the right hemisphere from performing this function by the process of reciprocal interhemispheric inhibition (Kinsbourne, 1975). According to Rastatter and his coworkers, this process of reciprocal interhemispheric inhibition may be functionally different in stutterers. (Rastatter and Dell, 1987b). They suggest that during visual language processing, the right hemisphere of stutterers exhibits an interhemispheric inhibiting effect upon the left hemisphere. This suppresses the more efficient linguistic functions which are present in the left hemisphere.

This theory can also explain the findings of increased manual reaction time (Rastatter and Dell, 1985) and vocal reaction time (Rastatter and Dell, 1987; Hand and Haynes, 1983) in stutterers as compared to nonstutterers.
According to Rastatter, stutterers employ linguistic coding strategies which are different from nonstutterers. "Linguistic representation within each hemisphere bound to coding strategies mandated by hemispheric organization, may form the basis for aberrant interhemispheric linguistic and possibly cognitive interactions" (Rastatter, Loren and Colcord, 1987).

The results of the tachistoscopic studies point towards right hemispheric processing of visual language in stutterers and align well with the findings from electrophysiological research. The linguistic and cognitive processing styles of stutterers need to be studied further before a sound theoretical position can emerge.

DUAL TASK STUDIES

The dual task paradigm is a behavioral technique that has been used to study hemispheric specialization for language. Research has shown that simultaneous performance of two tasks results in the deterioration of one or both tasks, presumably due to interference between the two tasks. In a dual task study, the subject is required to perform two tasks, such as a motor task and a speech task, simultaneously. Interference is measured by comparing the scores of each task when performed alone and under dual task conditions.
It was Kinsbourne and Cook (1971) who first investigated the effects of speaking on a motor task. Subjects were required to speak while balancing a dowel rod on the left or the right hand. They found that speaking selectively interfered with right hand performance in normal right-handed adults. Their results were replicated by Hicks (1975) who also found that as the phonetic difficulty of the verbal task increased, more errors occurred in right hand balancing while left hand balancing was unaffected. Also, more errors were present in the verbal task with right hand balancing but not with left. Kinsbourne and Hicks proposed a model of "functional distance". According to this model, two concurrently performed activities will interfere with each other if their cerebral representations are functionally close to each other. The closer the functional distance between them, "the more apt is the motor program generated by each to be perturbed by overflow from the other one." (Kinsbourne and Hicks, 1978). Thus, concurrently performed activities which are programmed within the same hemisphere will compete for contiguous functional space and show decrements in performance when compared to activities which are programmed from opposite hemispheres. This is known as intrahemispheric or lateralized interference.

Hemispheric specialization for language can be assessed using dual task methods for the following reason — a motor task performed by the hand is mainly controlled by the
contralateral hemisphere. Hence, greater right-hand interference produced by the verbal concurrent task indicates more left hemisphere involvement for the verbal activity. (Kinsbourne and Hiscock, 1983).

Dual task methodology has commonly used index finger tapping (Lempert and Kinsbourne, 1985; Green et al, 1990) and sequential finger tapping (Hicks et al, 1975; Lomas and Kimura, 1976; Greiner et al, 1986a) as the motor tasks. In index finger tapping, the measure of performance is the number of taps made. In sequential finger tapping, it is the number of sequences tapped as well as the number of errors made which are considered as performance measures. The verbal tasks have varied widely. They include repeating simple phrases (Brutten and Trotter, 1986) shadowing (Briggs, 1975; Green et al, 1990), reciting rhymes (Hiscock and Kinsbourne, 1980), reading (Sussman, 1982; Greiner et al, 1986a), memorizing (McFarland and Ashton, 1978; Ikeda, 1987) and speaking spontaneously (Greiner et al, 1986a).

Conditions necessary for lateralized interference:

There is some controversy regarding the procedures to be used in order to generate lateralized interference. While Kinsbourne and coworkers are of the opinion that lateralized interference can be demonstrated using a wide range of tasks and under different conditions, Lomas and Kimura believe that lateralized interference can occur only
under certain conditions. They (Lomas and Kimura, 1976) used a variety of tasks along with a speech task and a humming task. When dowel balancing was the motor task, right-handed male subjects displayed interference in the right hand when speaking. They also showed bilateral interference when humming. Index finger tapping produced bilateral interference when speaking but no interference when humming. With sequential finger tapping, subjects showed right-handed interference while speaking. Humming, however, did not produce interference in both hands. Lomas and Kimura state that it is not enough that two activities should be processed within the same hemisphere for lateralized interference to occur, there should be some functional similarity between the two activities. They propose that the left hemisphere contains a system which controls movement transitions which is also linked to speech articulation. Hence, intrahemispheric interference can occur in the left hemisphere of right-handers when the dual tasks are sequential movements and speech. In a later study, Lomas (1980) found that selective interference occurs only when subjects are unable to view their hands during sequential finger tapping. Thus, according to these investigators, motor tasks involving manual sequencing performed without visual guidance and verbal tasks with overt vocalization (articulation) are necessary if lateralized interference is to occur.
Subsequent studies have disproved this claim. Index finger tapping has been shown to produce lateralized interference. Bowers et al (1978) found that verbal tasks interfered more with right-handed index finger tapping than left. Similar results were obtained by Hiscock and Kinsbourne (1978; 1980), Hellige and Longstreth (1981), Kee, Bathurst and Hellige (1983) and Lempert and Kinsbourne (1985). Lateralized interference was also seen when the concurrent manual task was a complex co-ordinator (Briggs, 1975), a hole steadiness tester (Botkin et al, 1977), and a unimanual force production task (Digby et al, 1986).

Other studies have demonstrated that lateralized interference can occur under conditions of both visual guidance and nonvisual guidance (Thornton and Peters, 1982; Lempert and Kinsbourne, 1985 and Ikeda, 1987).

Further, it has been found that vocalization is not essential for producing lateralized interference with right-hand performance. A cognitive-verbal task is sufficient to produce interference (Bowers et al, 1978; Hellige and Longstreth, 1981; Kee et al, 1983; Ikeda, 1987).

Visuospatial Tasks and Interference Effects:

It has been argued that if intrahemispheric interference can be demonstrated in the left hemisphere, it should be possible to demonstrate it in the right. Thus, for instance, it should be possible to demonstrate interference with left-
handed tapping and a visuospatial task. So far, however, dual task studies have not been able to clearly demonstrate this effect.

A few studies have shown left lateralized interference. McFarland and Ashton (1975, 1978) have demonstrated interference in the left hand with a concurrent visuospatial task. Hellige and Longstreth (1981) also found that the tapping rate decreased more for the left hand than for the right when the concurrent task was one which involved visuospatial processing.

Other studies have reported conflicting results. Bowers et al (1978) found that tapping decreased in both hands with a visuospatial task. Summers and Sharp (1979) found that the spatial task produced decrements in right-hand performance rather than left. Left-hand tapping, however, was found to reduce recall. Sussman (1982) found interference in the left hand of left-handers but not right-handers for visuospatial processing.

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Dual Task Studies with Left-handers:

While right-handed subjects have shown interference in the right-hand with a concurrent verbal task, studies with left-handers have not yielded consistent results. Hicks (1975) as well as Lomas and Kimura (1976) observed bilateral decrements with verbal tasks in left-handed subjects. Greiner et al (1986) found that while interference occurred in both hands, the left hand was more interfered with than the right. Two studies warrant attention as they involve large scale left-handed populations. Orsini et al (1985) tested 257 subjects while Simon and Sussman (1987) tested 260 subjects. Both investigations revealed significantly more decrements in the left hand of left-handers.

The dual task findings are at variance with the results from language lateralization studies of clinical populations. The latter studies estimate that while about 66% of left-handers have left hemisphere dominance for language, about 17% have right hemisphere dominance and the remaining 17% are bilateral for language (Bryden and Steenhuis, 1991).

The bilateral decrements observed in some of the dual task studies have led Greiner et al (1986a) to suggest that verbal functions in left-handers are bilaterally organized. Others like Orsini et al (1985) who found left-handed decrements in left-handers propose that ".... manual dominance rather than language may be involved in the observed
dual task results." Hellige and Kee (1990) suggest that in left-handers, both hemispheric specialization and manual dominance may be involved. To test this hypothesis, Cherry and Kee (1991) made left-handed subjects perform a dual task and dichotic listening task. They divided subjects according to hand dominance for tapping. An analysis of baseline tapping rates showed that 75% of subjects were left dominant for tapping while 25% were right dominant. Subjects were also classified as consistent or inconsistent for sidedness advantage. Subjects who showed dominance on the same side for baseline tapping and dichotic listening (for example, right hand/right ear) were labelled as consistent. Subjects who showed dominance on the opposite side (for example, right hand/left ear) for the tasks were classified as inconsistent. They found that while performing concurrent verbal tasks, left-handers classified as consistent showed significantly greater interference on tapping by the dominant hand irrespective of whether the dominant hand was left or right. Left-handers in the inconsistent group showed equal interference in both hands. Thus both manual dominance as well as hemispheric specialization influence dual task results. Cherry and Kee (1991) suggest that further dual task studies should either design procedures that can separate the effects of hemispheric specialization from those of manual dominance or attempt to reduce the effects of manual dominance.
The Dual Task Paradigm and Stuttering:

With its ease of administration and the fact that it lends itself easily for use under a range of conditions, the dual task technique has been used by researchers in neuropsychological studies of stuttering.

Sussman (1982) used the dual task paradigm to study hemispheric lateralization for language and visuospatial processing in fluent right-handers and left-handers, as well as in stutterers. He used finger tapping as the motor task. Language tasks included reading a passage and counting backward by threes. Visuospatial tasks consisted of alphabet scanning and object chimera. While the concurrent reading and finger tapping tasks revealed a lateralized left hemisphere effect for right-handed subjects, it failed to elicit a laterality effect for left-handers and right-handed stutterers. In addition, there was a significantly higher absolute level of disruption in these two groups compared to right-handers. The object chimera task revealed a right hemisphere interference effect for left-handers and an interference in the opposite direction for stutterers. In addition, stutterers had the lowest absolute level of interference on the chimera task of all three subject groups. According to Sussman, low absolute levels of disruption are encountered when cognitive function is strongly represented within a hemisphere. High absolute levels of disruption are
associated with symmetrical functions. Sussman concluded that stutterers have a tendency towards symmetrical language representation and left hemisphere representation for visuospatial processing, a pattern of hemispheric representation which is quite unlike that of nonstuttering right-handers.

Sussman's findings have been questioned by Brutten and Trotter (1985; 1986) (a) because he used a small sample size of ten and (b) because he did not include a nonverbal vocalic condition. Hence, from the design one cannot "determine if the interference effects were due to meaningful speech or merely to the production of sounds" (Brutten and Trotter, 1986).

Brutten and Trotter (1985) attempted to overcome these limitations by using a relatively larger sample of 24 stutterers. The control task consisted of index finger tapping while the dual task conditions consisted of three verbal tasks of increasing difficulty and one nonspeech vocalic task. As in Sussman's investigation, they found that speech reduced the tapping rate in both hands. However, a similar effect was observed in the nonspeech vocalic condition. According to these investigators, if lateralization was being tested, an interference effect should have been observed in the contralateral left hand as the right hemisphere is reported to be dominant for nonverbal
vocalic conditions (Wyck, 1968). In addition, it was found that the tapping rates decreased in both hands as the concurrent task increased in difficulty.

From the findings of the above two studies, they concluded that ".... the neuromotor system of stutterers is generally less robust than that of nonstutterers" (Brutten and Trotter, 1986). They also felt that the dual task paradigm is not useful for demonstrating hemispheric dominance for speech as the controls did not show the expected right-hand decrement for the speech task and left-hand tapping decrement for the nonverbal vocalic task.

Greiner, Fitzgerald and Cooke (1986a) used the dual task paradigm to study hemispheric processes in right- and left-handed stutterers and nonstutterers using tasks that require concurrent speech and manual activity. Subjects were required to perform a left-hand and right-hand unimanual sequential finger tapping task in each of four experimental conditions. They were silent tapping, spontaneous speech, reading aloud and singing. Interference was seen in the right as well as left hand of right-handed subjects suggesting intrahemispheric as well as interhemispheric processing. Stutterers were found to have slower tapping rates than nonstutterers during the spontaneous speech task regardless of the tapping hand or handedness. Another finding was that concurrent motor tasks interfere with speech production —
speech rates were slower for both groups in the concurrent spontaneous speech task condition with the stutterers' speech rate being slower than that of the nonstutterers. Their results suggest that interhemispheric co-ordination processes are more responsible for the regulation of speech and motor control systems than intrahemispheric competition. Further, they suggest that stutterers have difficulties in the temporal regulation of the right hemisphere and this may create an imbalance between right and left hemisphere activation and inhibition.

One form of the dual task paradigm is the bimanual handwriting task where the subject is required to write with both hands simultaneously. In a study by Fitzgerald et al (1984) right-handed adult stutterers and nonstutterers had to write the digits 1-12 as quickly as possible using both hands simultaneously. Stutterers showed greater handwriting differences between the hands. They made more mirror reversals and had significantly poorer handwriting organization in the non dominant hand. They suggested that inefficient interhemispheric coordination may account for the poorer performance of stutterers.

In another study by the same group of workers (Greiner, Fitzgerald and Cooke, 1986), simultaneous handwriting was compared in right-handed as well as left-handed stutterers and nonstutterers. Two different handwriting tasks were
utilized. One required simultaneous handwriting of the digits 1-12 as fast as possible. The other task involved simultaneous handwriting of stimuli presented one at a time. Some of the stimuli consisted of digits and letters to preferentially engage left hemisphere processing. The other stimuli consisted of geometric forms in order to preferentially engage right hemisphere processing. The results showed that right-handed stutterers had significantly poorer nondominant hand performance for digits and letters as compared to right-handed nonstutterers. There were no differences between these two groups with regard to handwriting organization for geometric forms. Also, there were no significant differences in handwriting organization between left-handed stutterers and nonstutterers. With regard to mirror reversals, right-handed stutterers made more total mirror reversals, dominant and nondominant hand reversals than did nonstutterers. Left-handed stutterers showed more total reversals and nondominant hand reversals than did nonstutterers.

The above results are consistent with the findings of Fitzgerald et al (1984). Interhemispheric integration processes appear to be involved here as poorer handwriting organization and increased mirror reversals were observed in the nondominant hand of right-handed subjects, especially in stutterers. Greiner et al (1986b) have put forward the hypothesis that "Bimanual tasks involving symbols like digits
or letters that depend on motor lead control of the left hemisphere, interfere with the left hemisphere's inhibitory influence on motor activation of the right hemisphere". Their findings also support the contention of Moore and others (Moore, 1990; Boberg et al., 1983; Rastatter and Dell, 1987b), that right hemisphere function may be a source of interference in stutterers.

Recently, Webster conducted a number of studies in order to test the hypothesis of interhemispheric interference. He examined the motor and cognitive performance of stutterers under different conditions. Although the tasks that he employed did not require speech, they are relevant to the understanding of the neural mechanisms underlying speech.

He first compared the sequential finger tapping performance of stutterers and nonstutterers and found no significant impairment in the performance of the former. He concluded that the neural systems mediating sequential movement and presumably speech are lateralized in stutterers in the left hemisphere just as they are in nonstutterers (Webster, 1985; 1986a).

In another study (Webster, 1986b), he used a sequence reproduction task in which subjects were required to tap different combinations of sequences shown on a visual display panel. From the results of this investigation, he concluded
that the neural systems in stutterers, although lateralized in the left hemisphere are not as efficient as those in fluent speakers in organizing and initiating new movements. Not unlike the hypothesis of Fitzgerald et al (1984) and Greiner et al (1986b), he suggests that the left hemisphere mechanisms of stutterers may be unusually susceptible to right hemisphere activities. He also suggested that more than the motoric complexity of a task, it may be its cognitive complexity that distinguishes the stutterers from the nonstutterers.

Webster (1988) explored the interhemispheric interference hypothesis using dual task procedures which were bimanual in nature. Male adult right-handed stutterers and nonstutterers performed sequential finger tapping and index finger tapping with one hand while carrying out a concurrent manual task like button-pressing or knob-turning with the other hand. The two groups did not differ in baseline performance. Also both showed a significant right-hand advantage for both types of finger tapping. Stutterers displayed more interference in the condition of right-hand sequential finger tapping with concurrent manual task condition. It is presumed in this condition that the two hemispheres are activated. The two groups did not differ in the reversed dual task condition suggesting that the differential interference effects in the two groups could be due to interhemispheric interference rather than a general
difficulty by stutterers in performing two tasks simultaneously (Webster, 1986a).

Webster (1989) next replaced the sequential finger tapping task with the sequence reproduction task and used the knob-turn task as the concurrent task. Stutterers were found to have significantly longer sequence initiation times and fewer correct initial sequences than controls under baseline conditions. Under concurrent task conditions, stutterers made fewer correct initial sequences and had slower knob-turn initiation times than nonstutterers. Here again, the results were found to be consistent with the interhemispheric interference hypothesis.

In another study, Webster (1988) used a bimanual handwriting paradigm in order to replicate the findings of Fitzgerald et al. (1984) and Greiner et al. (1986b). This study differed from those of the latter where consecutive numbers had to be written with both hands simultaneously. Here four words were called out at a time to the subjects. They had to repeat the words following which they were required to write the four words with both hands simultaneously without visual guidance. This task presumably involves major activation of the left hemisphere. Stutterers made significantly more mirror reversals than nonstutterers with the nondominant hand. These results are consistent with the findings of Fitzgerald et al. (1984) and Greiner et al. (1986). In addition
it was found that the quality of letter formation of stutterers was poorer and they were slower in completing the trials than the nonstutterers.

Based on his findings, Webster has proposed that the Supplementary Motor Area (SMA) may be involved in the mediation of stuttering. The SMA is located on the mesial surface of the frontal lobe of the human brain. The SMAs of each hemisphere are strongly connected to each other through the corpus callosum. They also have projections to both the ipsilateral and contralateral primary motor cortices (Goldberg, 1985).

Regional Cerebral Blood Flow (rCBF) studies reveal bilateral activation of the SMA during automatic speech. This suggests that the SMA may be involved in the programming of the motor sequence to produce speech (Larsen et al., 1978, Roland et al., 1980). Damage to the SMA, particularly the left hemisphere, results in difficulties in initiating speech (Goldberg, 1985). Webster (1988) has drawn parallels between the speech initiation difficulties of the patients with SMA lesions and those of stutterers. Stutterers too, were found to have difficulty organizing and initiating new nonspeech response sequences (Webster, 1986b).

In bimanual tasks where the two limbs are required to function in a complementary and co-operative manner a high
degree of co-ordination between the SMAs through the corpus callosum is necessary (Kelso et al., 1979). Primates with unilateral SMA lesions were found to produce mirror-symmetric movements in bimanual coordination tasks which require independent movements of two hands as did patients with SMA lesions (Brinkman, 1982). Webster's studies have shown that stutterers made more mirror reversals in a bimanual co-ordination task (Webster, 1988).

Webster's work represents a systematic approach in neuropsychology towards understanding the brain mechanisms underlying stuttering. According to him, interhemispheric communication in stuttering is considerably vulnerable to interference from other ongoing neural activities. This may be due to a callosal gating deficit which has its source in the SMA.

Webster's studies suggests that subgroups may exist in the stuttering population (Webster, 1985; 1988). Unfortunately, he had not taken into account such characteristics as familial history, age of onset, or severity in his research. Also, his stuttering subjects varied in age, education and treatment history. Perhaps more meaningful information might have been obtained, if such subgroups had been compared on their motor and cognitive performance.
To summarize, various investigatory procedures have revealed the existence of hemispheric processing differences between stutterers and controls. A large number of dichotic listening tasks have found that stutterers unlike nonstutterers present with higher left ear scores for verbal tasks. EEG techniques, in general, reveal alpha suppression in the right hemisphere of stutterers during the performance of verbal tasks. Tachistoscopic studies have found that stutterers show a left visual half-field preference. Dual task studies indicate that stutterers do not show the expected pattern of right-hand tapping decrements in a motor-verbal dual task paradigm.

Various hypotheses have been put forward to explain these differences. These include reversed or bilateral speech mechanisms, inappropriate right hemisphere activation during speech which can disrupt motor speech fluency, and inefficient interhemispheric co-ordination. Evidence to support these hypotheses are limited and conflicting. It is clear that the theoretical issues pertaining to the neural mechanisms underlying stuttering cannot be resolved without adequate experimental evidence to support or refute them.

The present study was designed to investigate whether hemispheric processing differences exist between stutterers and nonstutterers with regard to verbal and visuospatial tasks using a dual task paradigm. The study also attempted
to overcome the limitations of previous dual task studies. A bimanual handwriting task was included to examine the hypothesis of inefficient inter-hemispheric communication in stutterers. The question of whether subgroups exist in the stuttering population was addressed by examining the effect of family history, age of onset and severity on test performance.

The details of the investigation are presented in the following chapter.