CENTRAL AUDITORY PROCESSING PERFORMANCE OF MALE AND FEMALE STUTTERERS AND NONSTUTTERERS

by

HARSHA KATHARD

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Faculty of Health Sciences,
University of Durban-Westville

Supervisor : Mr C.D. Govender

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ABSTRACT

Central auditory processing performance of male and female stutterers and nonstutterers was compared on a battery of central auditory tests. Thirty stutterers (15 male and 15 female) with a mean age of 23.10 years (17.2-31 years) comprised the experimental group, and 30 nonstutterers (15 male and 15 female) with a mean age of 22.2 years(17-32 years) comprised the control group. The test battery included dichotic (DCV test, SSW test, CST) and monotic (SSI-ICM test, ARLT) tests. Stutterers performed significantly poorer than nonstutterers on various parameters of individual tests. The stutterers' performance on the test battery was varied : 8(26.6%) stutterers passed all tests in the battery; 7(23.3%) failed dichotic tests only; 15(50%) failed dichotic and monotic tests of which 2(6.6%) failed monotic tests. Pass/fail rates indicated that although 15 (50%) nonstutterers failed the battery 22(73.2%) stutterers failed. This result confirmed that stutterers performed significantly differently from nonstutterers on the test battery($\chi^2 = 19.87$, df=1; $p<0.05$). Male/famale comparisons for nonstutterers indicated no significant differences ($p>0.05$) on individual tests except on the ARLT where males obtained longer latencies than females. Pass /fail rates on the test battery confirmed no statistically significant ($\chi^2 = 0.133$, df=1; $p> 0.05$) performance differences between male and female nonstutterers. For stutterers, although male performance was poorer than female performance on various parameters of individual tests ,the performance differences were not significant ($p>0.05$). However, pass/fail performance on the test battery indicated that significantly more males (13) than females (9) failed the test battery ($\chi^2 = 8.66$ df=1, $p<0.05$). The results are discussed in terms of the literature and theoretical and clinical implications are presented and discussed.

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Abbreviations used in the study

S	stuttererers (experimental group in the present investigation)
NS	nonstutterers (control group in the present investigation)
SM	stutterers-male
SF	stutterers-female
NSM	nonstutterers-male
NSF	nonstutterers-female
REA	right ear advantage
LEA	left ear advantage
NEA	no ear advantage
DCV	Dichotic Consonant-Vowel
SSW	Staggered Spondaic Word
CST	Competing Sentences Test
SSI-ICM	Synthetic Sentence Identification - Ipsilateral Competing message
ARLT	Acoustic reflex latency test
CV	consonant-vowel
R	right
L	left
RC	right competing
RNC	right noncompeting
LC	left competing
LNC	left noncompeting
BSER	brainstem evoked response
MCR	message-to competition ratio

GLOSSARY OF TERMS

The following terms have been used in the present study :

central auditory processing : The manipulation and utilization of sound signals by the central auditory nervous system which incoporates the range of activities from the awareness of sound to the analysis of linguistic information. For the purposes of the present study, the term incoporates what is traditionally referred to as central auditory perception (Lasky & Katz, 1983).

acoustic reflex latency : Time interval between the presentation of an acoustic stimulus and the first impedance change recorded at 10% of the maximum slope of the latency recording (Church & Cudahy, 1984).

contralateral acoustic reflex: measurement of reflex-related change in acoustic immitance in one ear with acoustic stimulation of the opposite ear (Grason-Stadtler, 1989).

ipsilateral acoustic reflex: Measurement of reflex-related change in acoustic immitance in the same ear that is acoustically stimulated (Grason-Stadtler, 1989).

tonotopic : refers to the the representation of stimulus frequency in spatially ordered sets of neurons (Pinheiro & Musiek, 1985).

disfluency : refers to discontinuities observed as a normal part of speech (Starkweather, 1987).

dysfluency : refers to marked problems with speech fluency such as that observed in stuttering (Starkweather, 1987).

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CHAPTER ONE

MOTIVATION FOR THE STUDY

1.1. INTRODUCTION

Extensive research efforts have been undertaken to identify the etiology/etiologies underlying stuttering. Emerging from such research was the formulation of various theories which may be categorized into three major theoretical groups : stuttering as a personality disorder, stuttering as a learning disorder, and stuttering as a constitutional/organic problem (Eisenson & Ogilvie, 1983).

The focus of this study relates to the *organic* group of theories which have arisen from an emerging body of literature suggesting that there are stutterers who have some type of organic or physiological dysfunction, or who have a proclivity to such organicity (Liberatrau & Daly, (1981). Among the organic etiologic theories that have been described, are those that suggest a central *auditory perceptual disorder*, as being, in part, etiological in stuttering behaviours (Toscher & Rupp, 1978). In this tradition, many investigators have examined central auditory processing performance of stutterers.

The impetus for comparing the *central auditory function* of stutterers and nonstutterers has arisen from two major theories about the etiology, and possible site(s) of lesion for stuttering (Hageman & Greene, 1989).

On one hand, researchers (Curry & Gregory, 1969; Hawver, 1978; Pinsky & McAdam, 1980), have used measures of central auditory function with stutterers to investigate cerebral dominance for speech and/or language. These investigations were based on the Orton-Travis theory which postulated that stuttering may be related to the abnormal bilateral representation of cognitive functions in the cerebral hemispheres (Pinsky & McAdam, 1980). The contention was that whilst the language of fluent speakers was confined to the left hemisphere, the language of individuals who stuttered was represented bilaterally. The model suggested that the bilateral control of the speech mechanism produced interhemispheric competition which manifested in stuttering. The implication was that differences between stutterers and nonstutterers would suggest a possible site of dysfunction in the cortical area (Rosenfied & Jerger, 1984).

On the other hand, some researchers (Stager, 1990; Hageman & Greene, 1989; Toscher & Rupp, 1978) have used measures of central auditory processing to investigate possible anomalies along the auditory pathway. The notion that stuttering might be due to a defect in the auditory feedback mechanism subserving speech production has been the focus of research on stuttering for many years (Rosenfield & Jerger, 1984). Early research (Harms & Malone, 1939; and Backus, 1938; cited in Bloodstein 1987), reported a very low prevalence of stuttering amongst the deaf. This finding suggested a relationship between stuttering and a disturbed auditory circuit. The role of auditory processing in stutterers was further explored by Lee in 1951, who noted that speech was disturbed when the speakers' voice was fed back to his ears after a definite time delay.

Based on these observations, Lee suggested that stuttering was the result of a faulty monitoring system. Further research noting the effects of auditory masking (Maraist & Hutton, 1957 cited in Starkweather, 1987), linked stuttering and auditory function. As a result of these and other findings, researchers have postulated central auditory processing models to describe auditory processes underlying stuttering (Fairbanks, 1954; Mysak, 1960). The primary assumptions underlying these models were that stutterers have disturbed speech-auditory feedback loops which occur as a result of a central auditory processing deficit at some level of auditory processing. Since stutterers have normal peripheral hearing sensitivity, any problems with auditory processing is likely to be related to deficits at a central level, and more specifically at the brainstem level (Hall & Jerger 1978; Toscher & Rupp 1978; Hageman & Greene 1989). The present researcher guided by the contention that stuttering may be linked/related to some central auditory processing anomaly, intends to explore this hypothesis further.

1.2. **MOTIVATION**

The motivation for this study has arisen from the following considerations :

i. A review of available literature has indicated whilst many studies have compared central auditory processing performance of stutterers and nonstutterers, the results remain largely inconclusive. Whilst some studies do support the contention that there are differences between stutterers and nonstutterers on central auditory tasks (Hall & Jerger, 1978; Toscher & Rupp, 1978; Hageman & Greene, 1989); others do not (Blood & Blood, 1984b; Molt & Guildford, 1979). It is therefore, the intention of this research study to assess stutterers on central auditory processing tasks, and to add to the body of knowledge in this controversial field of study.

ii. Stuttering is a multidimensional disorder (Preus, 1981 cited in Rentscher, 1984) and stutterers are characterised by heterogeneity with respect to many factors such as etiology, responsiveness to treatment, severity and symptomolology (Poulos & Webster, 1991). Research with stutterers has traditionally been plagued by the great deal of variability due to the heterogeneous nature of the stuttering sample selected. In order to reduce such variability, and not to dilute the power of the research findings, the group investigated needs to be homogenous (Rentschler, 1984). Differentiation of subgroups of stutterers needs to be considered in research design, and this aspect was considered in the selection of the sample used in this study.

Amongst the many factors considered to maintain homogeneity of the stuttering sample selected the following are considered relevant.

a. Family history of stuttering : Poulos and Webster (1991), have suggested that family history could be used as a basis for subgrouping people who stutter, in an attempt to reduce variability. Furthermore, Jannsen, Kraaimat and Brutten (1990), stated that it was likely that an inherited predisposition for stuttering could generate neuromotor deficits that could form the basis of stuttering. It was therefore suggested that using family history of stuttering as criterion in subject selection be considered. The present research project has taken cognisance of this and has included a positive family history of stuttering as a criterion for subject selection for stutterers.

b. Treatment considerations : all stuttering subjects considered in this study received some form of fluency enhancement treatment but reported persistent dysfluency.

c. Age : The subjects included in this study were young adults. This group was chosen because:

- the chances of spontaneous recovery from stuttering, at this age, would be unlikely (Andrews, 1984). All of the subjects who stuttered also reported the onset of stuttering in the developmental years, thus ruling out the possibility of including stutterers with specific acquired neurogenic etiology of stuttering.

- The effect of age (Katz, 1986), on central auditory processing has been noted. Blood and Blood (1984a), have indicated that adults perform better than children, and Amerman and Parnell (1982), have found that adults over the age of sixty obtained greater number of error scores on central auditory test measures compared with young adults. Therefore, all subjects were between seventeen and thirty two years old, so as to negate the influence of age-related factors.

d. Sex : In order to maintain a more homogenous sample, stutterers and nonstutterers were divided on the basis of sex. Blood and Blood (1989a), report that because the incidence of stuttering in males and females is so different, female stutterers may be processing auditory information differently from their male counterparts. Therefore, the use of combined samples of males and females is contraindicated.

iii. Of specific importance to the present study is the constant reference made in the literature to the limited investigation related to auditory performance differences of stutterers based on sex. (Hagemen & Greene, 1989). Investigation of this aspect is important for two reasons. Firstly, McGlone (1980), in an extensive review of sex differences in cerebral processing, suggested that there may be differences in the manner in which males and females process auditory information. This suggestion, as it may relate to male and female stutterers has received little attention.

Secondly, and perhaps of great significance, is the long established sex ratio. Bloodstein (1987), has presented a ratio of male to female stutterers as 3:1. Many explanations for the sex ratio have been described, and there may be a physiological basis such as that related to central auditory processing. This, therefore, warrants consideration. It is likely that the findings of this research would contribute to the explanation of the sex ratio.

Most investigations have used male stutterers as subjects (Blood, 1985; Blood & Blood, 1986; Cimorell-Strong, Gilbert & Frick, 1983; Libertrau & Daly, 1981) whilst others have used both male and female stutterers (Dorman & Porter, 1975; Gruber & Powell, 1974; Tsunoda & Moriyama, 1972). A specific objective of this study is, therefore, to compare the performance of male and female stutterers on central auditory processing tasks. For the purposes of the present study it is important that the performance of male and females, in stuttering and nonstuttering groups, be analysed separately, so as to facilitate comparisons between homogeneous groups.

iv. Some of the studies undertaken have used one or two specific measures to investigate central auditory processing in stutterers. This is considered unsuitable since single test measures may show considerable variability. Therefore, a battery of tests to measure central auditory processing has been recommended (Hall & Jerger, 1978). The present study was conducted using a test battery approach. This battery comprised the Dichotic Consonant Vowel DCV test, Competing Sentences test, Staggered Spondaic Word Test, Synthetic Sentence Identification Test, and the Acoustic Reflex Latency Test. A battery of this nature was chosen in an attempt to evaluate central auditory processing at the level of the brainstem, as well as at a cortical level. Thus, a need for a comprehensive assessement of central auditory processing for stutterers and nonstutterers was acknowledged.

1.3. SUMMARY OF FACTORS MOTIVATING THIS STUDY

- lack of consensus amongst researchers regarding the nature of central auditory processing differences between stutterers and nonstutterers

- the need for selection of a sample that is more homogeneous in nature, as heterogeneous samples have traditionally generated variability in stuttering research

- comparisons between stutterers and nonstutterers based on sex differences, are lacking in stuttering research

- there is a need to use a test battery approach in attempting to assess central auditory processing performance as this approach has not been rigorously adhered to in stuttering research.

1.4. CONCLUSION

In this chapter, the areas under investigation and the factors motivating research of this nature, have been identified. The chapters that follow will provide an overview of central auditory function, stuttering, and the theoretical perspective of stuttering as a disorder related to central auditory processing. A literature review, the design of the investigation, its execution, results and discussion thereof, will also be presented.

A review of three major bodies of literature that follows is a prerequisite so as to facilitate an understanding of stuttering and central auditory processing. The topics requiring review include:

a. Central auditory processing and measurement of thereof.

b. The nature of stuttering.

c. Theoretical perspectives on stuttering as a central auditory processing disorder.

CHAPTER TWO

CENTRAL AUDITORY PROCESSING AND STUTTERING

2.1. CENTRAL AUDITORY PROCESSING

The review that follows highlights salient aspects pertinent to central auditory processing. These include :

- Introduction
  - A description of central auditory processing
  - Auditory processing as a central neurological process
- Theoretical perspectives on central auditory processing
- Neuroanatomy, neurophysiological, and central auditory processing assessement
- Assessement of central auditory processing
- Motivation for choice of test battery used in the present investigation
- Description of tests used in the present investigation

2.1.1. INTRODUCTION

i. A description of central auditory processing

According to Lasky and Katz (1983), central auditory processing is considered to be the manipulation and utilization of sound signals by the central auditory nervous system. Central auditory processing includes a range of processes from the awareness of the presence of a sound, to the analysis of linguistic information. The actual auditory processing of the sound begins in the peripheral auditory system when sound is captured by the pinna and enters the ear canal. However, *central auditory processing* *begins at the level of the cochlear nuclei in the brainstem.* (Noback, 1985; Willeford & Burleigh, 1985).

For the purposes of this study it is necessary to consider why auditory processing is regarded as a *central* process. A brief theoretical perspective, to this effect, is provided.

ii. Auditory processing as a central neurological process

Auditory processing as described by Toscher and Rupp (1978), refers to the functions of the central nervous system involving the temporal management of auditory stimuli. The components of the processing function traditionally include attention, discrimination, auditory memory, auditory sequencing and auditory synthesis as higher cortical functions and, as such, indicate that perception and processing occur at some central level of the auditory system (Berry, 1969; Witkin, 1971; Rampp, 1972 cited by Toscher & Rupp, 1978).

The evidence supporting auditory processing as a central activity, has been gleaned from observations made by various researchers. Bocca and Calearo (1963), cited in Toscher and Rupp (1978), have stated that the patterns of neural activity produced in the auditory pathway are the result of, and are uniquely structured by the verbal message. Breakdown in neurological activity of the central auditory pathways inhibits or distorts these patterns. This results in anomalies of pattern formation and integration of information at cortical and subcortical levels. The breakdown in central auditory processing would then be reflected as deficits in the components of the auditory processing mechanism.

Berry (1969) cited in Toscher and Rupp (1978), further supported this view by stating that any disruption of neural activity would result in defiencies in the components of processing and hence would create "systemic short circuits" which may cause a processing failure. Further support for the premise that auditory processing is a central activity, has come from the studies of the effects of central nervous system pathology on auditory processing (Goldblatt, Marksesberrt & Reeves, 1974; Heurtus & Haymaker, 1969; Sanchez-Longo & Forster, 1958) as cited in Reeves, 1985. These are too numerous to describe but of early significance were the studies conducted by Jerger in the 1960s, noting the effect of lesions of the central auditory pathway on auditory perception. Further evidence was forthcoming from Kimura (1961); Luria, (1966); Eisenson, (1972).

It is clear then that the literature substantiates the underlying assumption that auditory processing is a central process, and that any dysfunctions in the central processing mechanism may be reflected in deleterious effects on central auditory processing tasks.

2.1.2. THEORETICAL PERSPECTIVES ON CENTRAL AUDITORY PROCESSING

There are two dominant views on central auditory processing. The first of these is a language processing view which subscribes to the notion that most information regarding language is in the mind of the listener, and that little information is gleaned from the acoustic signal (Duchan & Katz, 1983). This perspective suggests that language processing is the function of higher linguistic and cognitive knowledge, applied to an an apparently meaningless acoustic signal. This view of auditory processing reflects a top-down mode of processing.

In contrast, the auditory processing view suggests that whilst the role of language/cognition is not denied, the contention that listening is limited to a top-down mode of processing is not acceptable, because it places little emphasis on the acoustic signal and the analysis thereof. The assumption underlying the auditory processing view suggests that the acoustic signal is processed across several stages, and is manipulated in a variety of ways before it becomes influenced by higher level knowledge. Thus, the emphasis of auditory processes that occur before linguistic analysis is of importance.

The auditory processing theoretical perspective put forth by Duchan and Katz (1983) holds that that auditory processing of an acoustic signal is achieved by the central processing mechanism, and that this process is not necessarily dependent on the language system, though the links between the auditory system and the language system are not denied especially for the semantic interpretation.

For the purposes of the present study the auditory processing view is taken in the light of the following observations made by the present researcher.

Firstly, individuals are able to process auditory stimuli that are unfamiliar, although the meaning may not be apparent. eg. individuals are able to analyse (auditorily) the linguistic stimuli of a foreign language, although they may not be able to fathom the meaning. Secondly, learning disabled children often perform poorly on central auditory processing tasks, as opposed to language comprehension measures (Roeser, Millay & Morrow, 1983). In these children, auditory processing deficits are the primary problem (Sloane, 1986). The remediation therefore focuses on auditory processing skills such as the analysis of auditory signals, in contrast to language comprehension skills. This suggests that a problem of auditory processing is distinct from one of language comprehension thereby reemphasizing that the role of the auditory signal, and the processing thereof.

Duchan and Katz (1983), have provided further argumentation to support the auditory processing view and comment on the following :

- It is suggested that although some words in sentences may be unpredictable, the listener is able to identify the unfamiliar words. This reinforces the contention that the word must be heard and must be identified on the basis of present acoustic information.
- The dependency on the acoustically related information is perhaps most clearly apparent when an individual is hearing impaired and has reduced access to the acoustic signal.

The consequence is that speech and language development are disrupted, highlighting the dependence on and the importance of the acoustic signal.

Many further examples of acoustic processing of signals relating to developmental perspectives on sound identification are discussed by Duchan and Katz (1983). It is not in the ambit of this project to focus on these. (Refer to Duchan and Katz, 1983, who have provided a comprehensive discussion on this topic).

The theoretical arguments presented thus far indicate that the auditory processing approach is viable in its own right, and it is on the underlying assumptions of this approach that the present study is based. However, in order to understand the nature of central auditory processing, and the assessment thereof, a review in terms of neuroanatomy, and neurophysiology is necessary.

2.1.3. NEUROANATOMY, NEUROPHYSIOLOGY AND CENTRAL AUDITORY ASSESSMENT

The following is a description of the fundamentals of neuroanatomy and neurophysiology, as they relate to central auditory processing and assessment. An introduction to these aspects is considered to be important, to form a base for further discussion which is detailed, reflecting the complexity of the central auditory nervous system.

The central auditory system is morphologically organized into ascending and descending pathways as reflected in Figure 1. It is within these pathways that a succession of levels (nuclei) are encompassed where neural processing takes place (Noback, 1985). The system extends from the cochlear nucleus to the cortex, and includes the superior olivary nuclear complex, nuclei of the lateral lemniscus, inferior colliculus, and medial geniculate body. The ascending auditory system is complete with the projection of fibres from the medial geniculate fibres to the temporal lobes of the auditory cortex. The auditory cortex and multiple associated cortical structures define the central auditory pathway.

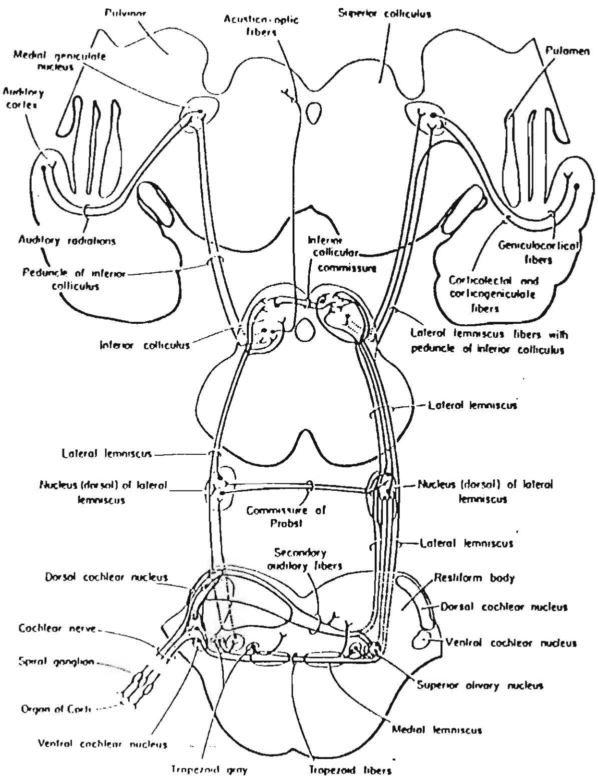

Figure 1 : Diagrammatic representation of the anatomy of the central auditory system reprinted from Crosby E, Humphrey T, & Lauer E (1962) cited in Willeford & Burleigh, 1985

2.1.3.1. Gross description of the brainstem

According to Musiek and Baran (1986), the brainstem is composed of several structures which encompass the ascending auditory pathway. The auditory brainstem pathway from a caudal to rostral direction is composed of the cochlear nuclei, superior olivary complex, the lateral lemniscus in the pons, the inferior colliculus in the midbrain, and the medial geniculate body in the thalamus. The reticular formation which is a medial structure in the brainstem extending from the midbrain to the spinal cord, receives multiple direct and indirect input from the various brainstem auditory structures.

a. *The cochlear nuclei*

The afferent fibres of the cochlear nerve terminate in the cochlear nuclear complex located on the outer aspect of the inferior cerebellar peduncle (Noback, 1985). The nerve sends three major branches to the anterior ventral cochlei nucleus (AVCN), to the posterior ventral cochlei nucleus (PVCN), and to the dorsal cochlear nuclei. The three divisions of the cochlear nucleus show broadly different response properties to auditory information (Pickles, 1982).

The cochlear nucleus is composed of a wide variety of cell types which are differentially distributed in the cochlear nuclei which can modify the incoming auditory signal in its own way depending on the cell morphology. Each division of the cochlear nucleus is similar to all other auditory nuclei in that they are tonotopically organized (Pickles, 1982).

In terms of processing function, Pickles (1982) has suggested that the neurons in the anteroventral nucleus relay auditory information to the next nucleus with very little transformation. However, the neurons in the dorsal cochlear nucleus appear to process complex sensory information at an early stage. They appear particularly responsive to tones which are amplitude and frequency modulated, and their inhibitory action may serve to extract signals from background noise over a wide range of stimulus intensities. A unique feature of the cochlear nuclei is that they receive only ipsilateral input from the auditory nerve.

Afferent connections comprise three main neural tracts that project from the cochlear nucleus complex to the superior olivary complex and higher levels, include the dorsal stria, the intermediate stria and the ventral stria. The neural tracts projecting from the cochlear nucleus have a greater number of contralateral than ipsilateral fibres, indicating that crossover takes place at a level low down in the ascending auditory pathway (Noback, 1985).

b. *Superior olivary complex*

The next major auditory relay station is the superior olivary complex which has several component nuclei, viz. the lateral superior olive, the medial superior olivary (MSO) nucleus and the nucleus of the trapezoid body. The largest of the nuclei is the lateral superior olivary (LSO) nucleus or the S-segment which occupies the most lateral position in the pons. Within the superior olivary complex are also two preolivary nuclei.

The complex neural input gives the superior olivary complex an anatomical basis for binaural representation, and is the first anatomic site of dichotic auditory input (Musiek & Baran, 1986; Willeford & Burleigh, 1985). The superior olivary complex has a role in sound localization since it is sensitive to the arrival time of impulses at each ear. Normal binaural fusion, and rapidly alternating speech perception are dependent on the integration of binaurally presented signals at the superior olivary complex thus making it a critical structure for audiologic tests of brainstem function (Musiek & Baran, 1986; Moore, 1991). The ascending fibres from the superior olivary complex and the cochlear nucleus travel through the lateral lemniscus tract to synapse at the inferior colliculus.

c. *Lateral lemniscus (LL) and its nuclei*

The lateral lemniscus is composed of ascending and descending fibres. It has two cell groups - the inferior ventral nuclei and dorsal nuclei. The inferior ventral nucleus receives projections from the ventral cochlear nucleus and bilateral innervation from the olivary complex (van Noort, 1969; Warr, 1969) cited by Jacobson, Martyn & Hyde (1985). The dorsal nucleus receives bilateral input from the lateral and medial superior olives and the dorsal cochlear nucleus. There is also a connection between the dorsal lemniscal nuclei on either side of the brainstem called the commissure of Probst which allows for further decussation for select ascending fibres (Jacobson, et al., 1985).

Most of the neurons of the dorsal segment of the lateral lemniscus can be activated binaurally, whilst most of the segments from the ventral segment can be activated only by contralateral stimulation. In terms of function, Willeford and Burleigh (1985), have suggested that the lateral lemnisci are simply transmission lines for ascending and descending pathways in the brainstem. The lateral lemniscus projects output to the central nucleus of the inferior colliculus (Noback, 1985).

d. *Inferior Colliculus*

The next major nucleus of the auditory pathway is the inferior colliculus. The inferior colliculus receives input from many structures including the dorsal and ventral cochlear nucleus, the lateral and medial superior olive, the dorsal and ventral lateral lemniscus and the contralateral inferior colliculus (Noback, 1985). The inferior colliculus is composed of two parts, viz. the central nucleus which is further divided into dorsal and ventral regions, and the pericentral nucleus. The central nucleus contains purely auditory fibres whilst the pericentral nucleus consists mostly of somatosensory and auditory fibres. The inferior colliculus also has a high proportion of interneuronal connections, and contains more auditory-sensitive fibres than any other brainstem structures. Although the functions of the inferior colliculus are not fully understood, Willeford and Burleigh (1985) have suggested that inferior colliculus has a role in sound localization, and more obviously serves as a relay centre for conveying auditory information to the thalamic levels.

The inferior colliculus has a commissure which permits neural communication between the left and right inferior colliculus. Another distinctive feature is its branchium, which is a large fibre that ipsilaterally connects the inferior colliculus to the medial geniculate body (Musiek & Baran, 1986).

e. *Medial geniculate body*

The medial geniculate body is located in the thalamus, and has ventral, dorsal and medial divisions. The afferents to the medial geniculate body are primarily uncrossed inputs from the inferior colliculus. The ventral division is composed primarily of acoustically responsive cells, whereas the other neurons are sensitive to both somatosensory and acoustic stimulation (Musiek & Baran, 1986).

The medial geniculate body also has neurons that are sensitive to binaural stimuli and interaural intensity differences. It has been hypothesized that the medial geniculate body begins the processing of speech stimuli (Musiek & Baran, 1986).

f. *Reticular Activating System*

The reticular activating system is a complex neural mechanism that is situated in the central core of the brainstem. Its general role is described as one of altering the level of conscious, and in sustaining the function of consciousness. Perhaps of significance to the present study, is that the reticular activating system and the cerebral cortex must receive electrical information in a synchronous manner that would allow for efficient processing of information to occur (Schnitker, 1972 cited in Willeford & Burleigh, 1985). The role of the reticular activating system in auditory alertness, reflexes and habituation is evident.

g. *Thalamocortical connections*

Musiek and Baran (1986), have suggested that there are many routes that the auditory fibre tracts take from the medial geniculate body to the auditory cortex. The first major pathway originates in the ventral medial geniculate body, and follows a sublenticular course to the Heschl's gyrus. Another pathway that extends from the medial geniculate body to the cortex, consists of auditory, somatic and possibly visual fibres. This tract courses through the inferior aspect of the internal capsule, extends to the external capsule, from which fibres connect to the insula. It is thus evident that the thalomocortical connections are multiple and complex (Musiek, 1986a).

2.1.3.2. Acoustic Reflex

The acoustic reflex has traditionally provided a sensitive index of auditory function extending beyond the middle ear. From the perspective of central auditory function, the parameters that need to be considered, include the reflex threshold, the latency, decay and the amplitude functions.

From an anatomical point of view, the acoustic reflex involves a direct and an indirect pathway. The direct arc consists of a three to four neuron chain which is activated when one or both ears are stimulated by a high intensity sound. The auditory nerve picks up the impulses from the cochlear and passes them onto the AVCN from where they travel to the ipsilateral or contralateral MSO or to the ipsilateral facial nerve nucleus. Neurons arising from in, and around the MSO terminate in either the ipsilateral or contralateral region near the motor nucleus of the facial nerve. The motor nucleus arising from this nucleus, descends to terminate on the fibres of the ipsilateral stapedial muscle. The existence of the indirect arc is not well understood (Musiek & Baran, 1986).

In further detailing the anatomical description of the neural pathways related to the brainstem, Clemis and Sarno (1980a & b), have reported that the nerve tracts and nuclei in the afferent portion of the polysynaptic reflex arc coincide with some of the proposed generator sites of the brainstem response. These include the eighth nerve, cochlear nuclei, and the superior olivary complex. Beyond this point, the acoustic reflex arc decussates to send contralateral fibres across the brainstem, and then both the ipsi and contralateral tracts continue their descent to the facial nerve nuclei.

As the use of the reflex threshold and its role in diagnostic audiometry has been well documented (Hall, 1985), this will not be included in this discussion. Of particular significance however, are the suprathreshold measures which have heightened the sensitivity of the acoustic reflex to brainstem pathology. Excessive decay of the acoustic reflex amplitude has been noted in experimental and clinical brainstem lesions, whilst abnormally prolonged acoustic reflex latency has also been associated with brainstem pathology. The latency function has been used for detection of retrocochlear deficits as it is a more stable parameter than the amplitude function (Norris, Stelmachowicz, Bowling & Taylor, 1974).

2.1.4. EFFERENT AUDITORY PATHWAY

Parallel to the ascending auditory pathway is the descending auditory pathway. The precise role of the efferent pathway is poorly understood, but its fibres are presumably integrated into feedback loops of various degrees of complexity. Noback (1985), emphasizes that the efferent system has a role in central hearing. Noback relates that the various inhibitatory and excitatory influences of the efferent system on the ascending system, may result in the enhancement of essential neutral signals and in the inhibition of unwanted neutral signals e.g. noise (Noback, 1985; Musiek & Baran, 1986).

2.1.5. AUDITORY CORTICAL ANATOMY, PHYSIOLOGY AND SPECIALIZATION

a. *Auditory areas*

The *auditory areas* in the cortex encompass the superior temporal lobe, the inferior-posterior frontal lobe, and the inferior parietal lobe. There are also several auditory structures within the cortical auditory region.

i. *Heschl's gyrus* which is located on the upper surface of the temporal lobe is considered to be the primary auditory area (Noback, 1985). Of significance is that in human specimens the Heschl's gyrus is different in the left and right sides. Some brains contain double gyri on each side; some have two on the left and one on the right, and vice versa. This suggests that as human auditory areas are not identical anatomically the possibility of influence on auditory processing cannot be disregarded.

ii. *planum temporal* which extends from the most posterior aspect of the Heschl's gyrus, appears to be significantly longer in the left hemisphere than in the right. It is suggested that it may be an anatomical correlate to language functions in man (Musiek, 1986a).

iii. *Supramarginal gyrus* which curves around the posterior end of the lateral fissure is in the approximate region of Wernicke's area, and is responsive to acoustic stimulation (Musiek, 1986a).

iv. *The Sylvian fissure*, the course of which is variable among the specimens studied (Pickles,1982), is considered of importance because it contains the primary auditory areas, as well as part of the language areas in humans. The inferior portions of the parietal lobe, and the inferior aspect of the frontal lobe, are also sensitive to acoustic stimulation (Willeford & Burleigh, 1985).

v. *The insula* which is a patch of the auditory cortex located medial to the middle segment of the superior temporal gyrus has nerve fibres that are responsive to somatic, visual and gustatory stimulation. However, the greatest neural activity is created by acoustic stimulation (Musiek, 1986a).

vi. *The claustrum* which is a narrow strip of grey matter located medial to the insula, also appears to be highly responsive to acoustic stimulation (Musiek, 1986a).

b. *Intrahemispheric connections of the auditory cortex*

The primary auditory area has both inter and intra-hemispheric connections to various parts of the brain. For the present discussion, the focus is on the intrahemispheric connection. The Heschl's gyrus has connections to its surrounding association areas (Willeford & Burleigh, 1985). There appears to be a multisynaptic pathway in the middle and posterior areas of the superior temporal gyrus, which also has fibres that connect to the insula and the frontal operculum. The auditory areas also have connections with the frontal lobe, and with the arcuate fasciculus connecting Wernike's area to Broca's area. The arcuate fasciculus courses medial to the superior temporal lobe and insula in its route from Wernickes area to Brocas area.

c. *Corpus collosum and interhemispheric connection*

The corpus collosum, the largest fibre tract in the primate brain, is located at the base of the longitudinal fissure, and connects the two cerebral hemispheres (Musiek, 1986b). In addition to the midline structure, the corpus collosum consists of heavily myelinated nerve fibres which connect the cortices of each hemisphere (Willeford & Burleigh, 1985). The fibres are primarily homolateral i.e. they originate at a certain locus in one hemisphere and connect to a similar locus in the opposite hemisphere. There are also heterolateral fibres which connect different loci in the two hemispheres. From an anatomical perspective, the corpus collosum comprises (posterior to anterior) the splenium, the trunk, the genu, the rostrum and the anterior commissure. The auditory segment of the corpus collosum is confined to its posterior half (Musiek, 1986b). Although the auditory area of the corpus collosum is relatively well described, there is a paucity of information regarding the pathway of the callosal fibres to the auditory cortex. From the available neuropsychological information, it is evident that whilst hemispheres may be dominant for certain functions, optimal processing can only be obtained if the two hemispheres interact (Willeford & Burleigh, 1985).

The role of the corpus collosum is vital in interemispheric transfer of information.

d. *Auditory cortical responses to complex stimuli*

Willeford and Burleigh (1985),have summarized the functions of the auditory cortex as follows :

i. each cerebral hemisphere receives projections from both ears, thus, binaural representation of auditory stimuli is present in each temporal lobe

ii. each hemisphere maintains the tonotopic organization of the cochlear and brainstem mechanisms by the orderly termination of the neurons in the auditory radiation area of the cortex

iii. each hemisphere has a primary auditory area which receives input from the lower auditory centres. The second and third order association areas that surround the primary auditory area serve elaborating functions

The auditory cortex appears to be better suited to respond to complex than to simple acoustic stimuli. Of particular importance is the processing of speech stimuli (Musiek, 1986b). Whilst only very few studies have measured near field cortical responses to speech, the research conducted by Steinschneider et al., cited by Musiek (1986), have indicated that combinations of neurons provide an electrophysiological basis for discrimination of various speech sounds.

Further investigation of cortical function using electrical stimulation on human subjects has been reported by Penfield and associates (Musiek, 1986b). On electrical stimulation of superior temporal and Heschl's gyri, subjects reported hearing complex auditory stimuli eg. voices. When the right auditory cortex was stimulated, most patients reported hearing music and singing. These findings suggest that brain function for auditory stimuli is specialized.

e. *Lateralization of function in the auditory cortices*

In the human adult brain the two hemispheres complement each other. The left brain is dominant for language and speech and rapid sequencing of auditory stimuli. The left hemisphere is dominant for recognizing and processing detailed information, and is described as having an analytical function (Musiek & Pinheiro, 1985). The right hemisphere is dominant for spatial judgements, and for recognizing the contours of acoustical information (Musiek, 1986b). The left hemisphere, in most right-handed people is considered to be dominant for language processing. The right hemisphere is dominant for holistic function (Musiek & Pinheiro, 1985).

The investigations relating to the specialised function of the left hemisphere for speech perception developed out of Kimura's (1961) experimental research using a dichotic digits test with a group of patients with unilateral temporal lobe lesions. Based on these findings, and other physiological evidence, Kimura (1963) developed a model that could explain the function of the central nervous system in the perception of dichotically presented stimuli. The model was based on the premise that the contralateral auditory pathway is more numerous and/or stronger than the ipsilateral pathway. When there is only monaural input to the auditory system, either pathway is capable of initiating the appropriate neural response to allow for the accurate perception of the speech signal. However, in dichotic presentations, the stronger contralateral pathway takes precedence over the weaker ipsilateral pathways, and there may be a suppression of the ipsilateral pathway under this condition. If one hemisphere is damaged, then reduced performance in the contralateral ear is expected when test stimuli are presented in a competing dichotic paradigm. Further support for this theory comes from Sparks, Goodglass and Nickel (1970), after they used digit and word stimuli to evaluate twenty left-brain-damaged and twenty right-brain-damaged subjects. Their results support the contention that the left temporal lobe is specialized for speech perception and processing. The right ear advantage (REA) observed on dichotic paradigms were regarded as an indirect measure of cerebral lateralization for speech stimuli.

Speaks (1978), proposed a model to explain right ear advantage (REA), and hence left cerebral dominance for perception of linguistic stimuli in normal subjects. It was proposed that :

i. left hemisphere is specialized for the analysis of linguistic material

ii. stimuli from the right ear travel directly along the contralateral pathway to the left temporal lobe where both auditory and linguistic analysis take place

iii. stimuli from the left ear travel along the contralateral pathway, where some form of auditory analysis takes place after which the stimuli travel along the corpus collosum (degraded pathway) to the left temporal lobe where linguist analysis is effected

iv. crossed auditory pathways are stronger than the ipsilateral pathway.

Thus, there appears to be substantial evidence and theoretical bases supporting the contention that the auditory processing of speech is the domain of the left temporal lobe.

REA interpretation : Whilst the REA for dichotic presentation of linguistic stimuli is observed for normal right-handed adults, the interpretation thereof is controversial. Traditional theorists including Berlin, Lowe-Bell, Cullen, Thompson and Loovis (1973) concur with Sparks et al., (1970) and have suggested that the REA is a reflection of the left hemsipheres dominance for speech perception and other related language functions. McNeil, Petit and Olsen, (1981), have investigated the human auditory system and have suggested that the contralateral pathway is capable of generating stimuli more efficiently than the ipsilateral pathway. In attempting to describe the neural mechanism accounting for lateralization, Studdert-Kennedy and Shankweiler (1970) have suggested that the auditory system common to both hemispheres is able to extract auditory parameters of speech but that the dominant hemisphere is responsible for linguistic interpretation.

It can be stated that the REA has been viewed as indirect evidence for the left cerebral hemispheres specialization for speech perception. The traditional manner in which the REA has been interpreted is subject to controversy. Friedes, 1977; Teng, 1981; and Efron, 1985 have suggested that the REA be interpreted with caution as it is not necessarily an indicator of left cerebral dominance for speech perception.

Teng's (1981) criticism is based on the observation that individuals differ with regard to input asymmetry. It is suggested that reversed dominance occurs in some individuals, whereby there is ipsilateral input dominance over contralateral pathways. The input asymmetry could be generated by subcortical processing mechanisms. According to Teng (1981) this explanation could account for the 20% of normal right handed subjects who do not demonstrate REA on dichotic tasks.

Furthermore, Friedes (1977), has suggested that the right ear advantage was strongly influenced by response strategy. This contention was based on the observation that subjects were able to change ear advantage when instructed to change response strategy. This led Friedes to concluded that the dichotic listening task may be an unreliable method of evaluating input processing dominance, because it is influenced by output factors.

Efron (1985), on the other hand has suggested that ear advantage may be influenced by many factors, and to use it as a measure of cerebral dominance without considering other factors would be unwise. Amongst the factors cited as influencing ear advantage are the influences of subcortical asymmetry and attentional bias. It is therefore suggested that ear advantage is not a stable phenomenon and therefore not a reliable indicator of cerebral dominance.

Whilst hemispheric dominance specialization theory to explain ear advantages has been criticised, no alternative viable theory has been suggested. The REA for perception of linguistic stimuli in right-handed individuals has been reported with relative consistency in the literature. The degree of ear advantage however, is reportedly more variable and may be influenced by factors such as response strategy and attentional bias (Blumstein, Goodglass and Tarter, 1975). Piazza (1980),has noted that whilst explaining ear advantage using the hemispheric dominance/specialization theory is not without controversy, it is apparently the most cited explanation. For the purposes of the present study the researcher has opted to use the hemispheric dominance theory to explain ear advantage since stuttering theorists (Blood and Blood, 1989b; Rosenfield and Goodglass, 1980, Libertrau and Daly, 1981) , have interpreted ear advantages in this context.

Ear advantage calculation : Another aspect that needs to be considered is the manner in which the ear advantage is calculated. Blood and Blood (1989b) have suggested that there are various of methods of analyzing dichotic data. Some of the controversy in this field of study is partly attributable to methods of analysis used. Among the methods that have been used are the absolute between-ear differences; t-tests for inter-ear differences; use of the laterality quotient; use of number and percentage correct from each ear; and the phi-coefficent, (Blood & Blood, 1989b). The problem with most methods is that they consider only direction of ear advantage, whilst neglecting to consider the magnitude. Therefore, if one has to consider that two subjects may demonstrate the same ear advantage although the magnitude of the ear differences scores may have been dissimilar.

Blood and Blood (1989b), have suggested that the real understanding for laterality may be obtained by considering the magnitude and direction of ear advantage. They have suggested that the phi-coefficient (Kuhn, 1973) offers this alternative. In addition to considering the magnitude and direction of advantage, it creates a category of NEA (no ear advantage). In doing so the criterion for determining ear advantage is more stringent. The present investigator suggests that whilst the ear advantage may be influenced by many factors often out of the examiners control, the method of analysis will serve to compensate for the influence of extraneous factors. In this way only a sufficient magnitude of ear difference will allow for an ear advantage classification as being LEA or REA. If the magnitude of ear differences is not great enough then the individual will be categorized as having NEA. For these reasons the present researcher opted to use the phi-coefficient to analyze dichotic consonant-vowel data.

f. *Selective auditory attention*

Another feature of the auditory cortical capabilities of humans is that they are able to focus their auditory attention on a single acoustic message present in a noisy background (Willeford

& Burleigh, 1985). This process of attending to certain signals whilst ignoring others has been the basis for many of the tests of central auditory function e.g., Competing Sentences Test and other dichotic measures. The localization of the auditory attending mechanism is not known, but electrophysiological data suggest multiple complex interactions in the cerebrum.

g. *Sequencing and temporal ordering in the auditory system*

Pinheiro and Musiek (1985a), have stated that all functions of the central auditory nervous system are influenced by time, since acoustic events are temporal in nature. It is suggested that the cells of the auditory nuclei, and those of the auditory cortex, are sensitive to the effects of time. Of significance to the present study is the temporal sequencing capability of the central auditory system. This function involves the processing of two or more auditory stimuli in their order of occurrence in time. It has been suggested that ability of the human auditory system to analyse sequential information provides a basis for understanding speech and language. Some investigators (Efron, 1963; Lackner & Teuber, 1973; cited in Pinheiro and Musiek, 1985a) suggest that temporal sequencing is the domain of the left hemisphere. It is suggested that the left hemisphere which is described as analytical, is better able to process serial ordering of temporal information. Other researchers (Shankweiler, 1966; Schuloff & Goodglass, 1969; cited in Pinheiro & Musiek, 1985), have suggested that the right hemisphere is suited to tonal sequences. The ability of the right hemisphere to process information holistically suggests that it has a role in temporal sequencing, and that it may be active in processing contours and overall patterns of acoustic information. To reconcile the opposing views, Pinheiro and Musiek (1985), have suggested that interhemispheric interaction may be responsible for proper temporal sequencing. They have further suggested that those subjects who are brain damaged are unable to process temporal sequences adequately. Therefore, it is likely that individuals who have central auditory processing problems experience difficulty in processing temporal sequences.

From the above discussion it can be ascertained that the auditory system is a complex mechanism responsible for a variety of auditory functions, and the assessment thereof is complex. The focus of the ensuing presentation relates to the assessment of central auditory processing.

2.1.6. ASSESSMENT OF CENTRAL AUDITORY PROCESSING

Whilst tests of central auditory function have been used primarily assist in confirming the presence and the site of lesion, they have also been used to assess the functional proficiency of the central auditory nervous system (Katz, 1986). The focus of this study relates especially to the functional profiency of the central auditory nervous system. However, where possible consideration is given as to the localization of function related to processing difficulty.

The assumptions underlying central auditory processing evaluation are as follows (Duchan & Katz, 1983) :

i. The neural pathways and linguistic signals are redundant. Rintelman (1985), has described the redundancy of the central auditory nervous system as stemming from the bilateral representation of each ear to each side of the brain via a complex neural network. This complex system results in multiple processing of auditory information in the brain. With respect to signal redundancy, Rintelman (1985), has suggested that high fidelity speech signals are so redundant that the central nervous system is not stressed in the normal listener during normal listening conditions. Therefore, in order to reveal problems in processing, the signal redundancies must be reduced.

ii. The normal listener uses a constructive listening process, and thereby uses knowledge of the language system and expectations; is able to fill in parts of a signal; and is tolerant of variability in the acoustical patterns of phonemes and syllables. By degrading the signal, processing is made more difficult; and the listener is unable to use the same expectancies, and has less time to process missing information.

iii. The normal subject does not experience problems processing degraded auditory information, whilst individuals with central auditory nervous system dysfunction may show difficulty.

2.1.6.1 <u>The nature of central auditory processing tests</u>

Duchan and Katz (1983), have stated that in order to assess the functional proficiency of the central auditory nervous system, stress needs to be placed on the system. The stress can be derived by degrading or distorting linguistic signals. The degrading or distortion of signals can be achieved by compressing or expanding the time frame, by presenting the signal in an atypical manner, for example by alternating the signals between ears, or by presenting the signals with competing messages. In addition, different signals may be presented to both ears (dichotic) simultaneously, and the intensity of the signal may be altered to reduce intelligibility (Pinheiro and Musiek, 1985b). By stressing the central auditory nervous system, auditory processing problems may become evident in a system that is deficient at central auditory processing, whilst for normal subjects, difficulties are less prominent.

In summarizing, the goal in assessment of central auditory processing is to administer tests that uniquely stress the auditory mechanisms at various levels of the central nervous system, in order to identify defiencies in an inefficient system (Willeford & Burleigh, 1985). Such stress is created by special test design that requires more complex responses in higher auditory centres than are necessary for responding to the awareness of simple pure tones or for recognizing and/or repeating simple speech stimuli. Thus, central tests involve stimuli, and the presentation thereof, that have been modified in such a way that the processing thereof becomes difficult.

There are many tests available that are used in the assessment of central auditory processing. Willeford (1985) has suggested that there is no ideal test battery, and that there is no single preferred measure. It is therefore, the task of the audiologist/researcher to select a battery of tests that are considered suitable for the population being tested. The present investigator selected a battery of tests that were previously considered sensitive in revealing subtle central auditory processing in stutterers.

2.1.6.2 <u>Motivation for the choice of test battery utilized in the present study.</u>

The tests were chosen for the following reasons :

i. The battery selected provides an evaluation of various level/processing functions of the central auditory nervous system. i.e. the combination of tests provides an evaluation of brainstem, as well as cortical functions (Hall & Jerger, 1978; Willeford, 1985). This allows for a comprehensive assessement of central auditory processing.

ii. The SSW, SSI-ICM, ARLT, and Dichotic CV test have been found to be sensitive in showing differences between stutterers and nonstutterers in previous research. (Jerger & Hall, 1978; Toscher & Rupp, 1978; Hawver, 1978; Taylor, 1991).

iii. The Competing Senetnces Test provides an evaluation of binaural separation ability as opposed to binaural integration challenged by other dichotic task. In addition, it is the only test in the present battery that utilizes sentence stimuli, and as such may allow for greater insight into the nature of stutterers' processing abilities.

According to the available literature surveyed, the Competing Sentences Test (CST) has not been used to compare stutterers and nonstutterers previously. This test was, therefore, chosen to contribute to the research literature on stuttering and central auditory function.

2.1.6.3. Description of tests used in the present investigation

a. *Dichotic tests*

Dichotic tests require the simultaneous presentation of a different signal to each of the ears. The tests are generally considered to examine auditory processing at the level of the temporal lobes (Musiek & Pinheiro 1985). Various types of stimuli have been used in dichotic testing. These include consonant-vowel stimuli, word stimuli, digit stimuli and sentence stimuli. The present investigation used consonant-vowel, word and sentence stimuli.

There are two different types of dichotic listening tasks i.e. binaural integration tasks and binaural separation tasks. (Musiek & Pinheiro, 1985). The binaural integration tasks require the subject to respond to the stimuli presented to both ears. The specific tests included in this study are the SSW, and the DCV test. The binaural separation tasks require the subject to respond only to the stimulus presented to one ear, while ignoring the stimulus in the other ear. The binaural separation task included in this study is the Competing Sentences Test.

1. *Dichotic consonant-vowel DCV test*

The DCV test has been used been used widely for experimental purposes (Willeford & Burleigh, 1985). The test protocol involves presenting a CV such as /ba/ to one ear, whilst simultaneously, a different consonant such as /da/ is presented to the other ear. There are six CV stimulus items (pa/ba/ta/da/ka/ga) that occur in all possible combinations, and are arranged in 30 paired items per test list. The subject is required to repeat what is heard in both ears (two-response mode), and the test is scored for items correct in the left ear, the right ear and both ears. Stop-consonant syllables are used as they were previously found to reveal relatively consistent trends in ear advantages for normal listeners. (Shankweiler & Studdert-Kennedy, 1967).

The stress in the central auditory system is created by presenting syllabic stimuli of short duration simultaneously to both ears. In addition, stimuli in both ears need to be reported, thus challenging the binaural integration as well as separation processes. The studies using CV stimuli have identified two major effects in normal adult subjects. These include the right-ear-advantage (REA), and auditory capacity. (Roeser, Millay & Morrow, 1983).

The REA has been interpreted as resulting from inhibition of the ipsilateral pathway, and the dominance of the left hemisphere for processing speech and language. Speaks (1978), model and other explanations for REA have been described previously (Kimura, 1961; Berlin et al., 1973). Normal right-handed individuals typically demonstrate REA on dichotic tests using linguistic stimuli. No-ear-advantage (NEA) and left-ear-advantage are also possible responses and are considered atypical ear advantages (Blood & Blood, 1989b).

In addition to ear advantage the auditory capacity effect has been commented on in the literature (Roeser et al., 1983) The auditory capacity refers to the maximum amount of information that can be handled by the auditory system as measured by the accuracy of recall. In the dichotic tests, subjects can report accurately the stimuli presented to one ear (single correct), or both ears (double correct). It is the double correct responses that provide a measure of auditory capacity, and it is this measure that is thought to reflect the systems' ability to store and recall acoustic speech information (Roeser et al., 1983).

The normative data for the DCV test varies and depends on factors such as age, hearing sensitivity, and language. Therefore, a normal control group must be used for comparison (Blood & Blood, 1989b).

In the present study the DCV test was used as a measure of ear advantage, as previous studies have reported that atypical ear advantages were more apparent for stutterers than normals (Blood & Blood, 1989b; Rosenfield & Goodglas, 1980). In addition, insight into the auditory capacity of stutterers could be obtained.

2. *The Staggered Spondaic Word Test (Katz, 1986)*

The test, as described by Keith (1983) is composed of two spondaic words with a staggered onset. It uses as acoustic stimuli, familiar spondee words that are partially overlapped to provide both competing and noncompeting words to each ear. During the test, the leading ear alternates on consecutive word pairs so that the first twenty pairs are presented to the right-ear-first (REF), and the remaining 20 pairs are presented to the left ear first (LEF) The subject is required to repeat all of the words presented. Extensive scoring and interpretational guidelines are presented by Katz, (1986).

The SSW test is now increasingly used to measure the functional profiency of the central auditory nervous system. The stress is created by dichotic presentation of words in a competing format, and the subject is required to repeat all words in competing and noncompeting conditions. To assess the functional profiency of the central auditory nervous system response bias, and error scores, are considered. The response bias identified on the SSW test includes the order effects, ear effects, type A patterns and reversals. These aspects provide indications as to the nature of processing of stimuli as opposed to errors made on the test. Furthermore, it provides an indication of temporal management of speech stimuli since subjects are required to repeat word sequences in a given order. The evaluation of these parameters against normative data (Katz, 1986) provides an indication of central auditory processing for performance individuals. Normal subjects generally show no significant response bias.

The performance of subjects with normal central auditory processing skills indicate no or very few errors, whereas individuals with central auditory processing problems may display a greater number of errors compared with normal listeners. In terms of functional profiency of the central auditory nervous system, a greater number of errors is evident especially on the competing portions of the test. In addition, response bias may be atypical and, therefore, suggesting central auditory processing problems.

The SSW test is considered to be a reliable measure of central auditory function (Katz, 1986). The test was included in the present investigation as other investigations using this test

(Hall & Jerger, 1978; Hawver, 1978) have noted significant performance differences between stutterers and nonstutterers.

3. *Competing Sentences Test (developed by Willeford in 1968)*
The test is composed of twenty five pairs of simple sentences of six or seven words in length. The test is presented dichotically, with one sentence at 35dBSL, and the other at 50dBSL (re:SRT). The lower intensity sentence is the target, while the higher intensity sentence serves as the competition. The subject is required only to repeat the target sentence accurately. A total of ten items is presented to each ear. The task challenges the central auditory nervous system because the stimuli are presented in a dichotic format, with the intelligibility of the signal being reduced in the target ear. The binaural separation process is challenged because only the stimuli in the target ear are reported. Furthermore, it provides insight into the central auditory nervous system ability to sequence temporal stimuli since subjects are required to report a sentence with words in the correct sequence.

The test was developed for the specific purpose of evaluating central auditory function in such a manner as to avoid dependence on the identification of highly transient single words , as these place a premium on concentration and attention. A further goal was to simulate language constructions encountered in everyday life. The CST as opposed to the SSI-CCM, involves broader message perception and is employed in an open-set paradigm which brings language performance and skill to bear on the message decoded. A specific consideration in test construction was the nature of the competing message. The competition sought in this test is similar in character to that of the items, thus creating stress in the system. This choice was influenced by the work of Treisman (1964), who reported that a message presented by the same talker, and involving similar content material, was a difficult task compared with a format using different speakers.

Normal young adults tend to score 100% in each ear. The test is sensitive to temporal lobe functions and to a lesser extent to brainstem lesions (Lynn & Gilroy, 1972, 1973, 1976 cited in Willeford, 1985). Scoring guidelines have been provided in the literature (Willeford, 1985). These guidelines indicate that normal subjects make few or no errors on the test, whilst subjects with central auditory processing problems may demonstrate impaired performance when compared with the norm.

As mentioned above, stutterers' performance on this measure has not been previously investigated, and was therefore included in the present study. In addition, knowledge of stutterers processing performance on the CST may provide an indication of stutterers' performance on dichotic sentence tasks.

b. *Monotic tests*

As compared to dichotic tests, monotic are tests that involve the assessment of each ear individually (Rintelman, 1985).

4. *Synthetic Sentence Identification Test - Ipsilateral competing message format : (Jerger & Jerger, 1973, 1978)*

It has been accepted that auditory tests using puretone stimuli have minimal diagnostic value in the assessment of central auditory function (Jerger, 1978). Research findings have suggested the use of speech tests to evaluate the more complex functions of discrimination and integration. Tests are constructed in such a manner as to evaluate the functional properties of the stations along the central auditory pathways. One such test which attempts to do this is the SSI-ICM.

The SSI-ICM test is a monotic test first developed by Jerger and Speaks in 1965. The test comprises ten third-order approximations of English sentences, with each sentence containing approximately seven words. The sentences are presented as a closed message set with a competing message (continuous discourse) presented to the same ear. The message to competition ratio is varied from +10 to -20dB in 10dB steps (Jerger, 1978).

When high fidelity speech is presented monaurally, the difficulty of the listening task can be increased by mixing into a single channel, a primary and secondary message. The listener's task is to respond to the primary message, and to ignore the competing message thereby creating stress in the central auditory nervous system. In addition to presenting the signals to the same ear, stress is also created by varying the relative intensities of the primary and secondary/competing signals. The message-to-competition ratios of the primary and the secondary signals are as follows : 0dBMCR (message and competition are at the same level); -10dBMCR (primary message is presented 10dB below the secondary signal); -20dBMCR (primary signal is presented at 20dB below the secondary message); +10dBMCR (primary signal is presented 10dB above the secondary signal).

According to Jerger (1978), most normal listeners perform at 100% when the message and competition are at the same level i.e. at an 0dBMCR. Normal performance drops to about 80% at an MCR of -10dB, and to about 55% at an MCR of -20dB. In normal listeners, the right ear scores are marginally higher than those in the left ear. Abnormal performances are indicated by deficits from the expected norms for one (contralateral) or both ears. This type of deficit is most likely to be indicative of brainstem level processing difficulties lesions (Jerger, 1978).

The test was selected for use with stutterers because studies have indicated that stutterers have performed poorer than non-stutterers on this measure, suggesting brainstem level processing problems for stutterers (Hall & Jerger, 1978; Toscher & Rupp, 1978).

5. *Acoustic reflex latency test : ARLT*

Objective tests that employ electrophysiological measures have also been used to measure central auditory function. The test chosen for the present investigation is the acoustic reflex latency test (ARLT).

The acoustic reflex latency is the time interval between the onset of the acoustic stimulus, and the onset of the stapedius muscle contraction (Church & Cudahy, 1984). They suggest that the initial temporal processing in the central auditory system involves the brainstem central auditory mechanisms. Investigations to this effect on pathological ears have indicated prolongation of latency characteristics with retrocochlear lesions (Clemis & Sarno, 1980b). The latency of the acoustic reflex has been shown to indicate dysfunction at the level of the brainstem (Mangham, Burnett, and Linderman, 1982). Research (Clemis & Sarno, 1980b), has indicated longer reflex latencies in subjects with brainstem lesions. The latency, relative to other parameters of the acoustic reflex is considered a stable parameter of the acoustic reflex (Norris et al., 1974).

This impedance method of measurement was used in the present study. The latency appears to be variable, depending on the frequency and the intensity of the stimulus sound, as well as the instrumentation differences. For the present study, the acoustic reflex latency was measured at the point where the slope function reached 10% of its maximum value (See Appendix T for visual presentation). Church and Cudahy (1984), have suggested that using a predetermined point in slope function reduces the influence of response stability across subjects. This feature is a preprogrammed function of the instrumentation used in the present investigation.

The acoustic reflex latency parameter has been examined in this study for three reasons. Firstly, aberrations in reflex activity have been linked to stuttering and secondly, abnormalities of the reflex latency are also of interest as indicators of brainstem dysfunction (Hannley & Dorman, 1982). Thirdly, recent research (Taylor, 1990) has indicated differences in the acoustic reflex latency measures between stutterers and nonstutterers. This specific parameter has been considered in this study.

The discussion has focussed on the nature of central auditory processing and the assessment thereof. The discussion that follows relates to the nature of stuttering. It is envisaged that only with this background will the conceptual and practical links between stuttering and central auditory processing be realized.

2.2. **THE NATURE OF STUTTERING**

The discussion that follows provides a brief overview of the nature of stuttering, with special emphasis on the aspects of this disorder that are pertinent to the present study. These include :

- definition of stuttering
- variability
- epidemology
- sex ratio
- genetics and stuttering
- stutterer/nonstutterer differences
- theoretical perspectives on stuttering

2.2.1. A DEFINITION OF STUTTERING

An appropriate starting point would be to consider a definition of stuttering. Ingham (1984), has noted that one of the recurring issues about stuttering is the failure to agree on an appropriate definition. It is not the purpose of this study to discuss the controversies surrounding definitional issues. The writer has, therefore, opted to use Wingate's definition since it is most frequently cited, and perhaps the most durable. Although the definition is often critisized because it contains too many qualifiers, and imprecise terms, it continues to be one of the most-documented definitions, and therefore, it comes close to being an acceptable definition of stuttering (Ingham, 1984). The definition is used as a basis for discussion.

The definition of stuttering (Wingate (1964) cited in Van Riper 1982, p. 12) is as follows :

The term stuttering means: I. Disruption in the fluency of verbal expression which is (a) characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely : sounds, syllables, and words of one syllable. These disruptions (b) usually occur frequently or are marked in character and (c) are not readily controllable. II. Sometimes the disruptions are (d) accompanied by accessory activities involving the speech apparatus,related or unrelated body structures, or stereotyped speech utterances. These activities give the impression of being speech-related struggle. III. Also, there are not infrequently (e) indications or report of the presence of an emotional state, ranging from a general condi tion of 'excitement' or 'tension' to more specific emotions of a negative nature such as fear, embarrassment, irritation or the like. (f) The immediate source of stuttering is some inco-odination expressed in the peripheral speech mechanism : the ultimate cause is presently unknown and may be complex or compound.

The definition is an attempt to describe the characteristics that are essential in differentiating stuttering from other disorders with which it may be confused. The description in essence, therefore, describes the primary speech behaviour common to stutterers, and indicates that the secondary behaviours are shown only by some (Van Riper, 1982).

The problem of speech fluency is obvious. The disruption of fluency in stuttering relates to the primary symptoms repetitions, prolongations, and blocks. Of significance, is the common observation that the symptoms may appear in isolation or in combination with each other. Furthermore, the disruption in fluency appears to be on the initial syllables of words (Starkweather, 1987). The effect of the disfluency is that the speech of stutterers is not as continuous, or as easily produced as that of nonstutterers. In addition, the dysfluencies appear to be marked in character, suggesting that they are different from the nonfluency patterns observed with normal speakers. The dysfluency appears to be involuntary in that the stutterers do not appear to have control over the occurrence of the dysfluency. Rubin and Culatta (1989), have stated that one of the outstanding features of stutterers is their ability to be fluent. This indicates that the speech dysfluency is not always present in the speech of stutterers. One of the controversial aspects related to speech dysfluency observed in stutterers is whether or not the dysfluencies are distinctly different from normal nonfluency. Starkweather (1987), has suggested that whilst normal nonfluencies and stuttering may be disturbed in the same way, there is one exception. Stuttering behaviours occur at the beginning of sentences whereas normal nonfluencies do not. Normal nonfluencies are likely to appear within the sentence, whereas stuttering is a problem with the initiation of utterances. Van Riper (1982) has described stuttering as a disorder of speech dysfluency as opposed to viewing it as a more severe form of normal nonfluency.

The secondary behaviours refer to the accessory activities that are associated with the dysfluent speech behaviour that may or may not be present for stutterers. These behaviours are often described as a way of coping with the speech dysfluency (Wingate, 1964, in Van Riper, 1982). Often, there appears to be anxiety or emotion associated with the dysfluent episode.

Whilst the definition has captured the distinguishing characteristics of the disorder, other aspects of the nature of stuttering that are not emphasized are discussed in the presentation that follows.

2.2.2. VARIABILITY

Perhaps one of the prominent features of stuttering is its variability (Starkweather, 1987). Inter and intra-subject variability is a prominent feature of the disorder. The symptoms are sometimes present and sometimes absent, sometimes mild and sometimes severe. Researchers have been able to identify many situations under which stuttering varies, but it is not clear as to why such variation occurs.

With respect to linguistic variability Starkweather (1987), has suggested that the most significant observation appears to be that more than 90% of stuttering occurs on the initial syllable of an utterance (as described previously). Other variables include length of word, position of word, and meaning of word. Variablity also arises from conditions resulting in fluency enhancement. Of significance is that stuttering occurs more readily on stressed than on unstressed syllables (Starkweather, 1987), a phenomenon Starkweather suggests, theorists have difficulty explaining. Fluency-enhancement stimuli include masking noise, rhythmic stimulation, delayed auditory feedback, and singing (Starkweather, 1987). Of significance to the present study is that the auditory feedback and auditory masking, generally result in a decrease in speech dysfluency, thereby, implicating a link between stuttering and auditory function.

It thus appears that there are many conditions under which stuttering varies, making one aware of the complex nature of the disorder. It also suggests that stuttering is a heterogeneous disorder ie. the basis for dysfluency may vary thus giving rise to subgroups of stutterers who may differ with regard to symptomatology, response to treatment, and severity, amongst others.

2.2.3. EPIDEMIOLOGY

The epidemiological data summarized by Andrews (1984), indicates that stuttering is a condition that will affect 5% of children at some time. Most children will begin to stutter before they are of school age and virtually none will begin to stutter after puberty. Stuttering, therefore, may be viewed as a disorder of childhood (Bloodstein, 1987). In the majority of cases the stutter will last for one year, and will remit spontaneously. The disorder persists in only 1% of the population. This indicates that a relatively small percentage of the general population is affected by the disorder. The present study is designed to examine the central auditory processing performance of individuals for whom the stuttering has persisted.

Stuttering occurs in all societies that have been studied (Van Riper, 1982) implying the universality of the disorder. The subjects in this study are all South Africans of Indian origin. This particular group was selected in an attempt to maintain the homogeneity of the group. This methodological consideration is repeatedly emphasized in stuttering research (Rentschler, 1984). Furthermore, research with this group of individuals can be compared with other research conducted with other population groups,thus allowing a greater data base for stuttering. Similarities and differences noted would provide more insight as to the nature of stuttering.

2.2.4. SEX RATIO

Of particular significance to this study is that the prevalence of stuttering is higher in males than females. According to Andrews, Craig, Feyer, Hoddinott, Howie, and Neilson (1983), three times as many boys stutter as girls. Eisenson and Ogilvie (1983), have suggested that severity of stuttering appears to be greater for males than for females.

The explanation for this discrepancy has been widely discussed (Van Riper, 1982; Andrews, 1984) and attributed to factors such as sex differences in constitution, physical maturation, speech and language development, and to differences in parental attitudes and expectations for boys and girls (Bloodstein, (1987). In the present study the central auditory processing of male and female stutterers are explored. At present however, there is limited information available on this subject, and information relating to sex differences and central auditory processing difficulties may contribute to an explanation of the sex ratio.

2.2.5. GENETICS AND STUTTERING

It has often been stated that stuttering has a genetic basis (Andrews et al., 1983; Cox, 1988; Kidd, 1984). Several studies cited by (Andrews et al., 1983; Kidd 1984; Peters & Guitar, 1991) have indicated that the risk of stuttering amongst the first-degree relatives of stutterers is more than three times the population risk. Both the genetic and environmental explanations have been offered (Kidd, 1984), but the genetic hypotheses have been popular, since the risk of the relative stuttering varies by virtue of the sex of the relative and the sex of the proband. Male relatives of female stutterers are at greatest risk of stuttering.

For the purpose of this study, only stutterers with a family history of stuttering have been included. This has been done in an attempt to test a more homogeneous population of subjects. Poulos and Webster (1991) have noted that many professionals view stuttering as a multidimensional disorder, and that stutterers are characterized by heterogeneity with respect to etiology, underlying mechanisms, responsiveness to treatment and severity, amongst others. This position finds support from a number of researchers cited by Poulos and Webster (1991). Specifically, Poulos and Webster (1991) have made special reference to a subgroup of adult developmental stutterers who have a genetically inherited predisposition for stuttering. Jannsen, Kraaimat and Brutten (1990) have further supported the contention of subgroups amongst stutterers and have suggested that if stuttering has a neuromotor basis, then it is likely that their neuromotor functioning has genetic basis. The present study therefore, is an attempt to examine central auditory processing in a subgroup of stutterers who have family history of the stuttering.

2.2.6. STUTTERER-NONSTUTTERER DIFFERENCES

Researchers have attempted to examine possible stutterer/nonstutterer differences in an attempt to postulate causative factors. Andrews et al., (1983), in a review of literature have reported that with respect to intelligence, stutterers as a group, do differ from nonstutterers. Investigations have revealed that stutterers as a group tended to perform half a standard deviation lower than nonstutterers on intelligence tests. It has been found that stutterers lag six months behind their peers educationally. Other differences indicate that stutterers are late and poor talkers, and lag in tests of sensory motor response (Peters & Guitar 1991). Of particular importance to this study is that differences have been noted on tests of central auditory function. Stutterers generally perform differently from nonstutterers (Hall & Jerger, 1978; Blood & Blood, 1989b). This aspect will be discussed in greater detail in the following chapters. It should be noted that whilst group differences have been reported between stutterers and nonstutterers, the individual stutterer may not show these differences. Studies reporting conflicting results between individual and group comparisons for stutterers could be reflecting the heterogeneous nature of stuttering, i.e. all stutterers are not alike and, therefore, perform differently from each other on a variety of measures. Furthermore, in most instances the differences between stutterers and nonstutterers appear to be subtle (Andrews et al., 1983; Peters & Guitar, 1991).

The researchers who have investigated stutterers/nonstutterers differences on a variety of measures have done so with the intention of revealing the etiology/etiologies of stuttering. When considering the heterogeneous nature of stuttering it is not surprising that the explanations for the disorder have been divergent. The discussion that follows provides an overview of the theoretical perspectives on stuttering with special emphasis on stuttering as a constitutional disorder.

2.2.7. THEORETICAL PERSPECTIVES ON STUTTERING

The major classification of the viewpoint offered to explain stuttering include the following (Eisenson & Ogilvie, 1983) :

i. stuttering as an organic/ constitutional problem
ii. stuttering as a learned disorder
iii. stuttering as a manifestation of an underlying personality disorder.

The explanations suggesting that stuttering may be a learned form of behaviour (Eisenson & Ogilvie, 1983) developed as a result of Johnsons' theory (1967), suggesting that the onset of stuttering and development of stuttering is established as a result of critical reaction to a child's normal patterns of disfluency. Other descriptions of stuttering as a learned behaviour include those Brutten (1970), and Sheehan (1953) cited in Eisenson, (1975). Another controversial position about stuttering is that it is a manifestation of an underlying neurotic personality. However, research has failed to provide support that stutterers are maladjusted and the theory fell into disrepute.

The present study focuses on the underlying theoretical perspective of stuttering as a constitutional disorder. The proponents of this view suggest that there might be physical reasons that predispose a person to stuttering, or that make him a stutterer (Peters & Guitar, 1991). The support for this contention has come from a variety of research studies that suggest a number of predisposing physiological variables relating to stuttering. Among these are a higher incidence of family history stuttering for stutterers; greater incidence of speech and language problems; stutterers/nonstutterers difference with respect to intelligence; as well as sensory-motor coordination (Peters & Guitar, 1991). Amongst the constitutional factors investigated stutterer/nonstutterer comparsions have been made on central auditory processing tasks, and it is this aspect that is investigated in the present study. At this point it is necessary to consider the theoretical perspectives on stuttering and central auditory processing.

2.3. THEORETICAL PERSPECTIVES : STUTTERING AND CENTRAL AUDITORY PROCESSING

As mentioned previously, there are two ways in which stuttering and audition have been linked.These include :

- stuttering and cerebral dominance
- stuttering and auditory feedback

2.3.1. STUTTERING AND CEREBRAL DOMINANCE

2.3.1.1. The Orton-Travis Thesis

Several researchers (Blood & Blood, 1989a & b, Tsunoda & Moriyama, 1972; Rastatter & Dell 1987a & b) have postulated that stutterers and nonstutterers differ with respect to their cerebral representation of speech and/or language. This contention arose from the Orton-Travis theory which proposed that speech is the functional equivalent of structural hemispheric dominance, by which the dominant hemisphere imposes its temporal organization on the nondominant hemisphere. It was hypothesized that this lack of cerebral dominance resulted in interference by one hemisphere with the speech performance of the other. The contention was that whereas the language of fluent speakers is confined to the left hemisphere, the language of individuals who stutter was represented bilaterally. The model suggested that the bilateral control of speech mechanisms produce interhemispheric competition that manifest in stuttering. Neuromotor disorganization and mistiming for speech leads to stuttering.

Furthermore, it was theorized that in the development of stuttering many children go through a stage of disfluency because language has not lateralized to the appropriate hemisphere. With maturation, however, the language lateralization process becomes more complete, and the disfluency disappears. However. a subgroup retain their bilateral representation and continue to stutter (Rosenfield & Jerger, 1984).

A description of the dynamics of how bilateral representation of language relates to stuttering was attempted by Travis in 1931, cited in Moore, (1984b). Travis hypothesized that stuttering resulted from the asynchronous arrival of nerve impulses in the bilaterally paired jaw muscles. Using electromyographic data recorded from the left and right masseter muscles of twenty four adult male stutterers, and nonstutterers, Travis reported that whilst the action potentials for the nonstutterers were practically identical, those of the stutterers were greatly different. It was suggested that the competition between the hemispheres during motor speech behaviour resulted in out-of-phase arrival of action potentials that disrupted speech. These reports did not go unchallenged and other investigators suggested that the explanations for differences noted in electromyographic recordings should be regarded as a consequence of stuttering, rather than the cause.

The theory lay dormant for many years as the evidence to support it was not forthcoming (Rosenfield & Jerger, 1984). However, with the introduction of the dichotic listening paradigm, the interest in the theory was reestablished. As a result of consequent research, other theoretical perspectives related to stuttering and cerebral dominance developed.

2.3.1.2. <u>Bilateral neurolinguistic organization</u>

Related to the Orton- Travis theory is a more recent explanation that supports the contention of bilateral neurolinguistic organization. In an attempt to provide a theoretical framework based on the concepts derived by Moscovitch (1983) cited in Rastatter & Dell, 1987a), suggested that for stutterers, the left hemisphere does not assume total control, and in fact relies on the right hemisphere for certain linguistic functions. Due to bilateral cerebral representation, it is possible that the speech-motor programmer may receive conflicting information from each hemisphere. Similar information may be received that is temporally out of phase and a disturbance in coordination is thought to occur when sensory input to the motor neuron groups is aberrant. The source of the aberrant input to the motor neuron pools may be the out-of-phase signals. This model highlights the role of the aberrant auditory processing (which is most likely reflected on the studies using dichotic tasks) as well as motor processes, thereby, providing a more comprehensive and realistic conceptualization of stuttering.

2.3.1.3. Right Hemisphere Processing

In contrast to the proposals suggesting lack of cerebral dominance in stutterers, some researchers suggest that stutterers demonstrate right hemisphere dominance for language (Peters & Guitar, 1991). The emerging pattern seems to suggest that stutterers rely more on the right hemisphere than on the left for speech processing. Peters and Guitar (1991) have suggested that the left hemisphere of the brain is more specialized for speech and language, because it has the ability to process rapidly changing signals better that the right hemisphere, which is specialised for more slowly changing signals such as music, and environmental sounds. Some investigators (Moore & Haynes, 1980) have suggested that poorer performance of stutterers on tasks of central auditory processing could suggest that stutterers do not use their left hemispheres for speech perception as efficiently as nonstutterers. Instead, they use their right hemisphere which is not suited to speech processing to a greater extent than nonstutterers (Moore, 1984b; Moore & Haynes, 1980).

Moore and Haynes, (1980), in supporting this hypothesis have reported that stutterers have been found to be inferior to nonstutterers in reporting nonsense syllables in the right ear in a dichotic paradigm thereby suggesting a reflection of the stutterers greater dependency on right hemisphere processing. In explaining the atypical performance of stutterers Moore and Haynes, (1980) have suggested that tasks requiring time-dependent segmental processing (such as for the DCVs) will be more defective than those requiring time-independent nonsegmental strategies, for stutterers.

2.3.1.4. <u>Stuttering as a temporal programming disorder</u>

Kent (1984) has disagreed with the right hemisphere processing contention put forth by Moore and Haynes (1980). Kent's criticism specifically referred to the suggestion that the right hemisphere processes information independent of the time domain. As an alternative, Kent (1984), suggested that for stutterers both hemispheres were able to process information in the time domain but that they differ in their preferred temporal ranges. The primary difference between stutterers and nonstutterers lies in their capacity to generate "temporal programs, or time structures of action" The temporal programme envisaged by Kent (1984) is a time plan or pattern useful for both perceptual processing of sequential patterns, as well as for the regulation of motor sequences. The operation of the temporal programme in speech production involves sensory and motor programmes that are linked in a complex manner. Kent (1984) has suggested that the central disturbance in stuttering involves a reduced ability to generate temporal patterns for perceptual or productive purposes. Stutterers are considered to have a faulty or unreliable mechanism for control of temporal structure. The production and perception of speech share certain control mechanisms and in linking this to stuttering, Kent has suggested that a single mechanism may control timing for both incoming and outgoing signals. Of critical importance to the present study is that faulty timing of incoming signals influences temporal management of outgoing signals. This processing difficulty is reflected in poor performance of stutterers on central auditory processing tasks.

In summarizing Kents' theoretical perspective on stuttering it must be emphasized that the weakness that underlies stuttering is a reduced capability to generate fine temporal programmes that are necessary for efficient auditory perception and for motor regulation ,and hence for fluent speech generation.

2.3.1.5. Neuropsychological theory of stuttering

Yeudall (1985) has developed a neuropsychological theory of stuttering which supports a cerebral dominance imbalance notion. He has suggested that the "activation balance between the cerebral hemispheres of the brain during expressive speech favours the nondominant hemisphere in stutterers rather than the dominant hemisphere as in fluent speakers". The dominant hemisphere normally maintains executive control of the motor-speech neural system, and inhibits the nondominant hemisphere during speech production. In stutterers the fluent speech is disrupted when the nondominant hemisphere inappropriately gains control of the motor-speech neural system just before speech initiation or during speaking. Whilst Yeudall's theory is in keeping with the Orton-Travis theory, and the explanation offered by Kent (1984), it provides a more comprehensive overview of how the neural mechanisms generate expressive speech disfluency. For the present investigation it is not necessary to detail the theory underlying speech dysfluency. The present focus relates to the way in which auditory processing problems may contribute to stuttering. Yeudall (1985) like Kent (1984) has posited that a common cortical region of the brain subserves both speech perception and motor output. In this regard it is suggested that stutterers may demonstrate performance differences on dichotic tasks indicating that they may be deficient in the processing of incoming information. Perhaps of significance is that the theory described by Yeudall conceptualizes stuttering as a broad spectrum neurobiological disorder of speech dysfluency, that is generated by a combination of processing problems at cortical, as well as subcortical levels. This provides a more comprehensive review of stuttering than the other perspectives described.

The theoretical perspectives considered thus far examined the role of cerebral dominance in stuttering. It is noted that many explanations have developed in an attempt to describe the stuttering disorder. It becomes apparent that the notion of anomalous cerebral asymmetries for stutterers is plausible, and that, at present the mechanisms that generate speech dysfluency are being investigated. The controversies as to the nature of cerebral processing in stutterers are by no means resolved, and therefore, further investigation is necessary. This provides in part motivation for the present study.

2.3.2. STUTTERING AND AUDITORY FEEDBACK

The following discussion relates to some of the theories that have been proposed relating auditory feedback and stuttering. At this stage it is necessary to consider Fairbank's (1954), model of speech as a servosystem, as it is upon this model that many of the early theories (Mysak, 1960; Martin, 1970) have been based.

2.3.2.1. The speech mechanism as a servosystem

Fairbanks (1954), described the speaking system as a bio-acoustical system. A two-way speaker-listener system was explored whereby the individual functions both as the receiver, and the transmitter of speech. It was suggested that the speaker hears himself while he talks i.e. auditory monitoring. However, Fairbanks (1954), suggested that this view misemphasizes the significance of self-hearing during speaking because it stresses the past. He suggested that the essence of the speaking system is the control of the output or the prediction thereof. A criticism of the monitoring interpretation (Fairbanks, 1954) is that it considers the ear as a receiver in the listening system rather than as a component of the speaking system. Fairbanks (1954), therefore, prefers the use of the term auditory feedback which accounts for the role of the ear in listening and speaking systems.

In describing the speech system as a servosystem, Fairbanks contrasted an open-cycle system and a closed cycle system. In the open-cycle system the control device that produces the output is controlled by some quantity that is independent of the output. This system is likened to that of a alarm clock in which the event is controlled by time. In contrast, the closed cycle system is one which employs feedback of output to the place of control, hence there is comparison of the speech output to the input. In essence the output will have the same functional form as the input. The system is also time based.

It is not necessary to review the model for closed cycle speaking. However, a figure illustrating the nature of the speech mechanism as a servosystem is presented to facilitate an overall understanding of the system. For the purposes of the present study however, an understanding of the creation of the error signal is essential, as this concept is used in models explaining stuttering.

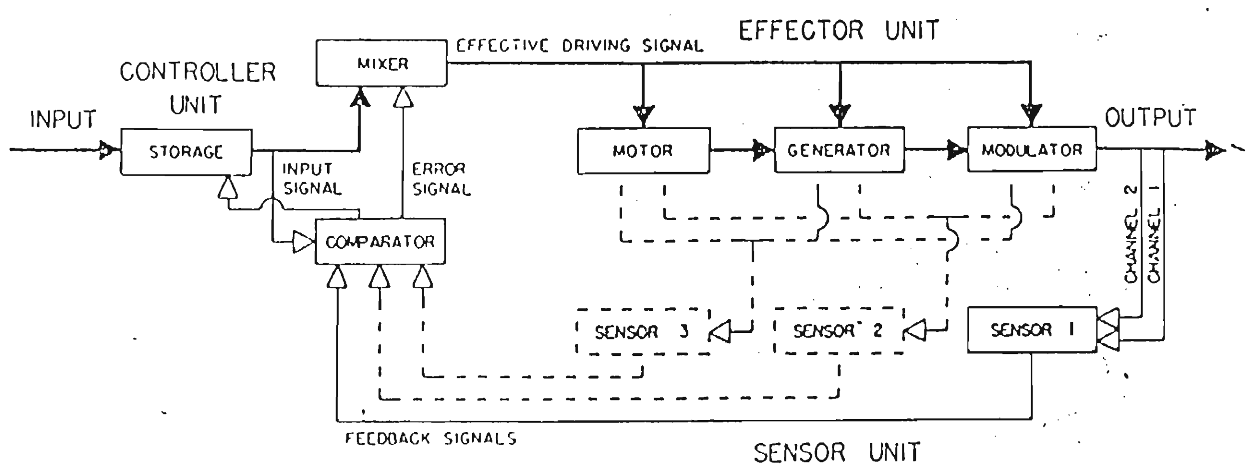

Figure 2 : <u>Model of a closed cycle control system for speaking (Fairbanks, 1954)</u>.

In the speech model, Fairbanks (1954), described the controller unit which has two components. viz. the comparator and the mixer. The role of the comparator is to determine the difference between the input and the feedback signals. At any given time it provides an indication of the "amount by which the control point has not been reached by the output, or the nonaccomplishment of the output". This measure is termed the error signal. At a point in time during speaking, the error signal is the amount by which the intended speech unit (in the storage device) has not yet been produced by the effector. At this point, the error signal does not equal zero, and it provides information to the effector to modify its functioning to bring the error signal closer to zero. To achieve this status, the error signal is continuously fed into a mixer. The function of the mixer is to combine the error signal and the input signal into an effective driving signal which instructs the effector. The effectors' operation is then altered causing the output to be relayed back to the comparator in the form of a feedback signal which is more nearly equal to the error signal thereby reducing the error signal. The reduced error signal is fed back to the mixer, which in turn modifies the effective driving signal accordingly. This process continues until the error signal equals zero. The system operates continuously.

Of significance is Fairbanks' contention that the speech system contains many components within a complicated arrangement and is easily disordered. Fairbanks constructed a mechanical model based on the principles described. It was suggested that the feedback delay in the model could be manipulated to cause repititions, prolongations and hesitations all of which are characteristic of stuttering behaviour. Whilst Fairbanks' model is simplistic, in that the complexity of the neural network for speech is not detailed, it has made significant contributions as to the role of auditory feedback in speaking.

2.3.4.2. Servo theory of stuttering

Using Fairbanks' (1954), model of the speech mechanism as a servosystem, Mysak (1960), described a servo theory of stuttering. In this model Mysak proposed an open-and-closed-cycle system model, and described four self-reflexive circuits where speech processing breakdown could occur. In this theory stuttering is considered to be a disorder of verbal automaticity. The symptoms of stuttering occur when the verbalizing automaticity mechanisms may be disturbed directly, or indirectly. The deautomaticity is seen as the possible result of the disturbances in the reflexive and automatic mechanisms in various parts of the total linguistic circuitry (Mysak, 1960).

One of these circuits is of particular relevance to the present study. However, a brief description of the other aspects are provided, in order to provide a more comprehensive view of stuttering, as described by Mysak (1960).

i. Integrator unit or perceptual-conceptual mechanisms :

   In this circuit speech fluency is said to be affected by the disturbance of the reflexive and automatic relationship between the concept and word mechanisms, or by a break in the circuit between the storage or governor components (servosystem terminology).

ii. Controller unit or secondary and primary motor speech circuit.

   There are at least two reflex and automatic mechanisms found in the controller unit :

   - the first exists between the governor (secondary motor speech area) and the mixer -effector complex (primary speech motor unit)- an anomaly of the motor speech and related areas may cause uncontrolled release of electrical potentials and may disturb the governor and mixer circuits

- the second exists between the comparator and the governor and, involves the development in the comparator of a predicted fluency error signal for particular articulatory cycles.

This system is of significance to the present study. The creation of a fluency error signal in the comparator by an outside source may disturb the total system and result in stuttering.

iii. Sensor unit circuit : The units deautomaticity is, as a result of greater peripheral involvement than central involvement. It has been proposed that aberrations in bone conduction, the Organ of Corti as well as auditory pathways may produce conditions resulting in fluency anomalies.

It appears that fluent verbalization depends on the integrity of a series of reflex and automatic processes. The importance of unity of the open and closed cycle linguistic circuitry has been emphasized by Mysak, (1960).

Mysak's contributions to a theoretical perspective were two-fold. Firstly, it described stuttering as a complex neurological phenomenon, whereby many systems may be operating to generate disfluency; and secondly it described the role of the error signal as it relates to stuttering.

2.3.2.3. Signal Detection Hypothesis : Perceptual defect theory of stuttering

Martin (1970), also developed a theory of stuttering based on the model suggested by Fairbanks (1954). More specifically, Fairbanks suggested a theory of the speech mechanism explicitly based on the notion that speaking involves the monitoring of feedback. Martin (1970), like Mysak (1960), referred specifically to Fairbanks' proposed "comparator" which was intended to match the feedback signal with some representation of the intended production. In this context speech was said to be guided by the presence or absence of an error signal, produced by the comparator. Martin's theory was specifically formulated to explicate the known relationship between stuttering and speech anxiety in terms of how certain kinds of anxiety could block or delay the feedback loop.

The view of perception in this model is associated with the signal detection account of psychophysical processes. A description of the basic aspects of the theory is presented so as to facilitate the application of those concepts to stuttering.

The signal detection hypothesis is as follows.

- Auditory signals are generally presented against a background of noise. The noise is assumed to vary, randomly or systematically, in intensity over time. Some of the noise will have the same qualitative properties as the signal to be received.

When the signal is presented, the noise and the signal are heard. The combined input will have the intensity of the signal and the noise when they are combined.

- The decision as to whether the signal is present or not, is related not only to the function of the intensity of the signal and to the noise. It is also the function of the input and the decision criterion. The perciever sets the decision criterion. When the intensity of the input exceeds the value of the criterion, the perciever decides that the signal is present. However, when the intensity does not exceed the criterion then the perciever decides that the signal is not present.

- An excessively conservative (stringent) criterion will block the perceptual process. Normally acceptable signals will be rejected as noise if the criterion is sufficiently conservative. There is also evidence that the decision time will be longer when the criterion is highly conservative, as opposed to when its not. Thus, the setting of an excessively conservative criterion may block the perception of the signal when the signal is weak, and may delay that perception when the signal is strong.

Martin (1970), used both the signal detection hypothesis and Fairbanks model of speech as a servosystem, and drew the following links between stuttering and central auditory processing : The comparator receives input from other central processors which specify the criterion in terms of when the feedback will be evaluated. It was hypothesized that for the moment of stuttering the criterion becomes excessively conservative, and the decision time in the comparator is slightly delayed, thereby delaying auditory feedback. This then results in speech dysfluencies like repetitions and prolongations which are characteristic of stuttering.

Martin (1970), acknowledged that a theory such as that postulated may not sufficiently explain a complex phenomenon such as stuttering, but it does attempt to provide a more integrated theory incorporating the perceptual defect of stuttering.

In summarizing, it is evident that the stuttering feedback models (Mysak, 1960; Fairbanks, 1954; Martin, 1970) whilst different from each other, share a physiological base. The primary assumptions underlying these models is that stutterers have disturbed auditory feedback loops that occur as a result of central auditory processing deficit at some level of auditory function (Hageman & Greene, 1989). The present investigator is of the view that whilst the models do not explain all aspects of stuttering, they are of value in that they provide a plausible explanation of the ways in which the auditory/speech systems are linked in describing stuttering.

The perspectives provided thus far reflect an attempt to set the stage for the further development of, and refinement of, the role of the central auditory nervous system processing difficulties in stuttering. A description of more recent explanations relating speech fluency and central auditory processing follows.

2.3.2.4. <u>Speech flow breakdown hypothesis</u>

Wynne and Boehmler (1982) have provided an explanation relating central auditory processing problems and speech disfluency. Whilst the model is not an attempt to describe central auditory processing links with stuttering per se, it does describe how central auditory processing problems may generate part-word repetitions. Since part-word repititions are symptomatic of stuttering, a description of the model in warranted.

Wynne and Boehmler (1982) have suggested that part-word repetitions provide an indication of the speech flow breakdown due to a central auditory deficiency, as opposed to language formulation problems. They have postulated that speech flow involves the integration of prosodic speech patterns which include syllable rate. Speakers generally maintain a syllable pulse pattern, which has been described as the basic physiological unit of speech. When the central auditory encoding process is disrupted during ongoing speech (e.g. by disturbance in the feedback mechanism), the correct encoded motoric pattern may not be available to generate the intended syllable pulse. However, whilst the motoric pattern is unavailable, the basic temporal pulse pattern of speech is maintained. The resulting behaviour is a repetition of the previously encoded pattern resulting in part-word repetitions. Thus, the description relates dysfluent speech to a breakdown in central auditory processing problems at a level of in the brainstem.

2.3.2.5. Speech production and central auditory processing asynchrony

Stager (1990), based the explanations of stuttering and central auditory processing problems on research generated on auditory brainstem findings. A subgroup of stutterers demonstrated prolonged latencies, and based on this observation, Stager (1990), generated two hypotheses as to how central auditory processing problems may be related to stuttering.

Firstly, it was suggested that the brainstem is the locus in the central nervous system where there may be interaction of the auditory and the speech production pathways. Stager (1990), cites research (Jurgens & Pratt, 1979; Jurgens & Richer, 1986; Kirzinger & Jurgens, 1985) that traces the phonatory pathway in man to a level lateral and dorsal to the superior olivary complex. It is also at this level that some brainstem responses are generated. It is possible that these auditory and speech mechanisms influence each other to produce dysfluency. (Stager did not describe the mechanism further).

The second of the two explanations offered by Stager (1990), relates to deficiencies in the auditory feedback mechanisms. The description is based on the assumption that precise synchrony of information at some point in interaction is required between the auditory and speech production mechanisms to generate fluent speech. If the auditory information is delayed, then the synchrony in the central auditory nervous system is disrupted. Stager (1990), has argued that the data generated currently does not allow for any further speculation. This description relates to the earlier models of feedback described to the extent that it provides a link between stuttering and central auditory processing problems.

The preceding review has focused on the role of auditory feedback and its role in stuttering. The researcher suggests that the earlier models described the processes that may be operating to generate stuttering hence generating research that has set out to investigate the nature of central auditory processing.

2.4. **SEX DIFFERENCES IN STUTTERERS**

The topic of sex differences in stuttering is and has been of general interest in the light of the well-documented sex ratio. Whilst the reasons for speculation as to the nature of sex differences have been forthcoming, they have not been based on empirical findings. The attempts to explain the sex ratio have ranged from psychological to physiological perspectives. The psychological views implicate the role of learning and the environment in stuttering. A study by Hutt 1985 cited in Starkweather, (1987) indicated that boys' mothers spoke at a faster rate than girls' mothers, and thereby suggested that the parent creates a more demanding communicative environment for the male, thus generating stuttering and contributing to the sex ratio. Other suggestions that have been popularized are that parents have greater expectations for their sons than for their daughters thereby creating a more stressful environment that may contribute to the sex ratio in stuttering (Van Riper, 1982).

Physiological explanations for the sex ratio have also been offered. The more popular suggestions relate to a possible genetic factor determining the sex ratio (Kidd, 1984). In this regard it has been suggested that males are predisposed generally to acquiring developmental problems, and by the same token are predisposed to stuttering. Other suggestions are that a genetic-hormonal disadvantage (Kent, 1984) places males at the risk for stuttering. Flor-Henry (1983), suggested that the differential effects of androgens and estrogens on the developing brain may influence the development of male and female brains differently.

Following this suggestion, it is postulated that prenatal hemispheric gender differences render the sexes differentially vulnerable to disturbances of the dominant hemisphere (left) in males, and to the nondominant hemisphere (right) in females. This predisposes the males to a lack of cerebral dominance, and hence increases the vulnerability to stuttering.

In attempting to relate the sex ratio to hemispheric differences, Kent (1984) has cited McGuinnes (1981), who suggested that the critical distinction between normal speakers and stutterers lies in their capacity to generate temporal programmes. Such temporal programmes are important in fine motor sequencing ability, verbal fluency, speed of verbal coding from visual display, and singing in tune for which there is female superiority. Thus, female superiority on sensorimotor tasks relates to their abilities in generating more fluent speech than males.

The speculations as to the reasons underlying sex differences are generally not well described in the literature, and therefore requires further investigation. It is possible that the present study could contribute to an explanation thereof.

2.5. SUMMARY

This chapter has provided an overview of central auditory processing, stuttering, and theoretical perspectives linking stuttering and central auditory function. The purpose of this study is to investigate the central auditory processing performance of male and female stutterers and nonstutterers using a test battery. The discussion that follows provides a review of literature focussing on pertinent studies undertaken in the field of stuttering and central auditory processing. The reviews will reflect particularly on contributions made by previous researchers, their shortcommings and more important on the issues that provide an extension for the rationale for the present study.

CHAPTER THREE

LITERATURE REVIEW

3.1. INTRODUCTION TO LITERATURE REVIEW

The previous chapters provided a motivation for the study and a review of pertinent theoretical issues. The discussion that follows is an attempt to provide an overview of research studies in the fields of stuttering and central auditory processing as it is against this background that the present study was conducted.

The literature review includes those studies in which tests employed in the present study were used. However, studies that used other tests/techniques to investigate central auditory processing not used in the present study, have also been reviewed. The reasons for including the range of studies reviewed are as follows :

- It is an attempt at providing a comprehensive review of the relationship between stuttering and central auditory process ing.
- Recommendations of previous studies have been carried forth in the present investigation, although test selection may have differed.
- The results of some studies, although using different methods, serve to support findings related to the present study in that they measure similar functions /levels of processing in the central auditory system.
- An evaluation of the findings of various studies served as

guidelines for the selection and use of tests in the present study.

As mentioned previously the measures of central auditory processing in stutterers have played two major roles in stuttering research, viz. as measures of cerebral dominance in speech language, and, in the search for abnormalities of the auditory feedback mechanism subserving speech production (Rosenfield & Jerger, 1984). The following presentation is a review of literature investigating central auditory processing performance in stutterers. The presentation is structured as follows :

- **Stuttering and cerebral dominance research**
- **Stuttering and auditory feedback mechanisms**
- **Stuttering, central auditory processing and sex differences on central auditory processing tasks for stutterers and nonstutterers**

NB: It should be noted that it is difficult to make direct comparisons between studies in the area of stuttering and central auditory research. This is due to the great number of methodological variables which influence test results that need to be controlled for. The literature review is, therefore, a presentation of relevant studies reflecting individual attempts at comparing and relating findings. This point of view in handling research pertaining to stuttering and central auditory processing is supported by Blood and Blood (1989b).

3.2. **STUTTERING AND CEREBRAL DOMINANCE RESEARCH**

Orton and Travis (1927), cited in Bloodstein (1987), first conceived the notion that stuttering may be related to abnormal bilateral representation of cognitive functions in the cerebral hemispheres, thus providing the impetus for further investigation into stuttering and cerebral dominance. Several investigators pursued this thesis (Rutherford & Bryngelson, 1937; Daniels, 1940; Jones, 1966; Gregory, 1969; cited in Bloodstein, 1987), and investigated the relationship between stuttering and cerebral dominance, using a variety of methodologies. These included handedness studies, dichotic testing, electrophysiological measures, and reaction time studies (Bloodstein, 1987; Rosenfield & Jerger, 1984). These methodologies will be reviewed because they have contributed information to the theory linking stuttering and cerebral dominance. However, the primary emphasis of the review presented pertains to that of dichotic measures used in stuttering investigations. Amongst the early efforts to assess the notion of incomplete cerebral dominance in stutterers, were the handedness studies.

3.2.1. A BRIEF HISTORICAL PERSPECTIVE

3.2.1.1. Handedness studies

Research efforts to associate stuttering with incomplete cerebral localization investigated the relationship between handedness and speech (Bryngelson & Rutherford, 1937; Daniels, 1940; Heltman, 1940, cited in Pinsky & McAdam, 1980). Right-handedness implied left cerebral dominance for speech, left-handedness implied right cerebral dominance and ambidexterity implied bilateral cerebral dominance. This linkage assumed an isomorphic relationship between manual laterality and speech laterality (Fitzgerald, Cooke & Greiner, 1984). Nevertheless, if speech and handedness are localized in the same hemisphere, it would be reasonable to expect a relationship between them, to the extent that they shared the same cerebral space (Fitzgerald et al., 1984).

Evidence supporting the relationship of handedness and stuttering were cited in clinical reports of left-handed stutterers. It was suggested that stutterers had a greater frequency of left-handedness compared with the normal population. However, the early research relating stuttering and handedness revealed contradictory findings (Pinsky & McAdam, 1980),and the Orton-Travis theory lost popularity as no conclusive statement could be made about stutterers and handedness. These findings are not surprising since it has been noted that handedness is imperfectly correlated with preference with foot, eye, or ear, and therefore, it is unlikely that it would be correlated with speech (Fitzgerald et al., 1984).

It was concluded that handedness is not a sufficiently strong correlate of cerebral dominance, and therefore researchers' attempts to investigate the link between handedness and stuttering failed to distinguish stutterers and nonstutterers on the basis of laterality (Bloodstein, 1987).

Whilst the investigations of handedness and stuttering were by no means conclusive, handedness research with stutterers contributed to shaping the methodology used in investigating stuttering and cerebral dominance. Handedness, as a variable factor, was subsequently considered in subject selection to obtain a more homogeneous sample. It was thus also a consideration in the present investigation.

3.2.1.2. Developments leading to the use of dichotic testing with stutterers

Following on from the inconclusive findings of the handedness studies, the cerebral dominance theory remained dormant for some time, and was later revived by Jones 1966, cited in Rosenfield & Jerger, 1984. Jones used the Wada Test with stutterers - a procedure whereby individuals become transiently aphasic following intracarotid barbiturate injection to their dominant hemisphere. Jones noted that four stutterers became aphasic following amytal injection to their right and left carotid arteries indicating that both hemispheres were contributing to language (Rosenfield & Goodglass, 1980). All subjects thereafter underwent unilateral corrective surgery, and subsequently ceased to stutter. Based on these observations, Jones concluded that the stutterers no longer had bilateral speech representation, and therefore, they no longer stuttered.

This study was criticized by Rosenfied and Jerger (1984) on three major issues. Firstly, several individuals who do not stutter have bilaterally positive WADA (bilateral cerebral representation). Therefore, bilateral representation for speech and language should not be considered a precondition for stuttering. Secondly, Jones did not comment as to how the presence of stuttering was ascertained. This, therefore, created doubt as to the criteria used in subject selection. Thirdly, three of the four patients were left-handed. This implied that bilateral language representations may have been an existing influence. Although the study was criticised, it did introduce a new technique for investigating cerebral dominance in stutterers viz. the WADA Test.

In an attempt to overcome the shortcomings of Jones' study, Andrews, Quinn, and Sorby (1972) investigated three right-handed stutterers for whom there were no demonstrable cerebral pathology. A fourth subject did show unilateral cerebral insult. The results indicated that for the three subjects with no cerebral pathology, language was confined to the left hemisphere as in nonstuttering individuals. The subject with the cerebral lesion had speech capacity in both hemispheres preoperatively. The study was unable to duplicate the findings of Jones, and led the authors to conclude that although the concept of incomplete cerebral dominance in stutterers was plausible, the findings supporting this hypothesis were not forthcoming. Further attempts to investigate this phenomenon were made by Lussenhop, Boggs, La Borwit, and Walle (1973) and the findings were conflicting, as bilateral speech representation was found in five of the 11 stuttering subjects. The findings on the WADA tests for stutterers did not entirely support the cerebral dominance hypothesis. Furthermore, the WADA Test was not used routinely because it is an invasive procedure.

A new development in the assessment of cerebral dominance for speech, was that of the dichotic listening paradigm, introduced by Broadbent (1954), cited in Musiek and Pinheiro (1985). Early investigations with dichotic listening tasks discussed by Brady and Berson (1975), indicated that the performance characteristics for normal right-handed subjects using the dichotic listening paradigm, revealed a right ear advantage (REA) for linguistic stimuli. Since the REA is regarded as an indication of left cerebral dominance for speech/language (Kimura, 1961; Speaks, 1978), the dichotic listening task became a popular tool for examining the cerebral dominance hypothesis in stuttering. A further advantage of using the method, was that it provided a quantitative measure of the degree of cerebral dominance/lateralization which is derived from examining the difference between the right and the left ear scores. In addition, it is a noninvasive method, and therefore, became a preferred method of investigation of ear advantage and hence, cerebral dominance with stutterers.

The initial investigations using the dichotic listening paradigm with stutterers were those using word stimuli. Two types of word stimuli have been used in central testing i.e. consonant-vowel-consonant (CVC) words, and spondaic words.

3.2.2. RESEARCH STUDIES : DICHOTIC TESTING AND STUTTERING

The first detailed study of dichotic listening in stutterers was conducted by Curry and Gregory (1969). The performance of 20 right-handed adult stutterers, and 20 controls, was compared on a Dichotic Word Test. Sets of six high frequency CVC words were presented dichotically. The subjects were required to recall all 12 words regardless of order. The majority of the control group (75%) showed right ear superiority, compared with 45% for the stuttering group who demonstrated right ear superiority.

Furthermore, the nonstutterers' mean absolute ear difference score was more than twice that of the stutterers. This demonstrated that nonstutterers lateralized speech to a greater degree compared with stutterers. Whilst the study did report differences between stutterers and nonstutterers, it was subject to criticism (Quinn 1972; Dorman & Porter, 1975; Rosenfield & Jerger, 1984). Among the criticisms made were that the recall of 12 words placed great stress on memory, and, thereby negatively affected results. In addition, males and females were mixed in the same design. Thus, whilst stutterers and nonstutterers did perform differently on the dichotic task, the influence of other variables on test performance may have reduced the significance of the findings.

Subsequent research comparing stutterers and nonstutterers (Slorach & Noehr, 1973; Dorman & Porter 1975; Sussman & McNeilage 1975a) failed to replicate the findings of Curry and Gregory. Quinn (1972) used a procedure similar to that of Curry and Gregory (1969), and compared 60 right-handed, predominantly male stutterers, and controls on the Dichotic Word Test. Quinn (1972), failed to find significant group differences, but reported two similarities with the findings of Curry and Gregory (1969), viz. both studies reported a difference between stutterers and controls, and both studies used stimuli with semantic value (both used CVC words). In contrast, the Quinn (1972) study showed only a qualitative difference between the stuttering and control groups i.e. both stutterers and controls showed a REA, but the REA was smaller for stutterers than for the control group. Thus, performance differences between stutterers and nonstutterers did not reveal a consistent trend, thereby warranting further research.

Somers, Brady and Moore (1975) noted that the issue of cerebral dominance for stutterers was essentially unresolved. They emphasized that the "confused cerebral laterality for speech" hypothesis had never been substantially refuted, and that dichotic test findings had been equivocable in their support for this hypothesis. They further commented that research strategies investigating the performance of adult stutterers have been influenced by many stimulus variables, e.g. a variety of dichotic test material consisting of syllables, digits, words had been used. In addition to stimulus variables, task variables, viz. response modes and interstimulus time between groups of recorded stimuli, also influenced test results. Of significance, was that the retrieval of dichotic material held in short-term memory also needed to be controlled for.

Somers et al., (1975) therefore designed an investigation to test the auditory perception of speech for stutterers and non-stutterers by obviating the influence of the memory factor, and at the same time using meaningful dichotic stimuli to elicit the greatest amount of REA. In doing so, digits and words were chosen as stimuli. A further aim of Somers et al., (1975) was to examine the effect of age on central auditory processing performance, as this was a much neglected variable in stuttering research.

To realize the aims of the study, Somers et al. (1975), selected 78 subjects (39 stutterers and 39 controls), aged between 4.5 to 48 years. Subjects included males and females, all of whom were right-handed and were divided into three age groups, ranging from childhood to adulthood. A single response mode was required for the dichotic word and dichotic digit test. The results indicated that the proportion of stutterers who failed to demonstrate a REA for dichotic words was significantly greater ($p<0.05$) than for nonstutterers. On the dichotic digits test 18% of stutterers, and none of the nonstutterers showed reversed or left ear preference. Based on these results Somers et al., (1975) suggested the possibility of existence of sub-clinical groups of stutterers i.e. a group showing atypical speech processing of dichotic verbal material, and, a group showing expected right-ear-preference.

With respect to findings related to age, the nonstutterers showed no age effect on the Dichotic Word Test. Stuttering children showed significantly ($p<0.05$) less right-ear-preference than did the nonstutterers. It was speculated that spontaneous remission of stuttering results with the development of greater degrees of speech perceptual ability and/or hemispheric dominance. Somers et al., (1975) have highlighted two significant issues viz. the need to control variables that influence central auditory processing performance e.g. age and memory, and, suggested the existence of subgroups in the stuttering population.

Thus far, a review of the literature has focussed on studies using dichotic word and digit tests revealing conflicting conclusions. A new measure of laterality for speech, that of the Dichotic Consonant Vowel test was introduced by Berlin and McNeil (1976) and the use of the CV stimuli became popular for the following reasons (Pinsky & McAdam, 1980). CVs were described as adequate in demonstrating REA, because they are technically more sophisticated. They allow for matching time onset, amplitude and duration. Furthermore, the CVs are not complicated by differential semantic content, and tend to yield less variable results.

In subsequent investigations, CVs became the tool of choice for investigating ear advantage.

Hawver (1978), used a test battery approach to assess stutterer/nonstutterer differences in central auditory processing. Amongst the tests included was the Dichotic Consonant Vowel Test. The experimental subjects comprised ten stutterers who ranged in age from 19 to 47 years. The 10 control subjects were matched on the basis of age, sex and race. The results of significance in the investigation, were that the performance differences between stutterers and nonstutterers were noted only on the dichotic tests, and not on the time-compressed and filtered speech tests. This implied that the dichotic tests compared with other tests included in the battery, were more sensitive in highlighting stutterers and nonstutterers differences. The results indicated that stutterers performed less accurately compared with the control subjects on the DCV test, and the SSW tests. The stutterers as a group, like the nonstutterers, obtained better scores on the right ear than the left.

The explanations offered by Hawver (1978) for the observed differences for stutterers on the DCV test related to a disruption in the transmission time of signals. Hawver proposed that, as a result of a problem with the transmission time, the processing is disrupted because the phonetic information of auditory signals may not have been adequately separated, and thereby interfered with the perception of signals in one or both ears.

The present researcher is of the opinion that this is a likely explanation for two reasons. Firstly, it concurs with the contention that stutterers have atypical auditory processing skills. Secondly, the stimuli allowed for the system to be stressed in a manner that allowed for perception in one or both ears to be interfered with. It should be emphasized that whilst Hall and Jerger (1978) and Hawver (1978) noted stutterer/nonstutterer differences on specific dichotic measures, the overall differences between stutterers and nonstutterers were regarded as subtle. It was also apparent that only those tasks that stressed the central auditory processing system sufficiently, were capable of revealing stutterer/nonstutterer differences.

Hall and Jerger (1978), like Hawver (1978), have contributed to the field of study by emphasizing the need to use test batteries that were sensitive to the nature of processing differences between stutterers and nonstutterers. Of the two dichotic tests viz. the SSW test, and the SSI-CCM test used in the study, the SSW test (as opposed to the SSI-CCM), was specifically identified as a sensitive measure in revealing stutterer/nonstutterer differences. The findings by Hall and Jerger (1978), and Hawver (1978) contributed to the motivation for the SSW and DCV tests being included in the present investigation.

Rosenfield and Goodglass (1980), have reported that there were many variables influencing test results, and that this was possibly responsible for the conflicting findings on central auditory processing tasks for stutterers. Amongst the variables identified were that children may be different from adults with respect to stuttering; and that males and females may differ with regard to underlying processes, and therefore should not be mixed in a stuttering research paradigm. In addition, handedness should be measured rigorously to ensure that one is testing a homogeneously-handed population. All of these variables were controlled for in the present study.

In an attempt to exercise strict control over these variables, Rosenfield and Goodglass (1980) selected a group of adult stutterers and nonstutterers using stringent criteria. They evaluated cerebral dominance in the left hemisphere using consonant-vowel stimuli, and tested right hemisphere laterality using melodic input. REAs were obtained for CVs, and left ear advantages for melodies for both groups. There were no significant ($p>0.05$) performance differences between the stutterers and nonstutterers. However, a significantly ($p<0.05$) greater number of stutterers than nonstutterers failed to show the expected ear laterality for either type of stimuli.

Rosenfield and Goodglass (1980), observed that group analysis of ear advantage for CVs did not distinguish stutterers and controls. The finding that individual stutterers showed deviant lateralization has special significance. Their explanation concurred with that offered by Somers et al., (1975) that there may be a subgroup of stutterers who have problems with cerebral dominance which may be related to their speech disorders. They have emphasized the need to examine individual data in stuttering research,and this recommendation was carried forth in the present study.

Blood (1985) has commented on the usefulness of the Dichotic Listening Test with stutterers and in addition emphasized two aspects. Firstly, reporting group mean data in dichotic listening paradigms is inappropriate without subgroup or individual data analysis. Secondly, the interpretation of abnormal laterality patterns for stutterers could be related to aberrant cerebral processing. However, in the light of the many variables affecting the interpretation of such a result, Blood (1985) suggested that other variables such as familial history and onset history, amongst others need to be considered. These recommendations (Blood, 1985; Rosefield & Goodglass, 1980) were also carried forth in the present investigation.

Pinsky and McAdam (1980), having noted the findings and controversies evident with previous research comparing stutterers' and nonstutterers' central auditory processing performance, used a range of assessment tools to examine the issue of cerebral laterality. The assessment tools included the Dichotic Consonant Vowel test, and electrophysiological measures including the alpha recordings, contingent negative variation, and readiness potential. Of significance for discussion at present, is the use of the DCV test. The results obtained with a small sample of five subjects indicated that all subjects except for one, showed the REA. A similar trend was obtained in the control group. This result did not support the hypothesis that stutterers demonstrated hemispheric asymmetry different to that of nonstutterers. This study was criticized because it used a small sample, and great variability noted in the results could have contributed to the nonsignificant differences obtained between stutterers and nonstutterers. The findings on other electrophysiological measures are discussed later (p. 101). Pinsky and McAdam (1980) in contrast to other studies did not find significant performance differences between stutterers and nonstutterers, thus, once again, highlighting the conflicting nature of the results generated by dichotic listening tasks for stutterers and nonstutterers.

The study by Libertrau and Daly (1981), attempted to overcome the problems noted in stuttering research with central auditory processing tasks, and have investigated the central auditory processing abilities of two carefully defined subgroups of stutterers viz. an organic group and a functional group. The groups of stutterers were differentiated on the basis of their performance on the Michigan Neuropsychological Test Battery. The organic group comprised six stutterers who exhibited three or more positive signs on the test battery, whilst the functional group (six stutterers) showed no sign of performance deficits on the neuropsychological investigation. The control group comprised of six nonstutterers matched for age and academic ability.

The results on the DCV test indicated that all groups obtained a slight right ear preference with no significant ($p<0.05$) performance differences between the groups on total correct scores. On one masking level difference (MLD) condition however, organic stutterers performed significantly differently from the control group (a discussion of this result is forthcoming p. 116). Libertrau and Daly (1981) concluded that the results of the study suggested no significant differences between stutterers and nonstutterers on the DCV test. The present investigator suggests that whilst the selected subgroup of stutterers did not perform significantly differently from the normal group, it is conceivable that other subgroups of stutterers may perform differently.

This suggestion concurs with the belief expressed by Libertrau and Daly who report that stuttering is not a unitary disorder. The need for further differentiation of subgroups of stutterers was established, and considered in the methodology of the present study.

Newton, Blood, and Blood (1986), having noted contradictory research findings generated by other studies investigating cerebral dominance in stutterers, have suggested that the type of dichotic stimuli as a variable in stuttering research needed to be considered. Newton et al., (1986) embarked on an experiment using dichotic digits, and the SSW test. The impetus for using dichotic digits was derived from a previous experiment conducted by Saul and Katz (1983), who reported that in brain-damaged subjects the dichotic digit stimuli were a reliable indicator of central auditory dysfunction. Saul and Katz (1983) have suggested that a certain type of organic stutterer would surface based on the analysis of scores obtained. The study sought to examine the performances of stutterers and nonstutterers using varied dichotic stimuli.

The digits were presented in three formats viz. 1. two-pair digit (TPD) 2. staggered digit simultaneous (SDS) 3. staggered digit offset (SDO). The SSW test was also administered. The subjects included nine adult stutterers, and an individually matched control group. All subjects had to fulfil predetermined criteria for inclusion in the study.

The SSW, SDS and SDO tests produced similar results in the stutterers and nonstutterers groups. No significant ($p>0.05$) differences were observed between stutterers and nonstutterers on error scores. However, a significantly ($p<0.05$) greater number of reversals were noted on the SDO and SDS tests than for the SSW test for both groups. The TPD test was found to be significantly more difficult for both groups than were other tests. Saul and Katz (1983) have suggested that the superior left ear performances of stutterers on the TPD test may be related to subtle differences in cerebral dominance. In addition, they have suggested the magnitude of the ear difference was smaller in the experimental group which may relate to the incomplete dominance pattern in the stuttering population.

Newton et al., (1986) also suggested that the larger number of reversals on the SDO and SDS when compared with the SSW test could be explained in terms of the digit stimuli not being semantically related. It was concluded that subtle central auditory processing differences between the stutterers and nonstutterers were observed. It was also suggested that digit tests in their traditional forms may not be sensitive to the subtle processing differences between stutterers and nonstutterers. In addition, the small sample size may have contributed to Newton et al., findings showing no significant difference between stutterers and nonstutterers. Further investigation with larger sample sizes was suggested.

The results on the SSW test in the Newton et al. study (1986) was in contrast to that reported by Hawver (1978), and Hall and Jerger (1978), once again highlighting the conflicting nature of results obtained for stutterers. Therefore it is considered important that an attempt be made to resolve this conflict. The need for a carefully controlled research study was evident, and provided impetus for the present investigation.

Blood and Blood (1989b), having noted the conflicting findings on stutterers' responses to dichotic stimuli reiterated that the differences may have been influenced by a number of variables including type of stimuli, severity of stuttering, age, sex, amongst others. In addition, Blood and Blood (1989b) have identified another potential variable to be that of data analysis, which could cloud the significance of research findings for stutterers.

In an attempt to investigate the potential influence of this variable, Blood and Blood (1989b), administered the Dichotic Listening Test (DVCs) to ten adults nonstutterers and ten adults stutterers. The results obtained were analysed using five different procedures. viz. difference score, laterality quotient, percentage of error, Berlin method, application of the phi coefficient. The results indicated that 40% of stuttering subjects manifested changes in ear advantage depending on the type of analysis used. This led Blood and Blood (1989b), to suggest that the statistical significance of results was determined by the choice of analysis procedure rather than the data. In attempting to address the issue of ear advantage, Blood and Blood (1989b) have suggested that the direction and the magnitude of the ear advantage need to be considered. Whilst only the direction of ear advantage is commonly considered, the magnitude of ear advantage is often a neglected issue. The use of the phi-coefficient as a preferred method of analysis was recommended, because it considered both the magnitude and direction of ear advantage. In addition, it offers more stringent criteria by introducing a category of no ear advantage (NEA), as well as the REA and LEA categories. Thus, the choice of statistical procedure is a further consideration in the analysis of results obtained on DCVs. This recommendation was pursued in the present study.

The research reviewed on dichotic tests and stuttering has revealed the following :

- The present investigator has noted that the only dichotic test using sentence stimuli has been that of the SSI-CCM test. However, this test was consistenly not reported to be a sensitive measure to demonstrate central auditory processing differences between stutterers and nonstutterers. (Hall & Jerger, 1978; Toscher & Rupp, 1978). The present investigator suggests that the SSI-CCM test does not stress the central auditory system sufficiently, because it uses synthetic sentences and continuous discourse as dichotic input. In doing so, subjects are able to process the stimuli easily because the stimuli are vastly different. The task is therefore an easy one as stimuli are easily seperated for processing. The use of other sentence stimuli that may stress the central auditory system to a greater extent than the SSI-CCM test has not been attempted. The present researcher is of the opinion that stutterers' performance on sentence stimuli may offer greater insight into the nature of central auditory processing. Thus, the present researcher included as part of the test battery, a dichotic test using sentence stimuli which would stress the central auditory nervous system.

- The Competing Sentence Test was test of choice. The CST is considered more stressful by the researcher, because it uses an open as opposed to a closed set response mode. In doing so, the subject cannot rely on listening for particular words as in the closed set message (SSI-CCM) to determine the proper answer. Rather, the subject has to listen to the entire primary sentence to respond accurately. Furthermore, the sentences are closely matched for length and semantic content. In order to recall the target sentence accurately, selective attention is challenged. Thus, a test using sentence stimuli was chosen as a means of assessing central auditory processing in stutterers.

- The studies have reflected conflicting results using dichotic tests to compare stutterer and nonstutterer performance. The trends reported appear to suggest that there may be a subgroup of stutterers predisposed to central auditory processing problems. The need to identify, and research, various subgroups of stutterers has been recommended. Among the studies that have reported significant differences between stutterers and nonstutterers, the DCV and SSW tests are reported to be sensitive measures (Hawver, 1978; Hall & Jerger, 1978). The need to use a battery of sensitive tests is highlighted.

- The methods of data analysis favour consideration of individual data, in addition to group data, and stresses the need for stringent laterality/ear advantage criteria that consider the magnitude, and the direction of the ear advantage. The phi-coefficient has been selected as a method of choice in the present study (Blood & Blood, 1989b).

The research reviewed thus far has focussed on adult studies. Research ulilizing dichotic tests have also investigated aspects of central auditory processing with stuttering and nonstuttering children. It is not the intention of the present researcher to provide an exhaustive review of literature pertaining to children. However, pertinent findings are summarized since they contribute to the general body of research investigating stuttering and central auditory processing.

- As in adult studies, there is controversy as to whether children who stutter differ from children who do not stutter with respect to performance on the dichotic tests. Whilst some studies have reported subtle differences between child stutterers and nonstutterers, (Cimorrel-Strong, Gilbert & Frick, 1983; Blood & Blood, 1984a; Blood, 1985) others have not reported significant differences (Slorach & Noehr, 1973; Gruber & Powell, 1974).

- The heterogeneity in the stuttering population has been emphasized in research with children (Blood, 1985). The need to research subgroups of stutterers, and to further consider the developmental influences as an added variable for children on performance of central auditory processing tests has been highlighted.

- Blood (1985) have reported that children who stuttered are likely to demonstrate atypical cerebral dominance patterns. He noted that for those who did not normalize atypical cerebral dominance patterns, it is possible that stuttering persisted. For those who normalized cerebral dominance, spontaneous recovery from stuttering was possible.

- Blood, Blood and Hood (1987), in a longitudinal study, researched ear preferences in child stutterers and nonstutterers.

They have concluded that stutterers and nonstutterers show similar trends in the development of ear preferences, but that greater numbers of stuttering children showed left ear preferences (LEP), or no ear preference (NEP). The results have suggested the possibility that stuttering children retain LEP in adulthood. The results for stuttering children on dichotic tests are generally subject to a greater variability than in adults, due to developmental influences. The results in general do provide support for the incomplete cerebral dominance hypothesis for children who stutter.

Thus far the review has focussed on the use of dichotic tests in determining the differences in ear advantages between stutterers and nonstutterers, as an indirect assessment of cerebral dominance. Other methods of investigation to assess cerebral dominance in stutterers have also been applied. Of particular significance are the electrophysiological methods, and the studies investigating reaction time for stutterers and nonstutterers.

3.2.3. ELECTROPHYSIOLOGICAL MEASURES USED TO INVESTIGATE CEREBRAL DOMINANCE IN STUTTERERS

The electrophysiological measures used to investigate cerebral dominance with stutterers include the electroencephalogram measures, and average evoked responses.

3.2.3.1. Electroencephalogram measures

i. *The Alpha Component*

With the development in technology, the electroencephalogram (EEG) became a popular method to study cerebral dominance characteristics (Rosenfield & Jerger, 1984) and the *alpha component* of the EEG has been the focus of attention. It is the component of the wave between 8Hz and 13Hz. It has been suggested that suppression of the alpha component is an indication of active cerebral processing. In normal subjects, the alpha is suppressed in the left hemisphere during processing of verbal tasks and meaningful units, and is suppressed in the right hemisphere during the processing of spatial tasks and for nonverbal information. (Moore, 1979; Galin & Ornstein cited by Fitch & Batson, 1989). The measure was chosen by many researchers as a tool to investigate stutterers/nonstutterers differences in processing of verbal stimuli.

Pinsky and McAdam (1980), reported no significant differences between stutterers and nonstutterers with respect to alpha localization. Both demonstrated a consistent pattern of cerebral activity indicative of localization of speech function in the left hemisphere.

Moore and Haynes (1980), also studied alpha asymmetries in stutterers and nonstutterers, and reported results in contrast to those of Pinsky and McAdam (1980). They reported that stutterers showed significantly ($p<0.01$) less alpha in their right hemisphere for verbal and nonverbal tasks compared with nonstutterers. This indicated that stutterers process both types of information in the right hemisphere. The explanation offered to explain stutterers' performance, was that stutterers processed perceptual and motor functions in the right hemisphere. This hemisphere is regarded as a nonsegmental processor. Speech however, is a segmental phenomenon, and the motor planning for speech involves arrangement of segments in the articulatory programme. Stutterers are purported to use their right hemispheres for speech perception and motor programming but this hemisphere is not suited for these specialized functions. As a result there is a disruption of speech-motor programming which manifests as stuttering. Moore and Haynes (1980) further suggest that stutterers do not have a problem that is solely limited to the auditory modality. They concur with the suggestion put forth by Wingate (1969) that auditory processing, as well as motor programming, should be included in a speculative account of the processes underlying stuttering.

Fitch and Batson (1989), also supported the contention that a basic neurophysiologic difference may exist in the symmetry of cerebral processing for stutterers. The results of the study indicated that stutterers had greater right hemispheric suppression, as compared with nonstutterers, who showed greater left hemisphere suppression. This confirmed previous findings that stutterers demonstrated more right hemisphere processing than left hemisphere processing, compared with nonstutterers.

It appears that whilst the hemispheric processing issue is unresolved, there are definite indications that stutterers have neurolinguistic processes different to nonstutterers. The alpha component seems to favour a right-hemisphere processing strategy for verbal stimuli for stutterers which is in contrast to the left hemisphere processing strategy used by normals.

ii. *Average Evoked Response Research*

Averaged evoked response has also been used as a tool to examine hemispheric differences between stutterers and nonstutterers

(Ponsford, Brown, Marsh & Travis 1975, cited by Moore, 1986). Potentials were evoked in response to meaningful words embedded in sentences. Whilst nonstutterers responses were most evident in the left hemisphere, stutterers showed a reversal of this trend with greater differences in the right hemisphere.

Zimmerman and Knott (1974) used a specialized form of AER, the contingent negative variation (CNV) method, to investigate hemispheric differences in stutterers and nonstutterers. The technique investigates the steady potential shifts at the cortical surface, as a measure of laterality. The changes in potential are direction specific, and predictive of the hemisphere in which language resides (Pinsky & McAdam, 1980) Zimmerman and Knott (1974) concluded that stutterers showed more variable interhemispheric relationships when processing verbal stimuli, than did nonstutterers. Pinsky and McAdam (1980) however, reported no significant performance differences between stutterers and nonstutterers using the CNV. The use of electrophysiological measures in investigating cerebral dominance of stutterers appear in general to support the hypothesis that stutterers may demonstrate atypical cerebral dominance. Furthermore, the electrophysiological studies generally appear to support the dichotic research studies that have reported stutterer/ nonstutterer differences.

3.2.4. <u>REACTION TIME STUDIES</u>

The reaction time studies have focussed on the possible nature of difficulties that may be experienced by stutterers in encoding and decoding rapidly changing components of speech (Peters & Guitar, 1991). The studies essentially assess the sensory and motor systems working together. The impetus for this avenue of research arose from previous studies (Pinsky & McAdam, 1980; Sussman & McNeilage 1975a), which suggested further evaluation of sensorimotor as opposed to sensory processes in stutterers. This recommendation was based on the contention that sensorimotor processes may be compromised for stutterers.

The impetus for using reaction time experiments in the investigation of cerebral dominance, is based on the premise that verbal/linguistic material is usually processed in the left hemisphere in normal right-handed subjects (Rastatter & Dell, 1987a). For normal subjects, slower reaction times are observed with input to the nondominant hemisphere, compared to the dominant hemisphere. Rastatter and Dell (1987a) have suggested that in comparison with the inspection of accuracy scores obtained on dichotic testing, reaction time studies may be more sensitive indicators of hemispheric specialization for verbal material. Further explanation offered by Cross (1987), suggested that whilst accuracy scores on the dichotic listening paradigm provided an index of hemispheric lateralization, they provided little information about the nature underlying sensorimotor processes (for stutterers), that occur within and between the two hemispheres for speech and language.

The initial reaction time experiments compared *vocal reaction time* of stutterers and nonstutterers, and found that stutterers were slower that nonstutterers in starting and stopping a sound production (Peters & Guitar, 1991). The research focus broadened when it was discovered that stutterers were slower in reacting with respiration (exhalation), and articulation (lip closing) in response to auditory as well as visual stimuli. Of significance for the present study was the suggestion that a central mechanism was responsible for the slower reaction time observed in stutterers (Peters & Guitar, 1991).

Cross (1987) compared reaction time and dichotic accuracy measures of laterality for stutterers and nonstutterers. *Manual reaction times* were obtained for recognition responses to the presence or absence of particular nonsense syllables presented auditorily to adult stutterers. The results for nonstutterers and stutterers yielded a mean REA for both groups. No performance difference between stutterers and nonstutterers was observed on the DCV test. The stutterers however, exhibited half the ear difference scores compared with nonstutterers, for reaction time. The group data also indicated that for performances on all the measures the stutterers were a more heterogeneous group than nonstutterers.

Based on these results, Cross (1987) suggested that whilst accuracy scores on the DCV test provided an index of laterality, for the perception of acoustic stimuli, the size of the ear difference scores is susceptible to extraneous variables beyond the control of the experimenter. In attempting to explain the results of the reaction time study, Cross (1987) suggested that the target recognition reaction time task activated two independent yet related mechanisms. The first involved the perception of the acoustic target signal and this process was lateralized to the left hemisphere. This suggestion was based on the observation that the stuttering group demonstrated REA, although it was not a consistent trend among stutterers. This effect was observed for both the dichotic accuracy scores, as well as the reaction time scores. The second mechanism which involved the activation of the language-motor integration process which translates perceptual information into the motor response was disrupted for stutterers. This interpretation was in agreement with that reported by Sussman and McNeilage (1975a & b) who have reported that stutterers presented problems with sensorimotor integration, rather than on speech perception per se.

Cross (1987) has suggested that whilst most stutterers may perceive acoustic stimuli efficiently in the left hemisphere, a subgroup may not have a well-defined left hemisphere for language-motor integration. This may be caused by a less efficient left processor or bilateral, or right hemisphere processing in stutterers. The present researcher is of the opinion that dichoic studies (Blood & Blood, 1989b; Rosenfield & Goodglass, 1980) reviewed thus far have, in fact, suggested that stutterers may process dichotic stimuli differently from nonstutterers. This is contrary to the position offered by Cross (1987) and therefore, the suggestion offered by Cross (1987) is subject to criticism. The interpretation offered by Cross, (1987) may apply to groups of stutterers, but not to individual stutterers who have demonstrated atypical ear advantages and hence, lateralization. Thus, the present investigator suggests that for at least a subgroup of stutterers sensory (auditory) processes may also be compromised.

Cross (1987) cautioned that data from reaction time and dichotic listening studies should not be interpreted as evidence of a causal relationship between hemispheric processing strategies and stuttering. A more specific understanding of how the two hemispheres function interactively and independently is still unknown and thus warrants further investigation.

A series of investigations into *manual, visual and vocal reaction times* have been conducted (Wilkins, Webster, & Morgan 1984; Hand & Haynes, 1983; Rastatter & Dell, 1987a & b). These investigations have to a large extent supported the contention that stutterers process linguistic information differently to nonstutterers. Rastatter and Dell (1987a & b) specifically investigated the neurolinguistic organization of stutterers. They measured the reaction time of the left and right hands while stimulating the left and right hemispheres. Significant differences ($p<0.05$) were noted between the stutterers and nonstutterers regarding the extent to which each hemisphere participated in the analysis of verbal information. The findings of the study were described using a model suggesting bilateral neurolinguistic organization in stutterers.

A follow up study conducted by Rastatter and Dell (1987b) investigated *vocal reaction times* in stutterers. The results supported the contention of right hemisphere processing of language in stutterers. A further observation that stutterers were slower in responding to experimental procedures was consistent with findings of previous researchers (Rastatter & Dell, 1987a, Hand & Haynes, 1983). It was suggested by the investigators (Rastatter & Dell, 1987a & b) that increases in central processing time may account for the increase in reaction time for stutterers. This increase is more likely associated with language processing, than with laryngeal slowness. Ferrand, Gilbert and Blood (1991) further highlighted the contention that for stutterers temporal functioning is disrupted at a central level.

The reaction time studies have highlighted that central processes are responsible for increased reaction times observed for stutterers. Whilst the role of central auditory processing in stutterers is essentially unresolved, and the extent to which central auditory processing is compromised for stutterers is still debatable. Until this issue is resolved, it is unlikely that a comprehensive picture of the central processes underlying stuttering will emerge. The present investigation envisages some contribution about central auditory processing in stutterers.

3.3. STUTTERING AND AUDITORY FEEDBACK MECHANISMS

3.3.1. AN EARLY HISTORICAL PERSPECTIVE

It is widely acknowledged that hearing is important to one's speech. Hawver, (1978) noted that this becomes evident when a normal speaking person becomes deaf, and a deterioration in speech follows. Such deterioration occurs over time, and is not always complete. This suggests that a double feedback system, involving both the auditory and kinesthetic sensory systems, are used in the production of speech. When the auditory system is impaired, the kinesthetic system continues to provide feedback to the speaker regarding his speech patterns. This feedback is, however, incomplete, and with the lack of appropriate auditory feedback, the speech production deteriorates (Hawver, 1978). The relevance of auditory feedback for speech production is thus established.

The connection between audition and stuttering was first drawn informally by Bleumel (1913), cited in Bloodstein (1987). Bleumel popularized Galladet's testimony that there were no stutterers in the congenitally deaf population. Based on these observations, it was theorized that the deaf individual does not stutter because he lacks the auditory image, and therefore, is not susceptible to disturbances in the auditory brain centre, which could affect his mental and oral speech. Other explanations for this phenomenon have also been forthcoming. Among these, was the possibility that distortions or delays in auditory feedback, which have been said to produce stuttering, were not present in the deaf. Backus (1938), cited in Bloodstein (1987), investigated stuttering in the hard-of-hearing, and the deaf populations, and reported a reduced prevalence of 55 stutterers in a population of approximately 14 000 children. A reduced prevalence of stuttering in the deaf population was also supported by Harms and Malone (1939); Voelker and Voelker (1939); cited in Hawver (1978), who also reported that stuttering was rare in the congenitally deaf population.

Following the discovery of the low incidence of stuttering in the deaf population, and noting its relationship to the auditory feedback mechanism, research began examining the effects of auditory masking on speech. Several researchers (Cherry & Sayers, 1956; Maraist & Hutton, 1957; Stromsta, 1958; Murray, 1969, Adams & Moore, 1972; cited in Starkweather, 1987) specifically examined the effects of masking on stuttering. It was noted that the frequency of stuttering decreased under continuous presentation of a high intensity white noise (Cherry & Sayers, 1956;

Webster & Dorman, 1970; cited in Starkweather, 1987). Furthermore, low frequency masking was found to be more effective in reducing the frequency of stuttering (Stromsta, 1967 cited in Starkweather, 1987), and that fluency improved when masking was contingent on initiation of voicing (Sutton & Chase, 1961; cited in Starkweather, 1987). It is not the intention of this study to provide an exhaustive review of auditory masking and its relation to stuttering, suffice to say that these studies supported the contention that stuttering is a perceptual defect, and that speech performance is related to auditory feedback.

Another avenue of investigation of stuttering as an auditory deficit was that of delayed auditory feedback (DAF). It had first been demonstrated by Lee (1951), cited in Timmons & Boudreau, 1972) that delayed auditory feedback produced stutter-like speech in nonstutterers. This observation generated research (Rawnsley & Harris, 1954; McKay, 1968; Timmons, 1971; Mahaffey & Stromsta, 1967; cited in Starkweather, 1987) investigating delayed auditory feedback effects on stuttering. Although the data conflicted, the general trends reported were that under delayed auditory feedback nonstutterers show increases in disfluencies, whilst the stutterers generally show a reduction in dysfluency (Fairbanks, 1955; Maheffy & Stromsta, 1965; Soderberg, 1968; cited in Timmons and Boudreau, 1972).

Stromsta (1972) had compared the auditory feedback systems of stutterers and nonstutterers. It was hypothesized that normally air and bone-conducted energy contributed to bilateral auditory feedback signals, and that these are integrated into total sensory feedback needed for adequate motor regulation of speech.

In the experiment, stutterers and nonstutterers were required to listen to an air-conducted tone introduced to the ear, whilst simultaneously, a bone conducted tone was introduced. The subjects were required to vary the phase and amplitude of the air-conducted stimuli until a critical judgement was achieved at which no sound was audible. The experiment was based on the fact that two pure tones 180 degrees out-of-phase, will cancel each other out. The results suggested that stutterers displayed greater asymmetry than did the nonstutterers with regard to physiological influences on the propagation of energy to the auditory receptors. It was suggested therefore, that the structures that supply the central nervous system with feedback information are known to be related to the control of speech performance. Thus, the Stromsta study strengthened the link between auditory feedback and stuttering.

The observations of the effects of auditory masking and delayed auditory feedback on stuttering, led to the generation of theories linking stuttering and auditory function. Amongst these were theories by Mysak (1960); Fairbanks (1954) and Martin (1970) These models are described in the previous chapter (p. 62). The significance of such models in shaping stuttering research was that they were based on the assumption that stutterers have disturbed speech auditory feedback loops that occur as a result of *central auditory processing* problems at some level of auditory functioning.

Rosenfield and Jerger (1984) have suggested that stuttering may be part of a more comprehensive disorder of auditory function in the stutterers' central auditory perceptual mechanism. This contention led to an allied avenue of enquiry that laid claim to the hypothesis that stuttering was linked to central auditory function. The contention was strengthened by studies reporting acquired stuttering following cortical and subcortical lesions (Canter, 1971). In an attempt to explore this premise, researchers used tests that were specially designed, to investigate the hypothesized link between stuttering and central auditory function.

3.3.2. RESEARCH STUDIES : STUTTERING AND CENTRAL AUDITORY FEEDBACK MECHANISMS

Gregory (1964) was amongst the first to explore the hypothesis that stutterers had an inherent or acquired difference in the central neural auditory system. Based on findings that perceptual problems could be identified in brain-damaged subjects via use of specialized audiometric techniques, Gregory assessed the performance of stutterers on pure-tone loudness balance procedures, median plane localization of pure-tones, and monaurally-and binaurally-distorted speech.

The subjects included 30 stutterers (25 male and five female), and ten nonstutterers (eight male and two female), with a mean age of 22 years. The experimental and control groups were matched for age and intelligence, and subjects were required to report an absence of neurological problems and have normal hearing. The results indicated that stutterers and nonstutterers performed comparably on binaural loudness balance procedures and median plane localization tests. Stutterers' performance on the speech discrimination tests was consistently poorer, but statistical analysis indicated that there was a significant difference ($p<0.01$) but only on the simultaneous binaural low-pass-left, high-pass-right condition. Gregory (1964) concluded that this investigation did not lend support to the hypothesis that stutterers possessed a central auditory nervous system disorder. Although Gregory did not report significant differences between stutterers and nonstutterers, he provided the impetus for the modification of conventional tests to assess auditory processing in target groups, such as stutterers. Gregory (1964) specifically recommended that test materials needed to be modified further, to stress the auditory system.

With the development of more sophisticated technology, central auditory tests became available, and these measures were capable of identifying central auditory problems because they were able to stress the auditory system sufficiently to create a breakdown in performance. The SSI-ICM test is one such measure. Toscher and Rupp (1978) hypothesized that because of subtle, neurologically-based auditory processing difficulties, performances of stutterers and nonstutterers would differ significantly on tests of central auditory processing. The motivation for this stance was based on theory and data suggesting that stutterers experienced difficulties in the monitoring and processing of auditory signals.

To test the hypothesis, 14 stutterers and nonstutterers were tested on the SSI tests presented in ipsilateral and contralateral formats, bilaterally. The stuttering group comprised of 12 males and two females with a mean age of 20,5 years (11,6-27 years). The control group comprised of 11 males and three females with a mean age of 21 years (12-27 years). All subjects had normal hearing, and were reported to have a negative history of perceptual processing problems. The test formats were randomly varied with the most favourable presentation message-to competition ratio (MCR) being presented first, and then progressing to more difficult conditions.

The analysis of variance indicated that there existed a significant ($p<0.01$) performance difference between stutterers and nonstutterers on the SSI-ICM test while no differences were noted on the SSI-CCM test. More specifically the error score data on the SSI-ICM test revealed that the stuttering group more than doubled the number of errors made by the nonstutterers. The SSI-ICM test as opposed to the SSI-CCM test, is designed to stress the central auditory system monotically and it was thus concluded that performance differences between the groups may be attributed to differences in rudimentary function, or neurophysiological organization, or both.

Toscher and Rupp (1978) maintained that whilst the results were not powerful enough to warrant a definitive statement suggesting that stutterers possess neurologically-based, auditory processing dysfunction, they do reinforce statements by previous researchers who have suggested that the mechanism producing stuttering behaviours might be related to a disruption of the neurological feedback circuit that permits normal fluent speech.

The Toscher and Rupp study was critisized by Rosenfield and Jerger (1984) on two accounts. Firstly, it used only a single test measure (though in differing presentation formats) to evaluate the responses for stutterers and nonstutterers. Due to the great degree of variability noted on single test measures, results need to viewed with caution. Secondly, the competing message used in the study was not standardised.

Hall and Jerger (1978) have also examined the central auditory performance of stutterers. The rationale for their study developed from the shortcomings of previous investigations which typically used single tests (such as that of Toscher and Rupp). Hall and Jerger (1978), emphasized that single test measures were incapable of adequately assessing the complex processes of the auditory system, and therefore used a battery of clinically valid tests. These measures included the acoustic reflex threshold, acoustic reflex amplitude function, PI-PB function, SSI-ICM test and SSI-CCM test, PI-SSI function and the SSW test.

The experimental group comprised of ten stutterers (nine male and one female), with a mean age of 23,4 years. The control group comprised ten subjects (nine male, one female), with a mean age of 23,6 years (10-35 years), with no apparent speech disorders. All subjects were right-handed, had normal hearing sensitivity and had hearing sensitivity difference of less than 10 dB between the ears. Educational levels for all subjects were comparable.

The test results indicated that relative to the control group, the performance of the stuttering group was depressed on three measures viz. acoustic reflex amplitude function, SSI-ICM test and the SSW test. The discussion of results pertaining to the reflex amplitude finding appears later in the discussion (p. 122) and the SSW test results have already been described (p. 85). The results for the SSI-ICM indicated that for both groups (stutterers and nonstutterers) the higher average score was obtained for the right ear than for the left. The ear difference was greatest at the most difficult listening condition. Also, the average percentage of correct scores for the stutterers was poorer than for the control group at each MCR.

The reduced performance of stutterers on the SSI-ICM test when not in combination with a CCM loss, has been clinically documented as characteristic of disorders affecting the brainstem pathways (Hall and Jerger, 1978). The greatest performance difference was noted at the most stressful listening conditions i.e. -20 and -10dBMCR. The deficit noted on the SSW test for the stuttering group, may also be suggestive of a brainstem level dysfunction, since subjects with brainstem disorders may also show SSW test deficits consistent with SSI-ICM test losses. The SSW test results obtained were also similar to those obtained on other dichotic measure. This combination of findings highlighted the subtlety of impairment in central auditory function of stutterers therefore warranted further investigation.

The recommendation of Hall and Jerger's (1978) study was that findings be validated, and that subgroups of stutterers be investigated, since it was noted that stutterers, as a group, were heterogeneous. The study has been criticized (Toscher & Rupp, 1978, Wynne & Boehmler, 1982), because the performance of the nonstutterers was by far superior to norm for the SSI-ICM test.

Thus, stutterers would have been at an unfair disadvantage when compared with the nonstutterers. Furthermore, the present investigator notes that male and female subjects were mixed in the research design, thereby introducing an additional variable that could complicate the interpretation of the test result.

Despite the shortcomings of the study, Hall and Jerger (1978) made two major contributions to this avenue of enquiry. Firstly, the suggestion relating to the site-of-lesion compromised being the brainstem was more specific than suggestions offered by other investigators. Secondly, their results were based on a battery of tests, thereby providing a more comprehensive assessment of the central auditory nervous system. This suggestion was considered in the present study, and a test battery sensitive to stutterer/nonstutterer processing differences was used.

Noting the suggestion that a battery of tests should be used when measuring central auditory processing performance, Hawver (1978) also investigated central auditory performance of stutterers and nonstutterers using a test battery. The test battery included the Berlin DCV test, the SSW test, the 60% time-compressed speech and the 500Hz low-pass filtered speech tests. The latter two tests will be discussed here, as the dichotic test results have already been discussed (p. 84).

The results indicated no significant differences ($p>0.05$), between the stutterers and nonstutterers on the time-compressed and the filtered speech tests. Hawver (1978) suggested that these tests are less sensitive to subtle disorders of the central auditory pathways. It reemphasized that not only must a test battery be considered, but that the sensitivity of the tests to isolate central auditory processing problems must also be considered. This implication was carried forth in the present investigation.

Libertrau and Daly (1981) followed up on the subgroup recommendation for research with stutterers, as mentioned previously (p. 91). The organic and functional group of stutterers were compared with nonstutterers. Two tasks were used viz. one measuring cortical level functioning, and the other brainstem level function. The masking level difference test is of significance to the discussion at present as it measures performance at a subcortical level (Liberatrau & Daly, 1981).

It was noted that on one condition of the Masking Level Difference task, organic stutterers performed significantly ($p<0.05$) poorer compared with the control group, and the performance of the functional group. The performance of the control group and the functional group was similar. It should be noted however, that the study used a small sample size and that only a single test measure was used to investigate brainstem level performance. Thus, the significance of results obtained is questionable.

Libertrau and Daly (1981) concluded that their result supported the contention that stutterers might display subtle auditory dysfunction at the brainstem level. These findings lent collaborative support to findings by Hall and Jerger (1978), and Toscher and Rupp (1978). In addition, it supported that contention that the neurophysiological organization in some stutterers may be different from that of normally fluent speakers, and that it may not in fact, be limited to just one specific level of brain functioning. The exact nature of the neurophysiology pertaining to stuttering was not described, therefore warranting further research and elaboration.

Libertrau and Daly (1981) have contended that stuttering is not a unitary disorder, but rather a generic label for a wider range of related disorders. This also relates to the contention that stutterers are not a homogeneous group, and that researchers must intensify efforts to differentiate subgroups of stutterers. The present research therefore attempted to contribute to this field of study by choosing a differentiated subgroup of stutterers, and using a battery of tests purported to assess cortical, as well as subcortical processing.

Hannley and Dorman (1982) in further attempting to control for variables that may influence central auditory nervous system test results for stutterers, selected a group of stuttering subjects who had completed a fluency training program. Twenty stuttering subjects were tested on the SSI-ICM test . In comparing the results to Hall and Jerger's result, they noted that their stutterers performed as well as Hall and Jerger's (1978) stuttering subjects. They contended that Hall and Jerger's normal listeners performed well above the normal range, thereby suggesting that their stutterers did not have unusually poorer performance. However, it could also be argued that stutterers who completed their fluency training programme possibly behave like normal speakers. Hannley and Dorman (1982), do acknowledge that there is evidence to suggest that stutterers may show a performance deficit on tests designed to indicate brainstem level dysfunction. It appeared that whilst there was evidence suggesting subtle differences in brainstem level performances, many variables including treatment clouded the interpretation, therefore making a conclusive statement almost impossible. This study used a single test measure which is not ideal. The Hannley and Dorman study highlighted the need to maintain homogeneity of the group studied, with respect to treatment and this suggestion was carried forth in the present investigation.

Wynne and Boehmler (1982) have investigated the central auditory function of fluent and disfluent normal speakers on a single MCR (-20dB) of the SSI-ICM test. The disfluent group comprised of ten adult subjects who had a significant frequency of part-word repetitions, and normal peripheral hearing. The control group comprised ten fluent speakers who were closely matched with the experiment group. The results of the study indicated that the dysfluent speakers had significantly ($p<0.01$) lower scores on the -20dBMCR, which suggested that central auditory function may be one of the variables contributing to dysfluent speech at the level of syllable production.

Wynne and Boehmler (1982) have suggested that a breakdown in syllable production and the syllable pulse pattern resulted from subtle central auditory processing deficiencies. When the proper temporal encoding pattern is not continued and preserved, the proper motoric pattern is not available for the speech output. The previously encoded motoric pattern is then spoken, hence part-word repetitions. The explanation offered by Wynne and

Boehmler (1982), could be applied to the stuttering population to the extent that stutterers demonstrate part-word repetitions as part of the stuttering symptomatology.

The study highlighted the sensitivity of the SSI-ICM test as a measure of central auditory processing, and provided a theoretical explanation for the findings of the study that clearly demonstrated the link between stuttering and central auditory processing problems. Thus, it expanded theoretical concepts offered by Hall and Jerger (1978), and Toscher and Rupp (1978) in linking central auditory processing and speech disfluency.

Nuck, Blood and Blood (1987) conducted a study similar to that of Wynne and Boehmler (1982). They investigated the performances fluent and disfluent normal speakers using the -10 and -20dBMCR conditions of the SSI-ICM test. The subjects included 40 adults. Twenty disfluent subjects (ten male and ten female), and twenty fluent (ten male and ten female) speakers, participated in the experiment. The results indicated significant ($p<0.05$) differences between fluent and disfluent speakers on both test conditions. No significant ($p>0.05$) ear or sex differences were noted. In applying the findings to stutterers, Nuck et al., (1987), supported the contention that central auditory processing problems, amongst others, may be a predisposing factor to stuttering. The researchers suggested that whilst the SSI-ICM test was sensitive to central auditory processing differences between fluent and dysfluent speakers a test battery should be used to further investigate the nature of the temporal processing problems that may underlie speech disfluency. The present researcher agreed with this viewpoint, and therefore used a battery of tests that were purported to challenge *various* central auditory processes.

Bonin, Ramig and Prescott (1985) have also examined the performance of stutterers and nonstutterers having noted the evidence of variability of auditory performance on central tests at brainstem, and at cortical level. It was hypothesized that if speech perception occurs in hierachical steps, then the outcome at one level of processing is dependent on the outcome of a previous level of processing. It was speculated that for stutterers, a breakdown may occur at a central auditory level. This breakdown may, in turn, interfere with the efficient processing and integration of auditory parameters such as intensity and time, which in turn, may affect the processing of speech at higher levels. The purpose of the study was not to demonstrate a direct correlation between auditory perception and speech production, but rather a attempt to note any differences between stutterers and nonstutterers on a sound fusion task.

The experimental group comprised of 11 subjects (eight male and three female) with a mean age of 31.2 years (20-45 years). The control group comprised of nine subjects (six male and three female) with a mean age of 30.1 years (20-45 years). All subjects had normal hearing bilaterally, and no history of neurological impairment. The specific intention of the study was to note if there were differences between stutterers and nonstutterers with reference to the point in time at which a sound is perceived as fused, and as separate, and is heard as two sounds. The results supported the hypothesis that there was a difference between stutterers and nonstutterers in the processing and integration of time intervals at the central auditory level. The mechanism responsible for this difference was based on the theory that there is a shorter processing time difference between the ipsilateral and contralateral pathways in stutterers resulting possible competition in signal transmission at the central auditory level.

Since speech perception appears to be hierarchical, inefficient processing and integration of auditory parameters at this central level, could affect the processing of speech at higher levels. Stated differently, it could be said that alterations in the conditions under which signals in the central nervous system are transmitted may facilitate effective auditory processing, which could then improve the feedback potential necessary for fluent speech.

The findings of the Bonig et al., study were viewed as preliminary and replication and expansion were suggested. The study needed to be replicated due to the heterogeneous nature of the stuttering population which could influence the outcome of results. In addition, it was recommended that various levels of performance of central auditory processing be investigated. The present study followed on from these recommendations (Bonig et al., 1985; Nuck et al., 1987) by using a battery of tests that were suitable in assessing processing performance mediated at various levels of the central auditory system.

Hageman and Greene (1989) investigated central auditory processing in 10 stutterers and nonstutterers with the aim of defining the level of processing breakdown. They used Sander's (1977) model to describe five levels of central auditory processing. These include :- 1. attention, 2. auditory selection, 3. auditory discrimination, 4. auditory memory, 5. auditory synthesis. Hageman and Greene suggested that instruments that have been designed to evaluate both quantitative and qualitative aspects of auditory comprehension, may also be useful in isolating levels of auditory perception that may possibly be compromised for stutterers. The Revised Token Test (RTT) (McNeil & Prescott, 1978, cited in Hageman & Greene, 1989) was chosen for this purpose. This test can be interpreted quantatively, (as mean overall scores), and qualitatively, (patterns of performance reflected within and across subtlest behaviours). The RTT is designed to detect even minimal auditory dysfunction. For specific use with stutterers, an adapted competing message was devised by Hageman and Greene. In this format subjects were required to listen to two competing token tests simultaneously. The task stressed the auditory comprehension system of normal listeners sufficiently to cause breakdown in listening performance. It was therefore thought to be a good test to show up performance differences between stutterers and nonstutterers should they exist.

The subjects included ten stutterers and ten nonstutterers (seven male and three female in each group). The mean age of subjects for the stuttering group was 33,8 years (21.4-62.7) and the mean age for stutterers was 35.6 (21.2-68 years). All subjects were matched for educational level, and reported a medical history free of neurological impairment, drug abuse or alcoholism. The subjects were required to complete two tasks, the first of which the standard RTT. For the second task, the subjects were required to respond to simultaneous binaural presentation of the RTT and adapted competing message RTT (ARTT) commands by touching relevant tokens.

The results showed that the stutterers and nonstutterers did not differ on the RTT. However, on the ARTT, stutterers showed significantly ($p<0.05$) more errors than did the nonstutterers. The patterns of results indicated that there were no qualitative differences between stutterers and nonstutterers, suggesting that the quality of auditory processing does not differ. It was suggested that the neurologically based differences do not occur within higher levels of the auditory system which decodes the linguistic elements of the message. Once the message reaches the decoding centres presumably in thalamic or cortical regions, stutterers and nonstutterers process information similarly. The breakdown in processing was purported to occur at the level of the brainstem or the reticular activating system with the processes compromised including attention allocation, effort, and arousal. These levels of processing relate to Sanders' (1977) model, which suggests that selective and intensive aspects of attention and arousal are required to process information auditorily. The study lent support to the findings by Hall and Jerger (1978), in suggesting that a brainstem level dysfunction had been identified for stutterers.

The study specified the level of brainstem dysfunction, and also highlighted the need to use instruments that would sufficiently stress the auditory system. The study in agreeing, with the findings of Hall and Jerger (1978), indirectly supported the use of the SSI-ICM test as a sensitive test to evaluate the performance of stutterers. The study used a new test that was capable of highlighting subtle performance differences between stutterers and nonstutterers. The test was considered for inclusion in the present study but was unavailable for use (Hageman & Greene, 1989).

The literature reviewed thus far, involved studies whereby subjects were required to respond to various parameters of tests. To an extent, subjectivity as a factor could have influenced test results. In an attempt to reduce the subjectivity inherent in central auditory testing, researchers have used objective tests to investigate stutterers and nonstutterers performances on central auditory tasks.

3.3.2.1 Objective measures

i. *Acoustic Reflex Measures and Stuttering*

Application of the acoustic reflex in stuttering research is in keeping with the notion suggesting that stuttering may be due to a defect in the auditory feedback mechanism subserving speech production. As one component of the auditory monitoring system, the acoustic reflex has come under investigation because of its intimate relationship with vocalization. It has been suggested that aberrations in acoustic reflex activities have been linked to stuttering (Rosenfield & Jerger, 1984).

It has also been established that the acoustic reflex mechanism contracts mainly in response to loud acoustic stimuli, and that the stapedial muscle contracts during vocalization. Rosenfield and Jerger (1984) have cited studies (Zakrisson, 1975; McCall &

Rabuzzi, 1973; and Jen & Suga, 1973) confirming that the stapedius muscle is activated during vocalization. Thus, having established the links between the acoustic reflex and vocalization, investigators focussed on stutterers' performances on various parameters of the acoustic reflex.

Early investigation into stapedius reflex muscle activity in stutterers and nonstutterers was conducted by Shearer and Simmons (1965). They investigated stapedius muscle activity in stutterers and nonstutterers during ongoing speech, and reported that stapedius muscle activity tended to parallel vocalization in nonstutterers. However, in stutterers this parallelism was less consistent. The differences between the groups were not significant, and it was concluded that there were no differences in middle ear muscle activity between the stutterers and nonstutterers. It is likely that no differences were noted as the study examined a parameter that was reflecting peripheral function, as opposed to central function.

Hall and Jerger (1978) included in their battery of tests measures of acoustic reflex parameters. The findings indicated that the slope of the function of the reflex amplitude for the 2000Hz signal was found to be more consistently gradual for the stuttering group; also for every sensation level above the reflex threshold, the amplitude function was smaller for the stuttering group compared with the control group.

In attempting to explain findings related to acoustic reflex amplitude function, Hall and Jerger (1978) refered to research by Bosatra, Russolo, and Poli (1977), and Borg (1973), and suggested that this aberration may be indicative of brainstem level dysfunction, since this is the central level at which the acoustic reflex is mediated. Clemis and Sarno (1980a), suggest that the acoustic reflex amplitude is not a very stable parameter of the acoustic reflex, and therefore, the extent to which the results obtained by Hall and Jerger (1978) are considered significant, is questionable.

Research by Hannley and Dorman (1982) using a case study method of research, and investigated young female stutterers with idiopathically absent acoustic reflexes bilaterally and their results suggested that stuttering was not a consequence of such a phenomenon. In addition, they investigated three stuttering subjects who had the stapedius muscle surgically resected, and noted that these subjects continued to stutter. They also investigated 40 stutterers whose acoustic reflexes were intact bilaterally, and concluded that the absence or presence of the acoustic reflex was not a necessary precondition for stuttering. The present researcher is of the opinion that whilst the reflex anomaly may not be causal in stuttering, the function of the reflex to the extent that it may contribute to temporal management of sound, may be compromised for a subgroup of stutterers. Thus, the reflex parameters should be considered as part of a greater auditory system that may be deficient in processing signals, thereby contributing to stuttering.

In commenting on prolonged latency of the acoustic reflex, Hannley and Dorman (1982) have indicated that prolonged latencies have been noted in patients with acoustic nerve tumours and cochlear disorders. Stuttering has not been identified as part of these syndromes. However, there is no research evidence cited by Hannley and Dorman (1982) to substantiate this claim.

In a more recent exploratory study (Taylor, 1990) examined the acoustic reflex latency parameter in stutterers and nonstutterers. The motivation for this investigation arose from findings of previous research suggesting the brainstem as a possible site of dysfunction for stutterers. The ARLT as a tool to investigate brainstem level dysfunction was selected in combination with the SSI-ICM test. The subjects included six male stutterers with a mean age of 22.2 years. A control group was matched for age and sex. The results indicated no significant differences between stutterers and nonstutterers on the SSI-ICM test. However, significant differences were noted between the groups on the ARLT measures. Specifically, stutterers demonstrated a shorter mean latency between stimulation and contraction time on ipsilateral stimulation. This finding was regarded as a novel one, and provided impetus for research in this area.

The research related to performance of stutterers on acoustic reflex measures is limited. However, support for preliminary findings can be derived from Brainstem Evoked Response (BSER) research for two reasons. Firstly, the research is to a large extent objective (as is the ARLT), and secondly, the reflex latency and some parameters of the BSER are mediated at a common level of the lower brainstem (Clemis & Sarno, 1980a). The review that follows provides a critique of BSER findings on stutterers.

ii *Brainstem Evoked Response Research*

Previous research reviewed has suggested brainstem level central auditory processing anomalies for stutterers (Hall & Jerger 1978; Hageman & Greene, 1989). The studies using BSER as a method to evaluate stutterers' performances have two reasons for attempting this avenue of investigation. Firstly, to confirm or reject findings of previous researchers relating to stuttering and auditory function at the brainstem level, and secondly, to specify the level of processing breakdown in the brainstem, should it exist.

Newell-Decker, Healey, and Howe (1982) used the BSER to investigate brainstem function of stutterers and nonstutterers. The experimental group comprised of eight adult male subjects, with a mean age of 25.8 years (16-33), and the control group was matched for age and sex. Stutterers were required to have normal hearing bilaterally. In addition, severity of stuttering was classified as mild, moderate or severe using the Iowa Scale (Darley & Spriestersbach, 1978). BSER were recorded in response to monaural and binaural clicks.

The results indicated the following :

- no significant differences in latency or amplitude differences ($p>0.05$) between stutterers and nonstutterers.
- greater variance in the stuttering group compared with the control group under the monaural stimulation condition at click rates of 12/sec and 5/sec.
- no significant relationship between stuttering severity, and performance on the BSER was found.

The following noteworthy aspects of discussion are offered by Newell-Decker et al., (1982) :

- Variability of stutterers' response on the BSER : It has been speculated that the stutterers' speech processing difficulties are related to neurologically based dysfunction at the brain-stem level. The neurological difference hypothesis is most likely because the variability in performance cannot be attributed to factors such as arousal level, or attention, because BSER is unaffected by these parameters.

- The findings also indicate that only a particular subset of stutterers had greater overall variance. This finding appears to be in agreement with the other studies mentioned that have also suggested heterogeneity in the stuttering population.

The study highlighted the nature of variability amongst stutterers and thereby supported the contention that a subgroup of stutterers contributed to overall performance differences. It was further suggested that the results of the study could be interpreted as evidence of neurologically-based auditory processing differences for stutterers at brainstem level.

Blood and Blood (1984b) further added to the body of literature on central auditory performance of stutterers. The specific purpose of the study was to investigate the severity of stuttering and its relationship to BSER testing. The aim was to investigate a more homogeneous group of stutterers. The subjects included eight adult stutterers (five male and three female) with a mean age of 22.8 years, (19-37 years). A control group was matched for age and sex. All subjects were required to have normal hearing bilaterally. Using the Stuttering Severity Instrument (Riley & Riley, 1984) four subjects were found to be moderate stutterers, and four were found to be severe stutterers.

The results indicated that stutterers as a group demonstrated prolonged central conduction time as measured by interpeak latency differences between Waves I to V. Five stutterers manifested abnormalities unilaterally, while three showed abnormal responses bilaterally. No relationship was found between BSER results and stuttering severity, thus confirming the previous results of Newell-Decker et al., (1982). The Blood and Blood (1984b) study made a valid contribution in reporting increased neural conduction times for stutterers. In addition, Blood and Blood (1984b), suggested that subgroups of stutterers be differentiated on the basis of family history and onset of stuttering. These recommendations were considered in the present study.

Newman, Bunderson and Brey (1985), pursued the investigations relating stuttering and central auditory function and their intention was to use the BSER in an attempt to show subtle differences between stutterers and nonstutterers in brainstem function. Subject selection differed from other studies. Active and recovered stutterers were employed, suggesting that results may be influenced by fluency status. It also an attempt to control for variability in the stuttering group.

The purpose of their study was to compare the BSERs obtained from the right and left ears of active stutterers, recovered stutterers, and normal speakers, for males and females. The click repetition rates were varied, and the latency intervals between waves I, III, and V were measured. The auditory processing systems of the subjects were stressed, and the effects of the stress condition were recorded. The transmission rate of wave V was used as a measure of the stress condition. Sixty eight subjects were used in the study. These included 22 male stutterers of which 16 were active stutterers, and six were recovered stutterers. Twelve female stutterers were included of which seven were active stutterers and five were recovered. The control group comprised of 22 normal speaking males and 12 normal-speaking females. The age range of subjects were between 19 and 53 years.

The results indicated that stutterers did not differ significantly (p>0.01) from nonstutterers, recovered stutterers did not differ from active stutterers, and differences between the ears were nonsignificant. The one main effect that was significant was sex. Females had significantly faster rates of neural transmission than did males. (The explanation for this finding appears in the discussion on gender and stuttering, p. 138). Thus, the study did not support the hypothesis that stutterers differed from nonstutterers on measures of the BSER, which is in contrast to previous studies reviewed. Perhaps the lack of significance could be related to Stager's (1990) criticism of studies using absolute latencies as opposed to relative latencies. Stager (1990), suggests that absolute latencies are measures of sensitivity, which stutterers and nonstutterers are not likely to differ on. The relative latencies which measure the intactness of the central auditory system need to be considered.

Stager (1990) also suggested that an explanation for the lack of significant differences between stutterers and nonstutterers was related to the type of statistics used in other studies. Given the current trend to look for heterogeneity among stutterers, the finding that individual stutterers show abnormality is of significance. Comparing group data in this instance would obscure differences should they exist. Stager therefore used analysis of variance to assess group differences, and in addition, selected criteria of abnormality to which stutterers individually, or as a group, were compared to. Stager (1990) selected the following parameters to assess stutterers/nonstutterers differences :

1. interpeak latency between waves I and V

2. amplitude ratio greater than 1 between waves V and I

3. latency shift in wave V between low and high stimulus presentation rates.

The subjects included ten male stutterers, with a mean age of 25.1 years (16-36 years). A control group was matched for age and sex. All subjects were required to have normal hearing. The results indicated that stutterers as a group did not differ from nonstutterers on previously mentioned measures. Individually, half the stutterers demonstrated latencies greater than two standard deviations from the mean of nonstutterers on at least one measure.

Drawing on the results of the study, Stager (1990) commented on the following :

- a longer neural conduction time was noted for some stutterers when the auditory system was stressed, thus implicating the role of brainstem auditory dysfunction for stutterers. This findings supports that of Blood and Blood (1984b)

- heterogeneity in stutterers was once again noted, and the need for selecting a homogeneous stutterers group for investigation was reemphasized.

Papanicolaou, Raz, Lormig, and Eisenberg (1986) used a novel procedure on 14 subjects. The subjects were engaged on overt speech, whispering, silent articulation, and covert rehearsal tasks. The experiment was designed following on Pinsky and McAdam's (1980) suggestion that the central auditory processing system should be investigated whilst speaking/stuttering. They reported that overt speech and whispering changed auditory brainstem responses in normally fluent subjects. Pananicolaou et al., (1986) observed a significant amplitude reduction of the fifth peak of the BSER was noted. This observed suppression of the irrelevant auditory input at the level of the upper brainstem implicated efferent control as a dynamic process related to the degree of attention required, and suggested a filtering phenomenon at the level of the brainstem. These results differ from other researchers (Hageman & Greene, 1989; Stager, 1990) who suggested the lower brainstem as a possible locus of dysfunction for stutterers.

Pursuing the study of Papanicolaou et al., (1986), Smith, Blood and Blood (1990) investigated the performance of stutterers and nonstutterers on various verbal rehearsal tasks, which included overt speech, whispering, silent articulation, and covert verbal rehearsal tasks. These parameters have been known to facilitate fluency in stuttering individuals. The study was designed to corroborate and expand the findings of Papanicolau et al. (1986) about the filtering phenomenon related to diverted attention at the brainstem level. It was also an attempt to determine whether there were performance differences between stutterers and non-stutterers, during an information processing task as evidenced by amplitude suppression or latency variability in BSER.

Twenty subjects were matched for age and sex. Ten of the 20 subjects were adults stutterers, with a mean age of 24.5 years (19-33 years). BSERs were recorded while subjects were actively engaged in the tasks mentioned.

The results revealed that stutterers demonstrated significantly larger Wave I absolute amplitudes, and significantly larger Wave V to Wave I relative amplitude ratios than nonstutterers. These findings suggest different processing of auditory information for stutterers at a low brainstem level - possibly below the superior olivary complex. These findings correlate with the findings of Hageman and Greene (1989); Stager (1990), and Blood and Blood (1984b).

The findings of Smith et al., (1990) however, did not support Papanicolaou et al., (1986) who reported that speech and whispering attentive tasks change BSER in a reliable and predictable way. Smith et al., suggest that in view of the differences between stutterers and nonstutterers that were noted on examination of Wave I, that this should be studied in greater detail.

Summary of BSER findings

The BSER findings have generally added to the literature in supporting a difference between stutterers and nonstutterers on central auditory processing measures. Since the differences were noted on latency measures, amongst other measures, it could be viewed as support for the contention that stutterers have a longer neural conduction time compared to the nonstutterers. The studies have also supported previous suggestions that processing differences were related to differences in function at the level of the lower brainstem, though other possibilities are suggested. The need to use objectives measures was highlighted and the recommendation was carried forth in the present study, hence, the acoustic reflex latency test was included in the test battery.

SUMMARY

The studies investigating the role of auditory feedback mechanisms in stuttering have revealed the following :

1. There is controversy as to whether central auditory processing differences do exist between stutterers and nonstutterers.

2. The brainstem has been singled out as the site of dysfunction, with the level of the lower brainstem being implicated. This suggestion is supported by research using the SSI-ICM test as well as BSER measures.

3. The heterogeneous nature of the stuttering population is re-emphasized. The need to control for variables influencing testing performance is apparent.

4. The need for further research into central auditory processing comparing stutterers & nonstutterers using a test battery approach is recommended.

3.4 GENDER AND STUTTERING

3.4.1. INTRODUCTION

The issues related to gender and stuttering have been introduced in the previous chapter. The review that follows attempt to highlight investigations examining sex differences for stutterers.

Early research investigating language proficiency in girls and boys reported that girls spoke earlier than boys, had greater articulatory proficiency, and better language control (Berry & Eisenson 1956; McCarthy, 1954; Tyler, 1965; cited in Timmons & Boudreau, 1972). Early investigations were also in agreement that the speech-defective population included a greater proportion of males than females (Schuell, 1946; Morley; 1952, cited in Timmons & Boudreau, 1972). The differences were reported to decrease with age. These reports lay the foundation for research examining sex differences in language related tasks. Since language and speech functions have a neurological substrate, investigations into anatomical and neurophysiological differences between males and females ensued.

Sex differences in central nervous system anatomy and function : Witelson 1989, cited in Govender, 1989) studied human brains and reported that there were marked sex differences with respect to size and weight parameters. Female brains were significantly smaller in weight ($p<0.0001$) compared with males. Similar findings were reported by Dekaban (1978), cited by Govender, (1989). Halloway (1980, cited by Govender, 1989), also reported larger brain sizes in males, and suggested that this is expected because males generally have larger bodies, and are taller than females.

Further anatomical difference has been reported in specific structure of the brain that may influence processing. Of particular significance are the gender differences noted in the splenium of the corpus callosum (Burton, Pepperrell & Stredwick, 1991). The splenium of the corpus callosum is found to be significantly larger in females than males. Based on this observation, functional differences in auditory function between males and females are likely.

<u>Sex differences : audiometric investigations</u>

Sex differences have been noted on conventional audiometric procedures, and on brainstem investigations. Jerger and Hall (1980) reported that females perform better than males on behavioural auditory tests. This contention is supported by Bunch and Raiford, 1931; Corso, 1963 cited in Govender, (1989) who also reported that females have better high frequency puretone sensitivity than males. Males appear to have better hearing sensitivity than females in the low frequencies. Females outperform males on speech testing (Jerger & Hall, 1980). On impedance audiometry, males have higher static compliance measures than females.

Govender (1989) reports that there are no clear cut reasons to explain sex differences on conventional tests, but that physiological differences, hormonal differences and anatomical differences possibly lead to performance differences between males and females. Of significance to the present study are the sex differences noted on the BSER as it is a measure of central auditory processing.

A summary of research findings cited by Govender (1989), indicates that females have a shorter latency compared to males, on various interpeak latencies. This trend appears to be consistent (Beagley & Sheidrale 1978; Stockard, Stockard & Sharbrough, 1978; Kjaer, 1979; Jacobson, Novotny & Elliot 1980; Jerger & Johnson, 1988 cited in Govender 1989). These findings were also confirmed by Govender (1989) who selected a group of subjects of the same race investigated in the present study.

The observed differences on BSER measures have lead researchers to concluded that females have a shorter neural conduction time for auditory signals compared with males. The reasons for the differences have been attributed to anatomical, hormonal and functional differences between males and females.

McGlone (1980), in an extensive review of literature relating to sex differences in cerebral lateralization, concluded that adult females may be less lateralized than males. It was suggested that there may be differences in the way in which males and females process information. Whilst there was controversy in the literature, McGlone reports that adult males and females may differ with regard to language representation in the brain. Based on research from dichotic listening studies, it was suggested that adult female brain asymmetry for language is less marked than for adult male brains. However, McGlone suggested that one should not ignore the obvious finding that males and females are more similar than different with respect to hemispheric asymmetry.

3.4.2. STUTTERERS: MALE/ FEMALE DIFFERENCES

The impetus for studying central auditory processing differences between males and females was linked to observed anatomical and neurophysiological differences in the nonstuttering population. It was felt that knowledge of sex differences for stutterers, may contribute to an understanding of the sex ratio.

Mahaffey and Stromsta (1965) were amongst the first to suggest that there may be inherent differences between males and females who stuttered with respect to speech and hearing processes. Further investigation of this contention (Timmons, 1971), reported that females performed differently from males with regard to adaptation on delayed auditory feedback tasks, thus strengthening the hypothesis relating to male/female differences for stutterers. It was hypothesized that observations of processing differences between male and female stutterers would help to unravel the sex ratio (Timmons & Boudreau, 1972).

3.4.2.1. Research studies : Male and female stutterers on central auditory processing measures

i. *Stuttering and cerebral dominance : Dichotic Tests*

Blood and Blood (1989b) have focused on processing differences between male and female stutterers and nonstutterers. They have cited McGlone's (1980) extensive review of literature of sex differences in cerebral lateralization, and concluded that females have a less pronounced cerebral lateralization than males.

It was suggested that there may be differences in the way males and females process information.

Blood and Blood (1989b) compared 18 male and 18 female stutterers and nonstutterers on the Dichotic Word Test, using CVC stimuli. The subjects were young adults with a mean age of approximately 24 years (18-36 years). All subjects had to satisfy strict selection criteria. They were required to respond to a 36 item Dichotic Word Test using a gestural double response paradigm. In addition, a reliability check was conducted and the test was found to be relatively reliable. The analysis of laterality quotients indicated that nonstutterers manifested significantly stronger mean laterality quotients than the stutterers. However, stutterers and nonstutterers showed similar no-ear and left-ear preferences. The sex factor was found to be nonsignificant. It was noted however, that female stutterers with atypical ear preference, tended to be severe stutterers.

Since no performance differences were noted between male and female stutterers, it was concluded that male and female stutterers process information similarly. Blood and Blood (1989a) do not provide further explanation for this observation suffice to say that the male/female dichotomy be investigated with different types of dichotic stimuli to throw more light on the subject. This recommendation was carried forward as this study used syllabic, word and sentence dichotic stimuli.

It should be noted that the research related to sex differences for stutterers and nonstutterers has been limited, and the present study attempted to address the need for further research.

ii. *Stuttering and auditory feedback mechanism : SSI-ICM test* Nuck, Blood and Blood (1987) compared central auditory processing performance in male and female fluent and disfluent normal speakers on the SSI-ICM test. The study was intended to confirm the results obtained by Wynne and Boehmler (1982). The performance of ten male and ten female stutterers and nonstutterers were examined on two MCR conditions of the SSI-ICM test, viz. -20 and -10dBMCR. The results indicated no significant differences between male and female fluent and disfluent speakers.

iii. *Brainstem Evoked Response :* Newman et al., (1985) (aspects of the study have been reviewed p. 138), suggested that the physiologic differences between male and female stutterers could perhaps account for the sex ratio. They suggested that the auditory system, and its intimate link with the act of speaking should be considered as a source of difference between male and female stutterers. Based on research comparing BSER on male and female stutterers and nonstutterers, Newman et al., noted that males displayed longer latencies on BSER measures. They questioned how a slower rate of neural transmission in the auditory system of the male might contribute to stuttering. It was speculated that the longer latencies in the auditory system of males, make them more susceptible to stuttering. Beyond this no further explanations have been offered. This study was one of the few studies that investigated central auditory processing in female stutterers.

Yeudall (1985) has reported shortened brainstem latencies in three adult male stutterers. They suggested that these processing differences my contribute to gender differences in stuttering. The explanation offered was that the shortened latencies could be related to the depletion of brainstem norepinephrine. The role of estrogens are thought to be involved with long-term regulation of norepinephrine; males were thus more vulnerable to the depletion of brainstem norepinephrine and hence shorter brainstem latencies. These findings are in contrast to those by Newman et al., (1985), who suggested that males have longer latencies. This perhaps reflects the heterogenous nature of the stuttering population.

3.5. SUMMARY

A wide range of investigations have examined the issue of *cerebral dominance* and stuttering. The findings suggest that the issue of stutterers or nonstutterers differences are essentially unresolved. Whilst some studies have reported no differences between stutterers and nonstutterers on cerebral lateralization measures, others have reported bilateral representation, and right hemisphere lateralization for stutterers. The role of intra- and inter-hemispheric processes have also been implicated for the stuttering population. There have been speculations about the nature of processing differences for stutterers, but no definite pattern has emerged. This is largely due to the heterogenous nature of the stuttering population.

The studies relating to the search for *abnormalities of the auditory feedback mechanism* underlying stutterers have also revealed contradictory findings. Most studies do support the contention that for a subgroup of stutterers, the central auditory processing mechanism may be compromised - brainstem level of dysfunction has been suggested. The many variables that operate in research of this nature have made interpretation of results and comparisons between studies difficult.

Further, the sex effect for the stuttering population is largely inconclusive and not extensively researched. From the review of the literature the following aspects were apparent, and the implications for the present study were thus derived.

1. The research studies comparing stutterers' and nonstutterers' processing on central auditory measures have reported conflicting findings. This provided the impetus for further research.

2. The need to select carefully differentiated subgroups of stutterers became apparent. Therefore, in the present study many factors including handedness, age, sex, and family history of stuttering were considered in subject selection.

3. The need to use a carefully selected battery of sensitive central auditory tests was emphasized, and the recommendation was pursued in the present investigation.

4. Data analysis in stuttering research (DCV tests) warrants careful consideration. Group and individual data need to be analyzed. Furthermore, the need to use a stringent measure, such as the phi-coefficent, was suggested. The present researcher took cognisance of these aspects.

5. There is a paucity of research related to sex differences in stutterers thus providing the impetus for further research.

The chapter that follows provides a description of the methodology used in the present investigation.

CHAPTER FOUR

METHODOLOGY

The aims, objectives and the methodology of the study are refelected in the ensuing chapter.

4.1. AIMS OF THE STUDY

i. To compare central auditory processing performance of stutterers and nonstutterers on a battery of central auditory tests.

ii. To compare central auditory processing performance of male and female stutterers and nonstutterers (within each group) on a battery of central auditory tests.

To realize the aims of the investigation specific objectives were formulated, as presented below.

4.2. OBJECTIVES OF THE STUDY

4.2.1. To compare the performance of stutterers and nonstutterers on the central auditory test battery viz:-

- Dichotic-Consonant Vowel (DCV) Test
- Staggered Spondaic Word (SSW) Test
- Competing Sentences Test (CST)
- Synthetic Sentence Identification - Ipsilateral Competing Message (SSI-ICM) Test
- Acoustic Reflex Latency Test (ARLT)

4.2.2. To compare male and female stutterers and nonstutterers (within each group) on the central auditory test battery.

Comparisions on selected test parameters were made as they related to the objectives of the study. The parameters are outlined below :

i. *Dichotic Consonant Vowel Test:*

a. accuracy scores

b. double correct scores

c. ear advantage i.e. REA, NEA, LEA.

ii. *Staggered Spondaic Word Test* :

a. errors scores on right and left competing and noncompeting conditions.

b. response bias

iii. *Competing Sentences:*

a. performance (correct) scores for left and right ears

iv. *Synthetic sentence identification test- ipsilateral competing message:*

a. performance (correct) scores for the left and right ears across the four message-to-competiton-ratios (4 MCR's) including -20, -10, 0, and +10dBMCR's.

v. *Acoustic reflex latency test:*

a. latency at 10% ON were compared for the left and right ears on ipsilateral and contralateral stimulation at 500Hz, 1000Hz, and 2000Hz.

4.3. DESCRIPTION OF INVESTIGATIVE PROTOCOL

The protocol comprised two parts; a preinvestigation to determine the suitability of tests for the population researched, and, the investigation.

Part One The Preinvestigation

In this part, a description of the preinvestigation considerations, and the procedures are presented. The purpose of the preinvestigation was to determine the suitability of the central tests for the population under investigation. The research design is also outlined.

Part Two The Investigation

The investigation comprised TWO SESSIONS

Session One This session comprised two phases that were used to preselect subjects for the investigation, based on predetermined criteria.

Phase One the questionnaire and handedness inventory, and fluency evaluation were administered to all potential subjects and,

Phase Two the potential subjects underwent an audiological evaluation.

Session Two: Subjects who fulfilled the criteria for Session One participated in Session Two. In this session, the central auditory test battery was administered.

PART ONE

4.4. PREINVESTIGATION PROCEDURES AND RESEARCH DESIGN

4.4.1. FAMILIARIZATION WITH TEST PROCEDURES

Prior to the investigation, the researcher familiarized herself with all test procedures used in this experiment. This was achieved over a period of three months.

4.4.2. DETERMINATION OF SUITABILITY OF TESTS

The suitability of tests for use with the population under investigation was determined by testing 20 normal, young adult subjects, who met predetermined criteria on each of the proposed measures. The subjects tested scored within the normal range, when compared to normative data provided in the literature. It was therefore concluded that the proposed measures of central auditory processing were suitable for use with the adult population whose first language is English. This normal pattern of results is expected for normal hearing, English speakers who have no other known deficits (Katz, 1986). Thus, the tests used in the present study appeared to be suitable for the population under investigation.

4.4.3. RESEARCH DESIGN

Since the recorded material is in American English, it is possible that results could have been influenced. Due to time and equipment limitations it was not possible to rerecord test material using a South-African voice. To accommodate for this shortcoming a *normal control group (nonstutterers)* selected on the same criteria as those of the experimental stutterer group was used in the design. The only difference in criteria for subject selection was that the experimental group comprised stutterers with a family history of stuttering, whilst the control group were nonstutterers with no family history of stuttering. Thus, in the present experiment, the experimental group performance (stutterers) was compared with that of the control group (nonstutterers) for male and female subjects within the groups.

PART TWO

4.5. THE INVESTIGATION - SESSION ONE

4.5.1. INVESTIGATIVE PROCEDURES

The following procedures were included :

i. administration of pre-test case history questionnaire

ii. assessment of handedness

iii. assessment of stuttering/fluency

iv. audiometric evaluation, including an otoscopic examination

v. administration of central auditory test battery

vi. retest for reliability

The investigative procedures (i), (ii), (iii) and (iv) were used to select the subjects according to predetermined criteria. The central auditory test battery was then administered to the subjects selected.

4.5.2. APPARATUS USED IN THE INVESTIGATION

i. *Consent form*

A written consent form was used. The subjects' willingness to participate in the investigation is reflected thereon (Appendix A).

ii. *Pretest case history questionnaire*

The questionnaire was constructed by the researcher to gather relevant information regarding identification details, age, sex, educational and language status, handedness, stuttering/fluency, hearing status, history of hearing loss, and other relevant neuro-medical information. The content areas selected were based on guidelines provided by Darley and Spriestersbach (1978), Ham (1986), Emerick and Hatten (1979), Rosenberg (1978), and Govender (1989) (Appendix B).

iii. *Handedness inventory*

The Annets handedness inventory, adapted and modified by Lazarus (1985), was used (Appendix C).

iv. *Fluency/stuttering assessment*

a. *Video recording equipment*

A video recording of each potential stutterer was made using a National NV-F70 video recorder via a National Panasonic F15 camera . The sound recording was obtained using PZM sound-grabber stereo microphones. The recordings were captured on Phillips E180 video casettes, and played back on a Phillips CM 8833-II colour monitor.

b. *Reading passage*

A contemporary reading passage from Varsity Voice was used to elicit a speech sample.(Appendix D)

v. *Audiometric test battery equipment*

a. *Sound proof booth*

The test environment comprised an isolated Industrial Acoustics Company (IAC) twin audiometric sound proof booth of double wall construction meeting the ANSI (1977) noise level requirements. It was used as the test environment for the audiometric evaluation , and the administration of the central auditory test battery.

b. *Clinical audiometer*

The Grayson Stadtler GSI 10, twin channel microprocessor based clinical diagnostic audiometer was used for air conduction testing and speech audiometry. The accessory item used included supra-aural ear phones mounted on MX cushions. The audiometer was calibrated in March 1991, according to ANSI (1977) standards.

c. *Impedance meter*

The GSI 33 middle ear analyser equipped with a probe tip assembly, and a contralateral earphone was used to administer the impedance test battery. The equipment was calibrated according to the ANSI (1977) standards, and was technically calibrated in February 1991.

d. *Otoscope*

The Welsh-Allen battery operated otoscope was used for the otoscopic examination.

e. *Spondaic word list*

The CID W-1 word list was used to establish speech reception thresholds (SRT) (Appendix E)

f. *Speech discrimination word list*

The C.I.D. W-22 word list was used to obtain SDT scores. The lists were published by CID (Hodgson, 1980) (Appendix F).

vi. *<u>Central auditory test battery</u>:*

a. *Audiometer*

GSI 10, as described previously.

b. *Cassette Player*

A Sony Stereo Cassette dual channel TC-K22 cassette player, and a Tecron 5507 power supply amplifier, were used to present the prerecorded central auditory tests.

c. *Impedance meter*

GSI 33 was used to elicit acoustic reflexes, and measure reflex latency.

d. *Precorded audio casettes*

The following commercially available prerecorded audio casettes were used:

- *Synthetic Sentence Identification Test* - commercially available cassette of the SSI-ICM test made by Jerger and Jerger in 1975 was obtained from Auditec of St. Louis in 1990

- *Staggered Spondaic Word Test List EC* - recording developed by Katz in 1973, was obtained from Precision Acoustics Laboratory in 1990
- *Dichotic Consonant Vowel Test* - this commercially prepared cassette developed by Lowe, Cullen, Berlin, Thompson, & Willet (1970) recorded at the Kresge Hearing Laboratory of the South, obtained in 1990 , was used
- *Competing Sentences Test* - a commercially available cassette developed by Willeford (1968) was obtained from Auditec of St. Louis in 1990.

4.5.3. MATERIALS FOR RECORDING DATA

i. *Questionnaire and Handedness inventory*

The responses were recorded manually on custom-designed questionnaire forms (Appendix C).

ii. *Speech sample : Stutterers*

The speech sample was recorded with the aid of a video camera (as described), and accessory items as described previously.

iii. *Otoscopic examination*

The results were recorded manually on the custom designed audiometric form (Appendix G).

iv. *Pure tone and speech audiometry*

The pure tone and speech audiograms designed by the Department of Speech and Hearing Therapy, University of Durban Westville, were used to record data manually (Appendix G).

v. *Impedance audiometry*

Custom designed forms were used to record tympanograms automatically (Appendix H). For latency measures, specially designed forms were used to transcribe numerical summary data automatically recorded by the impedance meter (Appendix I).

vi *Central Auditory tests*

The results for each test were recorded manually using standardized and custom designed recording forms (appendices J,K,L,M).

4.5.4. SUBJECT SELECTION CRITERIA

Session one served to exclude or select stutterers and nonstutterers in terms of the following criteria:

Age : All subjects were required to be between 17 and 35 years of age. This was necessary as it has been stated previously (Amerman & Parnell, 1982 ; Myrick, 1982) that age, and hence maturation influences test results. Also, the present researcher investigated adult subjects since cerebral dominance is well established in adulthood (Blood & Blood, 1984a). Young adult subjects were therefore selected .

Sex : A specific aim of the study was to compare male and female performances of stutterers and nonstutterers on central auditory tests, as there is a paucity of research in this area (Hageman & Greene, 1989). Fifteen male and female subjects were selected for each group i.e. stutterers and nonstutterers and this contributed to maintaining the homogeneity of the groups investigated.

Race : All of the subjects included in the present study were South African Indians. Subjects were selected from this background as the similar language and educational background would maintain homgeneity.

Language : All subjects were required to have English as their first language as it has been established that non-native speakers perform poorly on tests of central auditory dysfunction (Katz, 1986).

Intelligence : All subjects were required to be of normal intelligence since low intelligence influences the performance on central auditory tests negatively (Pinheiro & Musiek, 1985b). From personal communication with Vawda (1990), a registered school psychologist, it was ascertained that individuals who do not score normally on intelligence are not able to pass each successive year at school. To exclude the influence of low intelligence, the subjects in the present investigation were required to have reported passing each successive year at school.

Learning disability : All subjects were required to report a negative history of learning disability, since it has been established that individuals with learning problems perform poorly on central auditory tasks (Roeser, Millay & Morrow, 1983).

Fluency : The stutterers were required to display or report speech dysfluency that allowed a qualified speech clinician to be able to diagnose stuttering. Further considerations included :

- The present researcher attempted to examine the unchanging mechanisms underlying stuttering, and, therefore it was necessary to choose persistent stutterers i.e. in those for whom spontaneous recovery was unlikely. Andrews (1984), reported that the majority of stutterers spontaneously remitted before age 16. Therefore, adult stutterers with persisting dysfluency were included in the investigation.

- All stutterers were required to report a history of onset of stuttering in early childhood, as the present investigator-study intended to explore developmental stuttering, as opposed to acquired stuttering.

For nonstutterers, the following was considered;

- The nonstutterers were required to have a positive history of fluent speech from childhood, as determined from the questionnaire.

- The nonstutterers were required to have normal fluency as judged by the researcher, who is a qualified speech therapist.

Family history of stuttering : Stuttering subjects were required to report a positive family history of stuttering. This was done to achieve greater homogeneity of the group being tested (Rentschler, 1984, Jansenn et al., 1990). The family history was determined by interview with subjects which sought information about stuttering in the subject's biological family. Questions were included about stuttering in the subject's immediate and distant families. This method of data collection was supported by Poulos and Webster (1991).

Nonstutterers were required to report a negative family history of stuttering.

Therapy - All stutterers selected had had some form of fluency training. Thus, only those stutterers who reported persistent dysfluency having received therapy were selected.

Communication disorders - Subjects were required to report a negative history of communication disorders. This was done to rule out the possibility that other speech/language impairments which are associated with auditory processing problems (Pinheiro & Musiek, 1985b) might confound the interpretation of the results of this study.

Neurological integrity All subjects were required to report a negative history of neurological abnormality. This was necessary, because it is known that neurological abnormalities could confound the interpretation of test results reflecting the auditory processing mechanism (Blood ,Blood & Hood 1987; Willeford & Burleigh, 1985).

Drugs/Alcohol Influence : A negative report of history of drug and alcohol use was required for subject inclusion in the study. Korsan-Bengsten (1983), has reported that certain drugs can influence the performance on central auditory tests.

Handedness : All subjects were required to be right handed as determined by the modified Annets Handedness Inventory (Lazarus, 1985). Kinsbourne and Hiscock (1977), have reported that right-handers are usually left-hemisphere lateralized for language, whereas left-handers may have language represented in the left hemisphere, the right hemisphere, or both hemispheres. Since there is evidence of a relationship for right ear advantage for right-handers on dichotic listening tasks, and left cerebral dominance for language, it was considered important to control for handedness (Rosenfield & Goodglass, 1980). A criterion of right-handedness was therefore set for this study. A further advantage to this criterion was that it would maintain homogeneity of the groups investigated (Rentschler, 1984).

Central auditory test experience : Subjects were to report no previous experience with central auditory tests for inclusion in the study, as this could bias test results.

Hearing Status: All subjects were required to have hearing within normal limits. This prerequisite was based on findings reported by Pinheiro and Musiek (1985b), that conductive and sensorineural hearing losses negatively influenced the results of central auditory tests. Normal audiograms and tympanograms were neces sary for inclusion in this study.

- Each subject was required to have no more than a 10dB difference in puretone hearing threshold between ears as peripheral asymmetry could influence the results of central tests (Pinheiro & Musiek, 1985b).

- All subjects were required to obtain a negative score on the tone decay measure. This was necessary to exclude any subject with indication of possible eighth nerve pathology. For this experiment, excluding the influence of eighth nerve pathology was necesssary since the ARLT is a measure of both eighth nerve function, as well as brainstem pathology. Thus, if eighth nerve involvement could be ruled out, then any abnormalities observed on the ARLT may be related to the brainstem level of function (Borg, 1982).

- All subjects were required to have word discrimination scores of 90-100%. (Arnst, 1981; Katz, 1986). This was considered necessary to exclude speech discrimination problems that may negatively influence central auditory test performance.
- Only those subjects for whom acoustic reflexes could be elicite were included in the study.

4.5.5. DESCRIPTION OF SUBJECT SELECTION PROCESS

The time taken for the first session was approximately 45 minutes for the nonstutterers and 60 minutes for the stutterers, for whom video recordings of speech samples were made. Each subject was allowed a rest period as deemed necessary by the subject.

4.5.5.1. *Phase One*

i. *Completion of questionnaire*

The questionnaire was administered in a face-to face interview situation as recommended by Ventry and Schiavetti, 1986.

ii. *Handedness inventory*

The modified Annets Handedness Inventory was administered and scored for individual subjects by the researcher, according to guidelines provided by Lazarus (1985).

iii. *Assessment of fluency/stuttering*

All subjects were assessed with respect to speech fluency. For subjects who reported no history of stuttering (as per questionnaire), a fluency analysis of conversational speech was conducted by the researcher who has seven years clinical experience in assessement of fluency during the administration of the questionnaire. Those judged to be fluent were included as nonstutterers in the experiment.

For stutterers who reported persisting dysfluency stutterers, (as per questionnaire) a speech sample was elicited during reading, and a conversation with the researcher was made. Using this information, a diagnosis of stuttering was made by the researcher and the stutterers were selected to participate in the investigation. Video recordings of the stutterers' speech sample were made and examined by an independent qualified speech therapist with six years of clinical experience. The stuttering diagnosis was thus verified. One female stutterer did not consent to making a video recording of her speech sample. In this instance the diagnosis was verified only by the researcher.

4.5.5.2 <u>Phase two : Audiometric evaluation</u>

i. <u>*Otoscopic Examination*</u>

Prior to the administration of audiometric test procedures, an otoscopic examination was conducted to exclude external ear canal abnormalities (Hodgson, 1980).

ii. <u>*Impedance Audiometry*</u>

The following impedance subtests were conducted:

a. Tympanometry

b. Static compliance measures

c. Acoustic reflex thresholds.

Procedures for each of these tests, outlined below were conducted as per GSI-33 instruction manual (1989).

a. *Tympanometry*

Instruction to subject for impedance audiometry

Each subject was requested to remain motionless, and was advised against moving the mouth and head, swallowing, and speaking. It was also requested that he/she do not respond to the probe tone or, high intensity stimulus, during acoustic reflex testing. This was done to prevent extraneous movements from confounding the recording or the interpretation of the test result (Hodgson, 1980). An acoustic seal was obtained using an appropriate sized probe tip. The tympanogram was recorded automatically over the pressure range +200mmH_2O and -200mmH_2O, using a 226Hz probe tone.

b. *Static Compliance*

The data for static compliance measures were obtained from the tympanogram, in accordance with the procedure outlined by Jerger and Northern (1980).

c. *Acoustic reflex testing*

The test was performed at the point of maximum compliance. Ipsilateral and contralateral thresholds were obtained in the octave frequency range from 250-4000Hz. The ascending method of threshold exploration was used (Hodgson, 1980) and 2dB step sizes (Petersen & Liden, 1972; Gorga & Stelmachowicz, 1983) were used for threshold detection. The testing commenced with signal presentation at 70dBHL. The presence of the acoustic reflex was defined as a change in middle ear compliance of 0.02ml or greater (GSI Manual, 1989). The results were recorded automatically, and then transcribed.

iii. *Procedures for Pure tone audiometry*

a. *Pure tone testing*

Air conduction thresholds were obtained in the octave frequencies from 250-8000Hz, bilaterally. Carhart and Jerger's (1959) procedure was used, as cited by Hodgson (1980).

iv. *Procedures for Speech Audiometry*

a. *Speech reception threshold (SRT)*

The SRT was obtained using a standardized live voice presentation, as suggested by Hodgson (1980).

b. *Speech Discrimination testing*

A phonetically balanced word list was used to obtain speech discrimination test results. A live voice presentation was used. The test was presented 40dBSL (Katz, 1986), in accordance with guidelines presented by Berger (1978) cited by Rose (1978).

v. *Tone Decay Testing*

The STAT (supra threshold adaptation test) was administered at 1000Hz using the method outlined by Jerger and Jerger (1975) cited by Green (1985).

4.5.5.3. Criteria for interpretation of data obtained in session one: Phase one:

i. Questionnaire : Individuals who did not fulfil predetermined criteria were excluded from the study. Those who fulfilled criteria as previously described were included in the investigation.

ii. Handedness inventory : The inventory was scored according to guidelines provided by Lazarus (1985). Subjects who were classified as right-handed were included in this study.

iii. Stuttering : The criteria used to diagnose stuttering were those described by Ham (1986). Professional judgement of stuttering was also considered, as every definition/reference source does not provide an exhaustive review on stuttering symptomatology.

4.5.5.4 *Phase Two*

i. *Otoscopic examination* Subjects who had no visible outer and middle ear abnormalities were included in the study (Hodgson, 1980).

ii. *Impedance Audiometry*

a. *Tympanometry*

Tympanograms were classified according to the system advocated by Jerger (1970). Subjects with Type A tympanograms were considered normal.

b. *Static Compliance measures*

Measures between 0,28cc and 2.5cc were considered to be within normal limits (Jerger & Northern, 1980).

c. *Acoustic Reflex thresholds*

Acoustic reflex thresholds of 70-90dB SL were considered to be within normal limits (Jerger & Northern, 1980).

iii. *Pure tone audiometry*

The ANSI (1969) criteria cited in Green (1978) was used to evaluate hearing acuity. Pure tone threshold ranging from 0-26dBHL, for all test frequencies were considered to be normal.

iv. *Speech audiometry*

a. *Speech Reception Threshold*

The SRT was required to be within 5dB of the pure tone average to be considered normal (Hodgson, 1980).

b. *Speech Discrimination Test.*

A maximum speech discrimination score for each ear of between 90-100% at 40dBSL re: SRT was regarded as normal (Katz, 1986).

v. *Tone decay test*

Subjects included in the study were required to hear a signal for 60 seconds in each ear (STAT procedure: Green, 1985).

60 subjects were selected. Eight subjects (stutterers and non-stutterers) were excluded, as a result of failure on the peripheral audiometric test battery. The nonstutterers comprised 30 subjects (15 of each sex) with a mean age of 22 years and two months (17-31 years). The stutterers comprised of 30 subjects (15 of each sex) with a mean age of 23 years and 10 months (17.3-30). All of these subjects underwent the central auditory test battery.

4.6. **THE INVESTIGATION : SESSION TWO**

4.6.1. DESCRIPTION OF PROCEDURE : SESSION TWO

General Considerations

The time taken for the central auditory test battery was approximately 110 minutes. A rest period as deemed necessary by individual subjects was allowed between tests.

i. *Order of Presentation*

A random order of test presentation was adopted. The order of presentation was determined from a random table (Downie & Heath, 1969), as suggested by Hawver (1978), to prevent test order presentation from biasing the result.

ii. *Response mode*

All subjects responded verbally for the following reasons :

- During the preinvestigation/familiarization period it was noted that when a written response was used, the testing time was lengthened. Subjects were also more reliant on memory in the written mode. The test appeared to lose spontaneity, as there were breaks between items especially for the sentence and word tests.
- The tests as described in information manuals adopted a verbal response mode. Furthermore, the SSI-ICM is not conducive to a written mode of response.

The possibility that stutterers would have difficulty with the verbal mode was considered. During the preinvestigation trial period it was noted that since the verbal responses involved imitation, rather than propositional speech, stutterers did not appear to have a problem using the verbal response mode. This is consistent with theoretical orientation provided by Ham (1984), which confirms that stutterers have little difficulty on imitation tasks as opposed to propositional speech. To alleviate any anxiety the stutterers (as well as nonstutterers) were informed that they would have sufficient time to respond, and (for stutterers) that stuttering would not bias the test result.

iii. *Recording of Results*

The results of the tests were recorded by the researcher. In order to facilitate reliability, a trained independent assistant also recorded the results. The assistant was not present on some occasions, due to practical problems. In these instances an audio recording of the results was made using the Tandburg tape recorder. The assistant then used these tape recordings to record the results. Thus, for each subject the results were recorded by the researcher and an assistant. To reduce subjects' anxiety the assistant was positioned so that she could not be seen by the subjects.

NB: The description of procedure is presented as per individual test to facilitate ease of understanding.

4.6.1.1. <u>Dichotic Consonant-Vowel test</u>

<u>Test format</u> The DCV test comprises stop-consonant-vowel recordings of nonsense syllables. Simultaneous dichotic ie. 0msec presentation format was used. The test lists comprised lists H and I (Appendix J). Each list comprises 30 DCV presentations.

<u>Calibration</u> A 1000Hz calibration signal was used as described in the Auditec manual (undated).

Test instruction The following instruction was presented as per instruction manual:

"You will hear two words, and there will always be two of them. There will never be the same words and you will have to tell me what two words you heard. Guess if you have to, but always tell me two words."

Thus, a forced two-response mode was elicited.

Test Prerequisite Each subject was required to identify fourteen of the sixteen monaural DCV presentations.

Test Administration A total of 60 dichotic trials at 0msec (Musiek & Pinheiro 1985) were presented. At a point half way through the test, ie. at 30 items the earphones were reversed to counter balance any asymmetry generated by the earphones (Pizzamiglio, Pascalis & Vignati 1974).

Presentation level The hearing attenuator dial was set at 55 dBHL.

Response mode Verbal responses were required.

Recording of results This was done manually by the researcher and assistant.

Scoring Correct responses per ear (accuracy scores), and for both ears (double correct scores), were calculated for a total of 60 trials generating raw data (Appendix N).

Interpretation The results were interpreted according to guidelines provided in the literature (Porter, et al., 1976; Speaks et al., 1982; Blood & Blood, 1989b). For this particular study, three parameters were considered : viz. (a) accuracy of performance as determined by the number correct for each ear, as well as considering the combined correct scores for the left and right ears (b) the number of double correct responses was calculated (Roeser, Millay, & Morrow, 1983), and (c) ear advantage.

The ear advantage was computed for each of the subjects. The phi-coefficient (Kuhn, 1973; Blood & Blood, 1989b) was used as it provides three categories of ear advantages, i.e. REA, NEA , and LEA. This method of analysis provides more stringent criteria for determination of ear advantages, because it offers the advantage of considering the direction, as well as the magnitude of the ear advantage. This method of analysis is purported to be a more sensitive measure, when considering ear advantages on dichotic tests (Blood & Blood, 1989b).

The result of phi-coefficient application to determine ear advantage in the present investigation, appears in appendix O. Pass/fail rate on the DCV test was determined from consideration of accuracy scores and ear advantages for all subjects.

4.6.1.2. <u>Staggered Spondaic Word test</u>:

<u>Test description</u> : The SSW test is a dichotic listening task involving two different spondee words partially overlapped in time. Both ears receive different words at approximately the same time. The subject is required to repeat the entire sequence of words as it is presented. The arrangement of the test stimuli introduces the competing and the noncompeting conditions for both the right and the left ears. During the test, the word pairs are alternated between the ears. First, one ear receives the leading

spondee and on the next time the other ear receives it. According to Katz, (1986) the alternating sequence provides counterbalancing for the presentation of the test items.

Calibration and pretest considerations : The tape was calibrated using a 1000Hz signal, as per SSW manual (Katz, 1986). List EC was used in order to facilitate comparisons with other research studies. The right-ear-first procedure was selected (Arnst, 1981).

The researcher listened to the tape to ensure that the ear choice coincided with the output. Pure tone and speech audiometry details were entered onto the score sheet (Katz, 1986).

Presentation level : The test items were presented at 50dB SL.re:PTA.

Test instructions and practice items : Test instructions are prerecorded. Subjects were instructed to listen to the instructions, and were required to respond successfully to practice items before the test was administered.

Test instructions : "You will hear a group of words which will be presented to one or both of your ears. Wait until the group of words is completed and then repeat all of the words that you heard. If you are not quite sure of a word, guess. The first four groups will be for practice. Remember, wait until you have heard all the words before answering.

Test administration : All fourty test items were administered. The subjects were tested with stimuli presented to the right ear first.

Response mode : Verbal report of groups of words was required (Katz, 1986).

Recording of patient responses : Responses were recorded manually by the examiner and an assistant.

Scoring : The scoring was done in accordance with procedures suggested by Katz (1986). The results were computed as they pertained to central auditory processing, as opposed to site of lesion testing. The error scores, R-SSW and C-SSW scores and response bias were computed (Appendix P).

Interpretation : The error scores and response bias were used to compare performances between stutterers and nonstutterers as they related to the objectives of the study. Test results for stutterers and nonstutterers were related to guidelines presented in the SSW manual (Katz, 1986) and pass/fail rates were determined for all subjects.

4.6.1.3. Competing Sentences Test

Calibration : A 1000Hz test signal was used to calibrate the test cassette.

Test familiarization : Five sentences were presented to each ear in monotic and dichotic format, to familiarize subjects with the test procedure. Two practice items were presented to each ear in monotic format. This was done to determine whether subjects could repeat sentences accurately, and to rule out possible memory problems that could confound test results (Willeford & Burleigh, 1985). Three items were then presented in dichotic format for practice.

Test administration : The test was presented in a dichotic format, with the primary message being presented at 35 dBSL, re: PTA. The competing sentence was presented at 50dBSL.

Instruction : "You will hear sentences in both ears. Only repeat the sentence in your (right or left target) ear only (Musiek & Geurkink, & Kietel, 1982).

Presentation : A total of 20 test items were presented in the dichotic format. Ten target sentences were presented to each ear.

Response mode : Subjects were required to respond verbally.

Recording of results : Subjects responses were recorded manually by the researcher, and an assistant (appendix P).

Scoring : The test was scored according to the strict guidelines for adults suggested by Willeford (1985). A score of 10 was obtained for each correct response and these were converted to percent correct. Thus, a maximum score of 100 could be obtained for each ear. Individual performance scores are presented in appendix Q.

Interpretation : The results were compared to normative data provided by Ivey (1969) cited by Willeford (1985) . Scores below 90% correct for either were considered out of the normal range. The performance scores were compared as they related to the objectives of the study and were also used to determine pass/fail rates.

4.6.1.4. Synthetic sentence identification test - ipsilateral competing message

The SSI-ICM test was presented to each subject in the standard format, as outlined in the Auditec instruction manual (undated).

The following is a description of the procedure adopted.

Calibration : The tape was calibrated using a 1000Hz signal.

Presentation level : The presentation level for the primary signal was 30dBHL. The nature of the SSI-ICM test is such that the primary and competing messages are recorded on the same channel. The test requires a wide range of message-to-competition ratios. In order to achieve this range without distortion, the primary message is recorded 20dB below the calibration tone. The primary signal remains at this level, whilst the level of the competition is varied from 20dB above the primary signal, to 10dB below the primary to achieve the required MCRs. In order to present the primary message at the proper hearing level, the hearing dial is adjusted so that it is 20dB higher than the stated presentation level. Since the presentation level for the primary signal was 30dBHL, the attenuator dial was set at 50dBHL.

Prior to the test, subjects were required to read a list of the ten synthetic sentences, that were visually presented as part of the standard test material (Appendix R).

Test familiarizaton : The lists I and J were administered to each ear at 0dB MCR to ensure that subjects were fimiliarized with the test.

Test presentation : The test was presented to the right and the left ears. Each block of ten sentences was presented in random order at various MCRs. The competing message comprised of a continuous discourse presented to the same ear as the primary message. These ranged from +10dBMCR to -20dBMCR.

Instructions and response mode : "You are going to hear a continuous discourse in your (right or left) ear. Together with this you will also hear the sentences that you have before you being said. When you hear the sentence, call out the number of the sentence."

Recording of responses and scoring : The responses were manually recorded by the researcher and assistant. The number correct for each of the four conditions was recorded (Appendix S). For each condition a total of ten sentences were presented. Thus, the maximum number correct per MCR would be ten (100%), as the result was scored in 10% increments (Jerger, 1978).

Interpretation : The results of the nonstutterers were used to derive normative data to which the performance of the stutterers were compared. Pass/ fail rates were determined as per normative data.

4.6.1.5. Acoustic reflex latency test

Description of Test : An impedance method of evaluation was used in the present study (Church & Cudahy, 1984), The latency was measured at a point where the slope function of the generated curve reaches 10% of its maximum value (Appendix T). In using this predetermined point, the response stability across subjects could be improved, thereby generating less variability on the measure (Church & Cudahy, 1984).

Test instruction : As per impedance screening procedures

Test presentation : Ipsilateral and contralateral ARL measures were obtained at 10dB above the acoustic reflex threshold established at 500Hz, 1000Hz, and 2000Hz, bilaterally. The stimulus-on time was 300msec. A time base of 1000msec was utilised. An average of two readings was recorded in order to improve signal to noise ratios (GSI manual, 1989).

Recording of responses : Responses were recorded automatically by the GSI 33. The numeric summary data was then transcribed by the researcher (Appendix U).

Interpretation of Data The results of nonstutterers served as a normative data base, and pass /fail rates were derived for all subjects.

4.7. **TEST-RETEST RELIABILITY**

The test- retest reliability of subjects' responses on the battery of central tests was determined in the following manner:

A sample of nine subjects (five nonstutterers and four stutterers) was chosen (based on availability). The subjects were required to report no change in hearing status from the first test, for inclusion in the retest. The test battery was administered in an identical manner three months after the first test.

The reliability was assessed using Pearson-R correlation (Patel,

4.8. DATA ANALYSIS

The following procedures were used to analyse raw data obtained for each of the test measures. It should be noted that for each test group data were analysed. This gave rise to summary statistics and analysis of variance. In addition, pass/fail criteria per determined per test for individuals. The following description pertains to group data analysis.

i. Means, percentages, ranges, standard deviation and frequency distributions were used to provide summary data for stutterers and nonstutterers, males and females for each of the central auditory test procedures (Downie and Heath 1969). The data was generated using a SYSTAT (1991) programme.

ii. Univariate and multivariate analysis of variance with repeated measures, for test conditions, and ears, was used to assess the statistical significance of performance differences as they related to the objectives of this study. This type of analysis allows for observation of interaction effects for the variables analysed. Analysis of variance is a more stringent measure to test for significant differences between and within multiple dependant variables (Govender, 1989); Bhagwanjee (1992). The programme was generated by SYSTAT (1991).

iii. The phi coefficient (Kuhn, 1973, Blood & Blood, 1989b) was used to determine the nature of ear advantages generated from the DCV test data. The coefficient was used because it provides stringent criteria in determining magnitude and direction of ear advantage. (Blood & Blood, 1989b).

iv. Student t-tests were used to determine differences between means suitable for the sample size used in this investigation (Downie & Heath, 1969).

v. Percentage pass/fail rates were calculated for stutterers and nonstutterers and descriptive analysis of trends was used in an attempt to provide a qualitatative evaluation of the findings of the study.

vi. Chi-square was used as a test of significance for data expressed in frequencies. For the present study, it was used to determine the significance of differences in ear advantage and pass/fail rates as they related to the objectives of the present study. It was also used to determine significant differences between S and NS of pass/fail rates on the test battery.

The results were illustrated as follows :

- The use of table presentation format was used for all results generated from analysis of variance, and summary statistics.

- Histograms were used for easy visual inspection of information. The histograms were constructed for ear advantages generated on from the DCV test, and for pass/fail rates of subjects on the test battery.

- Graphical mode of presentation was used for individual scores generated on the Competing Sentence Test, and to illustrate patterns of error scores on the SSW test for stutterers and nonstutterers.

CHAPTER FIVE

RESULTS AND DISCUSSION

5.1. INTRODUCTION TO RESULTS AND DISCUSSION

In order to facilitate the management and presentation of this section, it was necessary to structure the chapter in the following manner :

A : The results of individual tests as related to the objectives of the study will be presented. This will be followed by an immediate discussion of the results for the particular test.

B : A composite presentation of the pass/fail rates on the test battery, and individuals' performance profiles on the battery are discussed, as relating to the objectives of the study.

For A, the test results and discussion will be presented and discussed in the following order;

- Dichotic - Consonant Vowel test
- Staggered Spondaic Word Test
- Competing Sentences Test
- Synthetic Sentence Identification-Ipsilateral Competing Message
- Acoustic Reflex Latency Test

This presentation format was deemed necessary in order to avoid confusion between the results and the discussion thereof, for individual tests. The format also allows for continuous access and flow of information from results to discussion.

For B, an attempt is made to present a composite review of pass/fail rates on the test battery as well as the performance profiles of individual subjects on the test battery. In the discussion that follows it was necessary to examine the performance on monotic and dichotic tests and relate to the levels of central auditory processing that the tests are designed to assess.

In using this approach, the objectives of the study viz.
- stutterers/nonstutterers comparison on central auditory processing measures;

- male/female comparison (for stutterers and nonstutterers) on central auditory processing tests;

will be linked to the presentation of results and the discussion thereof.

NB: For male/female comparisons, the results for stutterers and nonstutterers are presented separately. This method of presentation was adopted so as to facilitate comparison of male and female subjects and to exclude the influence of the stuttering variable, which may mask male-female comparisons.

The results for both objectives for individual tests appear in a single table. This format has been adopted to avoid lengthy presentation of results. The results have been summarized and presented in table form. Where necessary, figures have been used to highlight findings, as they relate to the objectives of the study. A description of analysis of variance tables is provided to facilitate ease of understanding.

Analysis of Variance : Description of Format

The tables reflect the result of a 2 x 2 x 2 analysis of variance i.e. maingroups (S & NS) x gender (M + F) x ear (R & L) with repeated measures on the last factor. In some tables 2 x 2 analysis of variance are provided. In these instances "Ear" is not considered. The tables are separated into two parts : i.e. between subjects analysis and within subjects analysis.

The between subjects analysis reflect differences between :

i. S and NS (maingroups)

ii. Males and females (gender)

iii. maingroups x gender : interaction between maingroups and gender.

The within subjects analysis reflect difference within groups on L & R ears, where applicable.

The analysis of variance allows for determining the statistical significance of differences, as related to the objectives of the study. For one-way analysis of variance (for ARLT) only between subject comparisons are presented.

SECTION A:

5.1.1 RESULTS : DICHOTIC CONSONANT-VOWEL TEST

Description of presentation

Table 1 : Summary statistics are presented for right and left ear accuracy scores, combined accuracy scores and double correct scores for S and NS, and males and females (within each group). Percentage calculations are also presented to allow for ease of analysis and interpretation.

Table 2 : Analysis of variance of combined accuracy scores reflecting statistical significance of differences between NS and S, and males and females within each group are presented.

Figure 3 : The figure is provided to illustrate S/NS differences in respect of ear advantage.

Figure 4 : The figure illustrates male/female ear advantage differences for S.

NB : The accuracy score refers to the number of CV's correctly identified in each ear. Combined accuracy score refers to the accuracy scores of the right and left ears combined. The combined accuracy scores of subjects were considered in the analysis of variance since right ear, and left ear scores individually are a reflection of ear advantage rather than accuracy of performance.

Table 1 : Summary statistics reflecting accuracy scores, combined accuracy scores, and double correct scores for S and NS, males and females within each group, on the DCV Test

	NS	S	NSM	NSF	SM	SF
ACCURACY						
R Mean	41.40	37.53	41.73	41.07	37.0	38.07
Std. Dev.	5.28	7.51	5.56	5.03	7.19	7.87
Range	30.54	24-51	30-54	32-49	24-51	25-49
% R Mean	69.0	62.56	69.56	68.44	61.67	63.44
Range	50-90	40-85	50-90	53-82	40-85	41-82
L Mean	31.10	34.90	31.73	30.47	35.13	34.67
Std. Dev.	5.04	4.88	4.85	6.23	5.83	4.64
Range	22-44	26-42	26-44	22-41	26-42	28-42
% L Mean	51.83	58.17	52.89	50.78	58.56	58.78
Range	37-73	43-70	43-73	37-68	43-70	47-70
COMBINED ACCURACY						
R & L Mean	72.50	72.43	73.47	71.53	72.13	72.73
Std. Dev.	6.97	7.37	6.42	6.85	7.42	6.28
Range	61-88	60-91	65-88	61-83	60-91	61-84
% R & L Mean	60.42	60.36	61.22	59.61	60.11	60.61
Range	51-73	50-74	54-73	51-69	50-74	51-70
DOUBLE CORRECT						
DC Mean	23.63	23.03	24.27	23.00	23.20	22.87
Std. Dev.	2.69	3.68	2.99	2.14	3.76	3.40
Range	20-29	18-31	20-29	20-27	18-31	19-30
% DC Mean	39.39	38.39	40.44	38.33	38.67	38.11
Range	33-48	30-52	33-48	33-45	30-52	30-50

Description of results in Table 1

Table 1 reflects the mean accuracy scores, combined accuracy scores, and double correct scores obtained for S and NS, and males and females within each group. The results are described as they relate to the objectives of the study.

STUTTERERS/NONSTUTTERERS COMPARISION

- Mean accuracy scores for the right ear indicate that NS

(41.4; 69%) had greater accuracy than the S (37.53; 62.56%).

- The mean accuracy scores for the left ear indicate that S (34.90; 58.17%) had higher scores than NS, (31.1; 51.83%).
- Combined accuracy scores indicate that S (72.43; 60.36%) and NS (72.50; 60.42%) performed similarly.
- S (23.03; 38.39%) and NS, (23.63; 39.39%) obtained similar double correct scores.
- The range and standard deviation of accuracy scores for right and left ears for S and NS indicates substantial variability in performance for S and NS.

<u>MALE/FEMALE COMPARISONS</u>

<u>Nonstutterers</u>

- mean accuracy scores for the right and left ears indicated similar performances for males and females.
- Similar double correct and combined accuracy scores were obtained for males and females.

<u>Stutterers</u>

- mean accuracy scores for right and left ears indicate similar performances for males and females.
- Similar double correct and combined accuracy scores were obtained for males and females.

Table 2 : Summary table of 2 x 2 (maingroups x gender) analysis of variance test for combined accuracy scores on the DCV test

SOURCE	F - RATIO	P
Maingroups (S; NS)	0.531	0.469
Gender (M; F)	0.531	0.469
Maingroups x Gender	0.114	0.737

STUTTERERS/NONSTUTTERERS COMPARISION

- No significant performance differences were obtained between S and NS with respect to combined accuracy scores (p>0.05).

MALE/FEMALE COMPARISONS

- No significant performance differences were obtained between males and females in each group, (p>0.05) on combined accuracy scores.

Table 3 : Frequency of ear advantages obtained for S and NS, males and females (within each group), on the DCV test

GROUP	NS	NSM	NSF	S	SM	SF
REA	24	12	12	12	5	7
NEA	5	2	3	12	7	5
LEA	1	1	0	6	3	3

Table 3 indicates the following :

STUTTERERS/NONSTUTTERERS COMPARISION

- the results for the NS indicates that 24 subjects obtained REA (80%), 5 NEA (16.6%), and 1 LEA (3.3%). This suggests that the majority of nonstutterers demonstrated REA, with 20% percent of nonstutterers demonstrating NEA and LEA.

- the results for the S indicate that 12(40%) subjects obtained REA, 6 (20%) LEA, and 12 (40%) NEA.

- the result indicated that 80% of stutterers and 20% nonstutterers demonstrated atypical ear advantages (LEA and NEA).

  Significantly more nonstutterers than stutterers obtained REA (χ^2=17.86, df=1, $p<0.05$).

These findings are illustrated in Figure 1.

MALE/FEMALE COMPARISONS

Nonstutterers

- Similar ear advantages were obtained for males and females.

Stutterers

- Similar trends were noted for males and females. More females (7) than males (5) obtained REA, whilst more males (7) than females (5) obtained NEA. An equal number of males and females obtained LEAs. The result indicates that more males than females demonstrated atypical ear advantage. These findings are illustrated in Figure 4.

Figures 3 and 4 are included to illustrate ear advantages for NS/S groups and for SM/SF groups .

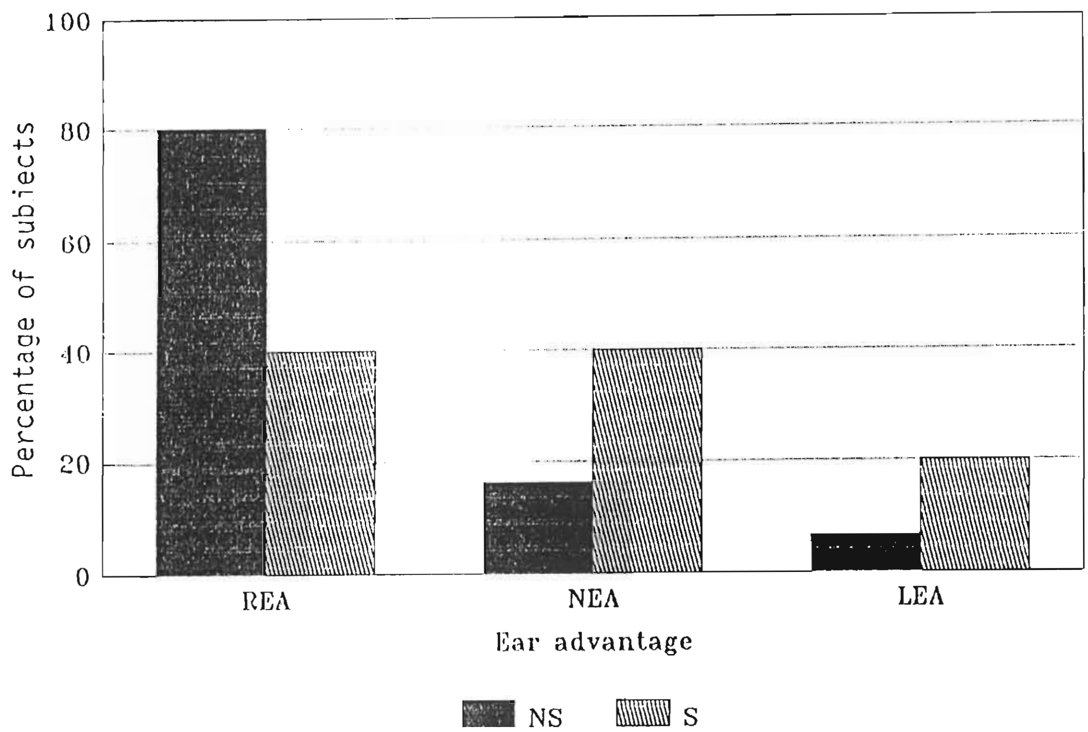

Figure 3 : Ear advantage for stutterers and nonstutterers (reflected in percentage).

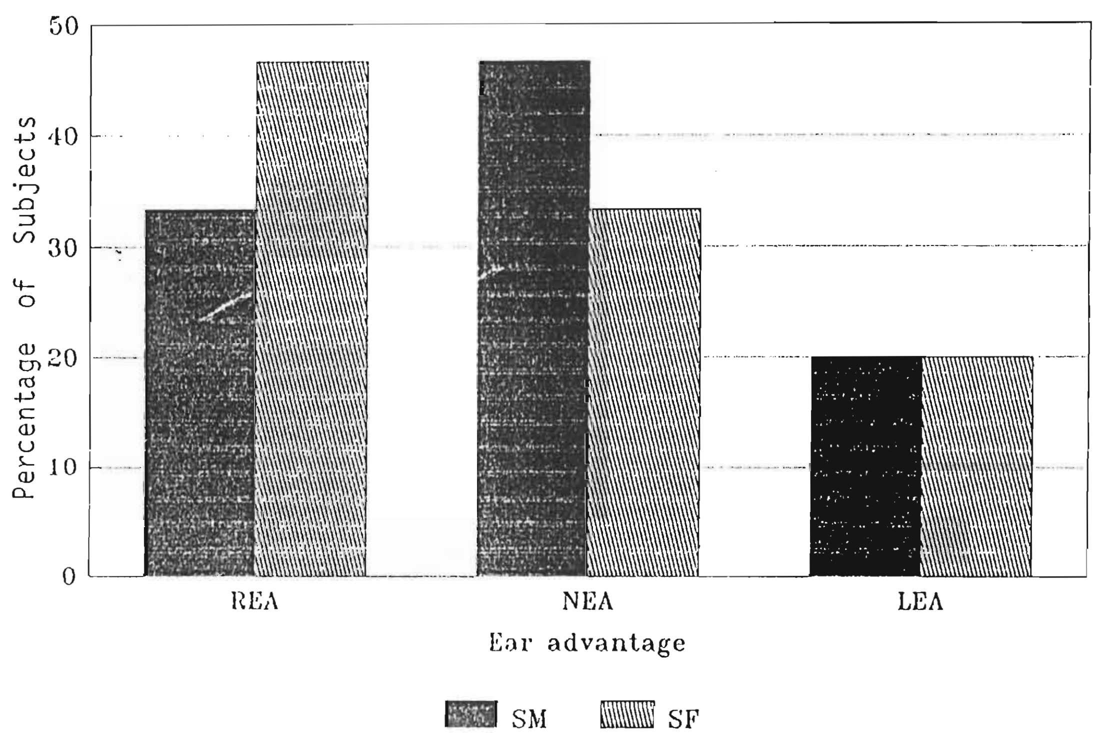

Figure 4 : Ear advantages for male and female stutterers on the DCV test (reflected in percentage).

A summary of performance trends on the DCV is as follows :

STUTTERERS/NONSTUTTERERS COMPARISION

S and NS appear to have performed similarly with respect to combined accuracy scores and double correct scores. S and NS performance with respect to right and left ear performances appear to differ. However, both groups performed better overall in the right ear. On the left ear S performances were superior to that of NS. This performance difference is related to the ear advantage.

MALE/FEMALE COMPARISION

Male and female S and NS performed similarly with respect to combined accuracy scores. Males and females nonstutterers performed similarly with respect ear advantages. Subtle male/female differences were obtained for stutterers with respect to ear advantages.

Pass/fail criteria and interpretation for S and NS

Stutterers did not differ significantly on combined accuracy scores compared with NS. Therefore, ear advantage rather than accuracy scores were used in the pass/fail interpretation for the DCV test. Subjects who obtained REA were considered to have passed the test. Subjects who obtained atypical ear advantages ie. NEA and LEA, were regarded as having failed the test. Using these criteria 18 stutterers (ten male and eight female) failed the DCV test, and 12 stutterers (five male and seven female) passed the DCV test. Five nonstutterers failed the test (two male and three female) and 25 nonstutterers (13 male and 12 female) passed the test.

5.1.2. DISCUSSION : DICHOTIC CONSONANT-VOWEL TEST

The following parameters of test performance are considered in the discussion, as they relate to the objectives of the study.

1. Accuracy scores
2. Double correct scores
3. Ear advantage

5.1.2.1. Stutterers/Nonstutterers Comparison

A description of the performance of each group (S and NS) is provided and this is followed by a comparison of S and NS.

Nonstutterers

1. *Accuracy scores*

The accuracy score reflects the number of CVs identified accurately in each ear. The right ear mean accuracy score for NS is 41.4 (69 %), whilst the mean accuracy score for the left ear is 31.1 (51.83 %) as indicated in Table 1. The accuracy scores reflect that the mean performance of the right ear was significantly superior to that of the left ear. A t-test indicated that there was a significant difference ($p<0.05$) between the right and left ear accuracy scores for NS. The results reflect superior right ear performance on the DCV test, a feature common to the majority of normal hearing subjects (Blood & Blood, 1989b; Porter, Troendle & Berlin, 1976; Speaks, 1978).

Comparable accuracy and combined accuracy scores were obtained by Hawver (1978), and Blood and Blood (1989b), implying that the NS in the present study performed similarly to control subjects in other investigations. It has generally been acknowledged (Ryan & McNeil, 1974), that there is a great deal of variability in accuracy scores for normal individuals on DCV test for both ears and this trend is also evident in the results of the present study. The variability in performance is reflected in the range and standard deviation of performances described in Table 1.

The variability in performance on the DCV test for normal subjects could be attributed to general intersubject variability. Whilst some subjects perform well i.e. obtain high accuracy on the test measure, other subjects are less accurate in the identification of CV stimuli. Millay, Roeser and Godfrey (1977), have suggested that using a two response mode (as in the present study) may increase performance variability because the information content of the second response is low. Therefore, subjects often resort to guessing and tend to generate variable performance. In addition, the extent to which speech/language functions are lateralized in normal subjects are variable (Efron, 1985), and this is, to an extent, reflected in the accuracy scores obtained on left and right ears. Thus, the range of performance and variability score obtained in this study for normal subjects is not unusual, and is in agreement with findings reported in the literature.

2. *Double correct responses*

Another aspect to consider in analysing the performance on the DCV test scores, is that of the double correct responses. The mean number of double correct responses for NS is 23.63 (39.39%) as reflected in Table I. A similar trend for normal subjects was reported by Speaks, Niccum and Carney (1982), and Porter, Troendle and Berlin (1976) who have reported a range of double correct responses for the normal adult from 28% to 38%. The measure of the double correct responses is considered to be an indicator of the ability of the auditory system to store and recall speech information and the "auditory capacity effect" is considered to be stable by age 15 (Rouser, Millay, & Morrow, 1983).

Thus, the performances scores (accuracy scores, combined accuracy scores, and double correct scores) for the NS appear to be in agreement with results reported for normal subjects by previous researchers (Blood & Blood, 1989b; Hawver, 1978; Speaks et al., 1982). The NS performance could thus be described as representing a normal pattern of performance.

Stutterers

1. *Accuracy scores*

The mean accuracy scores for the right ear is 37.53 (62.56%) and for the left ear is 34.9 (58.17%) as reflected in Table 1. The mean performance difference between the right and left ears is not significant ($p>0.05$) as determined by a t-test. Mean accuracy of scores for the present study indicates that the mean performance of the right ear is better than the performance of the left ear for stutterers. A comparison with results obtained from other studies is difficult because the of the influence of may variables e.g. sex, response modes, and number of trials, amongst others. However, it is evident that mean accuracy scores reported for group comparisons for stutterers by previous researchers (Hawver, 1978 ; Rosenfield & Goodglass, 1980) show trends similar to the present study, that is, higher accuracy scores were reported in the right ear and the performance difference between the ears was not substantial.

The variability in test performance observed for NS, is also evident for the S in the present study. In addition to the factors which contribute to variability in test performance for normals, variability for stutterers may also be generated by the hetergenous nature of the stuttering population. The performance variability on the DCV test is possibly related to atypical ear advantage evident for subgroups of stutterers (Rosenfield & Goodglass, 1980), and this factor may have contributed to varied overall results for the stutterers.

2. *Double correct scores*

The number of double correct responses obtained for S is 23.03 (38.39%) reflected in Table 1. This appears to fall into the normal performance range as reported by Porter et al., (1976). Therefore it may be assumed that S have similar abilities to store and recall speech information as NS.

Stutterers/nonstutterers comparison

1. *Accuracy scores*

A comparison of accuracy scores for the right ears for S and NS, indicates that the NS obtained higher scores (41.40) 69% than did the S (37.53) 62% as reflected in Table 1. This result is in contrast to the accuracy scores obtained for the left ear, for S and NS. The mean accuracy score for S (34.90) 58% are higher than that of the NS (31.10) 51%. It appears that the mean right ear accuracy score is better for the NS when compared with the S whereas left ear mean accuracy score for S is better than the left ear mean accuracy score for the NS. However, both groups obtained a higher mean right ear than left accuracy score.

The combined mean accuracy scores for the S and NS indicates that the S performed similarly (mean = 72.43) 60.42% to the NS (72.5) 59.61%. These results are reflected on Table I. The performance differences (as reflected in combined accuracy scores) between the S and NS are not statistically significant ($p>0.05$) as indicated in Table 2. The result therefore suggests that when the combined performance of right ear and left ears are considered for S and NS, it could be stated that no overall performance differences were noted between S and NS on the DCV test with respect to accuracy of recall. Thus, the performance differences between S and NS for the right and left ears appear to be related to the ear advantage of subjects than to the accuracy of performance per se.

2. *Double correct scores*

No significant differences ($p>0.05$) were obtained between NS and S with respect to double correct scores (t-test $p>0.05$). This suggests that S and NS had similar auditory capacities to store and recall speech information. This result is contrary to the findings of Hawver (1978), who reported poorer performances of stutterers compared to normal subjects on the DCV test. However, an analysis of double correct responses was not presented by Hawver (1978). Therefore, it is not possible to determine whether the performance differences were due to ear preferences, or to auditory capacity differences. Blood and Blood (1989b), report similar stutterer/nonstutterer performance trends as in the present study. i.e. an average of combined left ear and right ear scores are comparable.

In summarizing the results obtained on the DCV test, it appears that the accuracy of response of S and NS were similar in the light of the double correct responses and combined accuracy scores. Statistical analysis of performance scores indicated that whilst the NS performed marginally better than the S, there were no significant differences ($p>0.05$) on the combined accuracy scores and double correct scores between S and NS.

3. *Ear advantage*

The ear advantage for each subject was obtained via the application of the phi-coefficient (Kuhn 1976; Blood & Blood, 1989b). The summary of results are presented in Table 3 for stutterers and nonstutterers.The results obtained for the NS indicate higher mean accuracy scores were obtained for the right ear than for the left. i.e. REA. The application of the phi-coeffieient indicated that 80% of the NS demonstrated REA. A similar trend was reported by Rosenfield and Goodglass (1980), and Blood and Blood (1989b) for normal subjects. For stutterers 12(40%) obtained REA, 6(20%) LEA and 12(40%) NEA. This indicates that more stutterers than nonstutterers obtained atypical ear advantage and statistical analysis ($\chi^2=17.86$, df=1 $p<0.05$).indicated that this difference was significant.

In attempting to explain the right ear advantage, Berlin et al. (1973) have suggested that the REA is a reflection of the left hemisphere's dominance for speech perception and other related language functions. It has been established by McNeil, Pettit and Olsen (1981), that the human auditory system has a stronger contralateral pathway which is capable of projecting stimuli with greater speed and intensity than the ipsilateral pathway. Since most people are left-brained for language (Penfield & Roberts, 1959 cited in Musiek & Pinheiro, 1985), a REA is evident on dichotic tasks. Thus, one could interpret the REA obtained in the present study as reflecting the primacy of the contralateral auditory pathway operating in conjunction with the left hemispheric dominance for speech and language.

The models described by Speaks (1978), and description of the underlying neural mechanism described in chapter 2 (p. 29) also apply here. The stability of ear advantage is often a subject of controversy (Teng, 1981; Efron, 1985; Friedes, 1977). However, the present investigator noted that on retest, the subjects in the present study did in fact retain their ear advantages. Minor changes were observed with respect to the magnitude of ear advantage but on application of the phi-coefficient there was no change in direction of ear advantage. This result indicated that whilst the stability of the ear advantage may vary slightly, it is not in essence an unstable measure especially when the phi-coefficient is used as a stringent measure to determine ear advantage. This contention was also held by Blumstein, Goodglass, and Tarter (1975) who have suggested, that the majority of subjects tend to maintain the same category of ear advantage on retest. However, one cannot discount the influence of factors that may be beyond the examiners control that may produce changes in ear advantage e.g. individual change in listening strategy.

The results of the present investigation also indicated that 20% of NS did not demonstrate REA. Blumstein, Goodglass and Tarter (1975), have reported that there is a subgroup of right-handed subjects who show a left ear preference. It was estimated by

Blumstein et al. that approximately 15% of normal subjects may show left-hemisphere dominance. A similar trend was noted in the present study when NEA and LEA was considered for NS. In attempting to explain the LEA in normal subjects, Blumstein et al. (1975) have suggested that many factors (response mode, attentional bias, subcortical asymmetry), in addition to cerebral functional asymmetry of language processing contribute to the side of ear preference in dichotic listening.

Teng's (1981) suggestion of reversed input ipsilateral dominance could also describe this result, especially for the LEA in some nonstutterers. The present researcher suggests that subcortical asymmetry, as well as attentional bias, may contribute to atypical ear advantage in for nonstutterers. However, the present researcher did not reinstruct client to change the listening strategy and therefore a conclusive statement to this effect cannot be made. It is also possible that the atypical ear advantage is a feature of the range of variability in performance for normal subjects.

Research studies stutterers/nonstutterers comparison

Comparisons of the results of the present study to previous studies is difficult because numerous variables, such as different subject selection criteria, response modes, stimuli, and statistical procedures tend to influence the interpretation of results. However, an attempt is made at comparing results, with noted limitations.

In the present study 40% of stutterers demonstrated REA, 40% NEA, and 20% LEA. 40% of stutterers, as opposed to 80% of nonstutterers demonstrated REA. This indicates a notable and significant difference between the groups with respect to ear advantages. More stutterers than nonstutterers demonstrated atypical ear advantages.

The results of the present study are in contrast to previous studies which reported *no differences* on dichotic measures between stutterers and control group subjects. The studies indicating no significant measures on dichotic tests included reports by Slorach and Noehr 1973, Sussmann and McNeilage (1975a), Dorman and Porter (1975), Pinsky and McAdam (1980), and Hannley and Dorman (1982). Pinsky and McAdam (1980) have acknowledged that it was quite possible that the relatively small sample size used in their study was not sufficient to show up subtle differences between the control and experimental groups. Sussman and MacNeilage (1975a) have used group mean data and concluded that stutterers had REA similar to normal subjects. However, application of the phi-coefficient indicated that only 55% of the stutterers obtained REA. Their conclusion was based on mean group performances of stutterers which masked individual atypical performance.

The findings of Dorman and Porter (1975) do not lend support to the findings of the present study, although their subjects included adult stutterers and normal controls chosen using criteria similar to the present study. Furthermore, stimuli used i.e. DCV's and the two-response mode required of their subjects was like that used in the present study. They reported no differences between the stutterers and the control group on the magnitude of REA, and it was concluded that their study did not offer support for the Orton-Travis theory. Libertrau and Daly (1981), who used subgroups of organic and functional stutterers with a school-age population, also found no significant differences between the groups with regard to ear advantage. The study used a small number of subjects, thus reducing the significance of results.

Noting the heterogeneous nature of the stuttering population, the report of conflicting findings regarding ear advantages is not unusual. A further point to consider is that it is quite possible that some stutterers do not display auditory processing differences, and this may, in fact be reflected in the findings of those studies reporting no significant differences. The present researcher has noted that in previous studies individual stutterers' performance may have differed, and having used group data analysis subtle differences were not revealed. If only the mean group data was considered in the present study in respect of mean performance scores for the right and left ears, the overall result for the S would in fact indicate an overall right ear advantage. Thus, it is only with the analysis of individual results, and the use of the phi-coefficient did the atypical nature of ear advantages become apparent for some stutterers.

It is evident that the results of the present study do not agree with the findings of some previous studies. The reasons for this may include :

i. The present investigation attempted to maintain the homogeneity of the S more so than was done in previous studies and differences were more easily apparent. Furthermore, since all S in the present study had family history of stuttering, there exists the possibility that these subjects had inherited neuromotor predisposition for stuttering (Jannsen et al., 1990). The central auditory processing performance may have been influenced by the neuromotor predisposition and hence, atypical performance was clearly apparent. Thus, the result in the present investigation appears more decisive, than in other studies where the subgroup emphasis and homogeneity for stutterers was not considered.

ii. A second aspect that could have contributed to the decisive nature of results obtained in the present study is the manner in which data were analysed. Individual and group data analysis were considered in the present study. Of importance is the choice of statistical procedure used in data analysis viz. phi coefficient (Blood & Blood, 1989b). This procedure allows one to consider magnitude and directional characteristics of ear advantage, as compared with other procedures which consider only the direction of ear advantage. The disadvantage of considering the direction of ear advantage without considering the magnitude is that the extent of the performance difference between the ears is neglected.

The findings of some previous studies (Rosenfield & Goodglass, 1980; Brady & Berson, 1975; Blood & Blood, 1989 a, b) tend to *support* the findings of the present study. The results of these studies, though varied, suggest that there may be a subgroup of stutterers who may display atypical central auditory processing. Rosenfield and Goodglass (1980) have reported findings similar to that of Brady and Berson (1975), and lend support to the findings of the present study. They used dichotic stimuli, and reported that whilst the analysis of ear advantage for group data did not reveal differences between the stutterers and control group subjects, it was observed that more individual stutterers than control subjects demonstrated deviant hemisphere lateralization. It was therefore concluded that there was a subgroup of stutterers who had anomalies in cerebral dominance and that this may be related to their speech disorder.

Hawver (1978), supported the contention of central auditory processing differences for stutterers as compared to nonstutterers using DCV stimuli. The results of the Hawver study could be seen as support for the present study, to the extent that it did demonstrate processing differences between stutterers and nonstutterers. It was suggested that stutterers performed significantly more poorly than nonstutterers on dichotic testing. Laterality computations were not evident in the Hawver study to highlight the nature of ear advantages. However, the examination of the results generated by the Hawver study indicated that whilst the stutterers as a group did obtain overall REA, the magnitude of the ear difference scores were not as great as for the control group. This perhaps suggests that the stutterers performed more atypically compared with the subjects in the control group.

A more recent study by Blood and Blood (1989a) using CVC stimuli has indicated a significant difference between stutterers and nonstutterers in terms of the magnitude of ear preference. The mean laterality quotient for the normal subjects was greater than for the stutterers suggesting greater performance differences between the right ear and left ear of normal subjects than stutterers. A similar finding was reported in the present study. Unlike the findings of the present study, there were no significant differences between the groups with respect to the number of right-ear -preferences, left-ear-preferences, and no ear preferences. This may be attributed to the differences in the nature the stimuli (CVC stimuli were used). It is quite possible that because the stimuli in the Blood and Blood study (1989a) were more meaningful to that used in the present study, differences were noted.

A further experiment by Blood and Blood (1989b) using a group of ten stutterers and nonstutterers indicated findings similar to the present study. On application of the phi-coefficient, the majority of the normal control subjects (70%) demonstrated REA, whilst the majority of the stutterers (70%) demonstrated NEA, and LEA. A similar trend was evident in this study, possibly, because the same reputed and more sensitive statistical procedure was used to assess ear advantage (Kuhn, 1973).

Further evidence for stutterer/nonstutterer differences can be marshalled from studies that have used different dichotic stimuli such as dichotic digits and words. Research by Somers, Brady and Moore (1975), Newton, Blood and Blood (1986) and Curry and Gregory(1969), supported the contention of differences between stutterers and nonstutterers in processing dichotic stimuli. In addition, the research findings conducted with children (Cimorrel-Strong & Frick, 1983; Blood & Blood, 1984a; Blood, 1985) also lend support to the contention that a subgroup of stutterers demonstrate atypical processing on dichotic tasks.

Tsunoda and Moriyama (1972), also investigated cerebral dominance in stutterers by using Tsunoda's cerebral dominance test (1968).

Whilst 79.3% of the control subjects displayed dominance for consonant vowel sound in the right ear, this pattern was only evident for 38.6% of stutterers. Tsunoda and Moriyama (1972), suggested that there was a subgroup of stutterers for whom stuttering may be due to abnormal cortical function. The result of the study could be viewed as supportive of the results obtained in the present investigation.

Speculation arising from S/NS differences on the DCV Test

It is evident from the results presented in Table 3 that all stutterers in the present study did not perform in the same manner with respect to ear advantages. Also, the ear advantages of a subgroup stutterers were more atypical than the NS. For the purposes of this discussion a subgroup model pertaining to ear advantage for S would be used. i.e. explanations accounting for the findings will be presented as per subgroup determined by ear advantage. The groups include viz. REA, LEA, AND NEA.

i. *Right ear advantage*

It was evident from the results of this study that there was a subgroup of stutterers who displayed REA. This result may be interpreted in three ways.

Firstly, it would be plausible to consider that these stutterers performed much the same as NS. i.e there is no evidence in these stutterers for atypical hemispheric lateralization (as determined from the results of this test). It is possible that their speech dysfluency may not be related to atypical cerebral dominance. Noting the popular view of stuttering as heterogeneous disorder, it is possible that the dysfluency in these subjects was generated by other processes. The theories which suggest neural mechanisms other than that of auditory processing, e.g. psychological and learning theories, may be considered as alternative explanations for explaining REA in this group of stutterers.

Secondly, the present researcher suggests that perhaps it is not at this level (cerebral) of processing that differences occur between stutterers and nonstutterers. Suggestions of a brainstem level dysfunction are also possible (Hageman & Greene, 1989; Stager, 1990). Those stutterers who did not generate atypical performance on this test may have generated atypical performances at other levels of processing, such as that of the brainstem. A discussion of the result to this effect appears later in the chapter (p. 256).

Thirdly, Peters and Guitar (1991), have suggested that stuttering may be generated by speech and language being localized in an under-developed left hemisphere. It was speculated that the speech and language function for stutterers was localized in the left hemisphere (as in nonstutterers) but that its reduced capacity for handling speech and language may be related to stuttering. In this instance, the poor capacity to process auditory information is likely to be reflected in poorer accuracy scores of stutterers who have REA. Whilst this was not a general performance trend for most stutterers in the present investigation, it was evident for some stutterers viz. SM10, SM11, SF7, SF12 (Appendix O). The mean performance scores for these stutterers were below the mean for the S and NS. This finding concurs with that suggested by Hawver, (1978) who reported that for the group of stutterers investigated, accuracy scores of stutterers were poorer than for normal subjects.

ii *Atypical performances : NEA and LEA*

The NEA and the LEA performances may be regard as atypical when one considers that the norm is the REA (Blood & Blood, 1989b). The theoretical perspectives best suited to describe the atypical ear advantages of some stutterers are as follows :

a. *Orton-Travis Thesis.*

For the present study, NEA could be viewed as indicative of bilateral cerebral processing. The theoretical explanation offered by Orton-Travis could apply here, as the model suggests that the bilateral control of the speech mechanisms produced interhemispheric competition that manifested in stuttering.

The NEA of stutterers may also be explained by a bilateral model for neurolinguistic processing (Rastatter & Dell, 1987a). This explanation could be applied to the findings of the present study which indicate that 40% of stutterers obtained NEA. The explanation offered is that both hemispheres participate simultaneously in the processing of auditory information which is supposedly compromised for stutterers. Due to bilateral cerebral processing the speech motor programmer may receive conflicting information from each hemisphere. Since this information may be temporally out-of-phase, a processing problem is likely to occur. As a result aberrant information is generated to the motor system, and hence, stuttering.

In an attempt to account for the LEA, the issue of right hemisphere processing is considered for stutterers, because LEA implies right hemisphere dominance for auditory processing (Moore & Haynes, 1980).

b. *Right hemispheric processing and stuttering*

In attempting to integrate findings related to the issue of cerebral dominance in stutterers and nonstutterers, Moore and Haynes (1980), have postulated that some stutterers may be using the right hemisphere more than the left hemisphere for processing language, hence the LEA. As described previously, the right hemisphere which has been regarded as a nonsegmental processor, is not ideally suited to language perception and motor programming functions. Therefore, processing in the right hemisphere may be atypical and may disrupt the temporal mechanism vital for perceptual and motor functions. It is likely that the disrupted temporal process may be related to the generation of dysfluency.

c. *Stuttering as a disorder of timing*

Kent (1984), modified the explanation suggested by Moore and Haynes (1980). In terms of anomalous hemispheric asymmetries, Kent (1984), suggests that both hemispheres are capable of processing in the time domain, but appear to differ in their "preferred temporal ranges". The left hemisphere is capable of finer temporal resolution than the right (Hammond, 1982; Kent, 1984). The nondominant hemisphere may contribute to the processing of information distributed over longer time intervals. LEA and NEA for some stutterers in the present investigation may be a reflection of atypical cerebral processing of auditory information. Kent (1984), suggests that since speech perception and production share a single central mechanism, a disruption in time-based processing of the incoming signal negatively influences the temporal motor speech output, hence, generating stuttering.

5.1.2.2. Male/female comparisons

Nonstutterers

Accuracy scores and double correct scores

The combined accuracy scores as reflected in Table 1 for the NSM and NSF groups depict the following trend. The NSM (61.22%) performed better than the NSF 60.42%, but the performance differences were not significant (p>0.05) as reflected in Table 2. A similar result was obtained for the double correct responses. It was concluded that there were no significant performance differences between the males and females nonstutterers. This suggested that males and females were able to process dichotic CVs with equal accuracy.

Ear advantage

The majority of the male and female nonstutterers obtained the REA (80%). The only difference observed between males and females was that one male subject demonstrated an LEA, whereas none of the females demonstrated this. With respect the NEA, more females than males obtained a NEA. These differences are subtle. Similar findings were reported in the literature. Hiscock and MacKay (1985), investigated the performances of adult male and female subjects on dichotic digit and CV stimuli, and reported that there were no significant differences between male and females, although the males did perform better than the females. It was concluded that the present study did not provide support to suggest that speech/language is differentially lateralized in male and female subjects. However, McGlone (1980), in a comprehensive review of sex differences in human brain asymmetry suggested that some evidence derived from dichotic studies indicate that the male brain may be more lateralized than the female brain, but concluded that the patterns of male and female brain asymmetry are more similar than they are different. This study does not support the contention of sex differences for accuracy of performance or ear advantages for NS on the DCV.

<u>*Stutterers*</u>

Accuracy and double correct scores

The combined accuracy scores for the left and right ears indicated that there were no significant performance ($p>0.05$) differences between SM and SF groups as reflected on Table 2. A similar result was observed for the double correct scores. Thus, there appeared to be no differences between male and female stutterers with regard to accuracy of performance on the DCV test.

Ear advantage

A comparison of the SM and the SF groups indicated that while ear advantage trends were generally similar for both groups, subtle differences existed as reflected in Figure 4. Perhaps the most evident feature was that seven (46.6%) female stutterers demonstrated the REA as compared with five (33.3%) male stutterers. Males and females presented with the same number of LEA (20%) whilst for the male stutterers presented more NEAs (46.6%) than the female stutterers (20%). More male stutterers (66.6%) than females stutterers (46.6%) demonstrated atypical ear advantages.

A survey of available literature has indicated that little research has been conducted in this area. However, a recent study by Blood and Blood (1989a) compared male and female stutterers and nonstutterers on the Dichotic Word Test. For the stuttering group it was concluded that there were no significant ($p>0.05$) sex differences with respect to ear advantage. 33% of female stutterers and 28 % of male stutterers obtained atypical ear advantages. The results are in contrast to the present study which found that more male stutterers than female stutterers performed atypically with respect to ear advantage. However, the sex difference in the Blood and Blood study was marginal, as in the present study and hence, the sex differences in both studies could be described as subtle. The higher percentage of male and female stutterers obtaining atypical ear advantages in the present investigation is due to the application of the phi-coefficient. A further factor that could have attributed to the differences between the Blood and Blood (1989a) and the present study, is that the Blood and Blood study (1989a) dichotic words (CVC) as opposed to CV stimuli used in this study. Although similar in construction, the stimuli vary to the extent that the CVC stimuli are more meaningful whilst the CVs are not. It is possible that greater ear advantage differences are generated when using meaningless stimuli.

Speculation for subtle ear advantage differences between male and female stutterers

The results in this investigation indicated that the performance for the male and the female stutterers were more atypical than NS. Statistical analysis ($X^2=1.99$ df=1, p 0.05) indicated no significant differences between male and female stutterers with respect to ear advantage. However, subtle differences cannot be ignored.

a. It is possible that both male and female stutterers may have auditory processing strategies that are atypical, and are linked to stuttering. The females who stutter may have this inherent difference which predisposes them to speech dysfluency. This is a tentative suggestion. In terms of accounting for the sex ratio for stuttering it is possible that the male, from a developmental perspective is more prone to processing inadequacies in the developmental years, Flor-Henry (1983). Though there is much controversy about early hemispheric specialization in males and females, Buffery and Gray (1972), suggested that left hemispheric specialization occurs earlier in females than males. Based on this suggestion it is speculated that the males, to a greater extent may be disadvantaged with respect to hemispheric specialization, and therefore vulnerable to dysfluency. Blood, Blood and Hood (1987) state that younger male stutterers presented with less REAs than did the control group subjects.

Females on the other hand appear to mature earlier, (Flor-Henry 1983), and may be less influenced by the lack of hemispheric specialization. However, it is possible that there is a subgroup of females who develop atypical processing strategies, thus making them vulnerable to stuttering. Since, a larger portion of males are affected in the developmental years, it is possible that this subgroup retains the atypical laterality which may be linked to stuttering.

b. Blood and Blood (1989a), commented that the female stutterers who presented with a more severe form of stuttering tended to demonstrate atypical performances on the dichotic task. Whilst the issue of severity was not considered in this study, the researcher observed that the females generally presented with a milder form of stuttering. It is possible that this contributed to their performances being less atypical, than for the males who presented with more severe overt stuttering behaviour.

c. Kent (1984), further elaborated on the male/female processing differences, and suggested that males are less adept than females at auditory sequencing tasks involving fine motor control. Males may be at risk because testosterone slows the growth of the left hemisphere, which is more suited than the right hemisphere for processing rapid auditory patterns and complex motor sequences. Whilst this may explain the male predisposition to stuttering, it does not account for the female disposition.

It appears that similarities in accuracy scores and ear advantage, for male and female stutterers exist. The female stutterers have less atypical ear advantages compared to the male stutterers but the difference is subtle. This performance difference could be related to the sex ratio, but further evidence is required to determine if this is a stable trend.

SUMMARY

Thus, on the DCV test significant differences appeared to emerge with respect to ear advantages between S and NS. No significant performance differences were noted on accuracy and double correct scores between S and NS.

No significant sex differences with respect of ear advantage and accuracy scores were observed for NS. For S, more males than females appeared to display atypical ear advantage.

5.2.1 RESULTS : STAGGERED SPONDAIC WORD TEST

Description of presentation format.

Table 4 : Summary statistics are presented for error scores and percentage correct obtained by S and NS and males and females within each group. Error scores are presented for ears (R & L) and conditions which include the right noncompeting (RNC), right competing (RC), left competing (LC) and left noncompeting condition (LNC).

Table 5 : Analysis of variance of errors scores for main-groups (S and NS), gender (M and F) and ears (RL) are presented. The significance of performance differences between S and NS, and males and females within each group, as well as interactions are derived from the table.

Table 6 : A summary table of frequency distribution of errors scores is presented for S and NS and males and females (within each group).

Figure 5 : The figure provides an illustration of the nature of error patterns demonstrated by S and NS on the left and right competing and noncompeting conditions.

Table 7 : A frequency distribution of reversals obtained for S, NS and males and females within each group is presented.

Table 8 : Analysis of variance of reversals for maingroups (S and NS), and gender (M and F), is presented. The significance of performance differences between S and NS, males and females within each group is derived.

SSW TEST RESULTS

The analysis of results for the SSW are presented in two categories which are considered in central auditory processing evaluation on the SSW test (Katz, 1986; Keith, 1983).

a. SSW scores :

Error scores (as defined by Katz, 1986) are analyzed and *percentage correct* scores are presented and commented upon.

b. Response bias

The response bias considered include ear effects, order effects and reversals.

NB: Errors are defined (Katz, 1986) as omissions of target words in the test, linguistic and non-linguistic substitution for target words, and a voluntary no response (subject indicates that he was unable to process the target word). Error scores refer to the number of errors.

Table 4 : <u>Summary statistics for error scores (% error scores & %correct scores) for NS and S, males and females within each group for R and L and competing conditions on the SSW test</u>.

	NS		S		EAR R NS		EAR R S		EAR L NS		EAR L S	
Error (NS; S)	43		87		17		44		26		43	
Mean	1.4		2.9		0.56		1.46		0.87		1.43	
Std. Dev.	0.84		1.6		0.76		1.52		0.96		1.75	
	M	F	M	F	M	F	M	F	M	F	M	F
Error (M; F)	23	20	48	39	9	8	23	21	14	12	25	18
Mean	1.53	1.3	3.2	2.6	0.6	0.53	1.53	1.4	0.93	0.8	1.67	1.2
S.D.	0.94	0.77	1.82	1.64	0.88	0.62	1.63	1.35	1	0.91	2.05	1.33
Range	0-5	0-3	0-11	0-8	0-2	0-1	0-4	0-4	0-2	0-2	0-7	0-3
% age Correct	99	99.13	97.73	98.33								
	99.07		98.03									
% age Error	1	0.86	2.27	1.6								
	0.93		1.9									

	CONDITION RNC NS		CONDITION RNC S		CONDITION RC NS		CONDITION RC S	
Error (NS; S)	3		2		14		42	
Mean	0.1		0.07		0.47		1.4	
	M	F	M	F	M	F	M	F
Error (M; F)	1	2	1	1	8	6	22	20
Mean	0.07	0.13	0.07	0.07	0.53	0.4	1.47	1.3
S.D.	0.25	0.34	0.25	0.25	0.72	1	1.63	1.35
Range	0-1	0-1	0-1	0-1	0-1	0-1	0-4	0-4

cont/...

	CONDITION							
	LC				LNC			
	NS		S		NS		S	
Error (NS; S)	23		38		3		5	
Mean	0.77		1.27		0.1		1.17	
	M	F	M	F	M	F	M	F
Error (M; F)	12	11	22	16	2	1	3	2
Mean	0.8	0.73	1.46	0.06	0.13	0.07	0.2	0.13
S.D.	0.75	0.85	1.78	1.12	0.25	0.34	0.4	0.34
Range	0-2	0-2	0-7	0-3	0-1	0-1	0-1	0-1

Table 4 reflects error scores for S and NS on the SSW test. Male/female error scores within each group have also been presented. Percentage correct scores are also presented.

The following trends are noted.

<u>STUTTERER/NONSTUTTER COMPARISONS</u>

- S obtained a greater number of total errors (87) compared with NS (43).

- NS obtained a greater number of errors on the left (26) than the right (17) ear. S obtained a similar number of errors on right (44) and left (43) ears.

- 88.5% of errors were made on the competing condition (for S and NS).

- The greatest difference in error scores between S and NS was observed on the RC condition.

- The percentage error for NS is less than 1% and for S is 1.9% and the percentage correct for NS is 99.07% whilst for S it is 98.03%. Thus, overall performance for both groups were high, implying subtle nature of performance differences between S and NS.

MALE/FEMALE COMPARISON

- Male and female stutterers and nonstutterers within each group performed similarly across ears and conditions. Male stutterers however, obtained a greater number of errors (48) than the female stutterers (39).
- The differences on error score for male S and female S were observed on the LC. Similar number of errors were noted on the RC.

Table 5 : Summary table of 2 x 2 x 2 (Maingroups x Gender x Ears) analysis of variance with repeated measures on the last factor for the SSW test

BETWEEN SUBJECTS

SOURCE	F	P
Maingroups (S; NS)	6.471	0.014*
Genders (M & F)	0.533	0.468
Maingroup x Gender	0.059	0.809

WITHIN SUBJECTS

SOURCE	F	P
Ears (R; L)	24.159	0.000*
Ears x Maingroup	5.521	0.001*
Ears x Gender	0.280	0.839
Ears x Maingroup x Gender	0.266	0.850

* $p<0.05$

The following information was derived from Table 5 :

STUTTERERS/NONSTUTTERS - COMPARISON :

- A significant difference in error scores was noted between S and NS.
- Within subject analysis :

  Significant differences were obtained between errors scores on the left and right ears for S and NS combined. The ear x maingroup interaction was also significant suggesting that the L/R ear difference was generated by one of the main-groups. Right and left ear error scores indicate that the NS generated the significant ear differences. All other interactions were nonsignificant.

MALE/FEMALE COMPARISON

- No significant male/female difference in error scores were noted within each group. Interactions between maingroups and gender were nonsignificant.

Table 6 : Frequency distribution for error scores for S and NS & males and females within each group on the SSW test

NO. OF ERRORS	NS	M	F		S	M	F
0	9	4	5		10	5	5
1	7	4	3		4	2	2
2	8	4	4		1	0	1
3	5	2	3		2	0	2
4	0	0	0		3	2	1
5	1	1	0		5	3	2
6	0	0	0		2	2	0
>6	0	0	0		3	1	2

(number of subjects corresponding to number of error scores obtained is presented).

STUTTERER/NONSTUTTERER COMPARISONS

- The results reflected indicate that 24 NS (80%) scored two errors or less. For S, 15 (50%) scores two errors or less.
- The table also indicates that there was a subgroup of stutterers who obtained less than two errors. It is evident that not all of the stutterers obtained similar error scores.

MALE/FEMALE COMPARISONS

- Males and females within each group appear to have performed similarly as indicated in Table 6.
- Males stutterers however, obtained a greater number of errors compared with females stutterers.

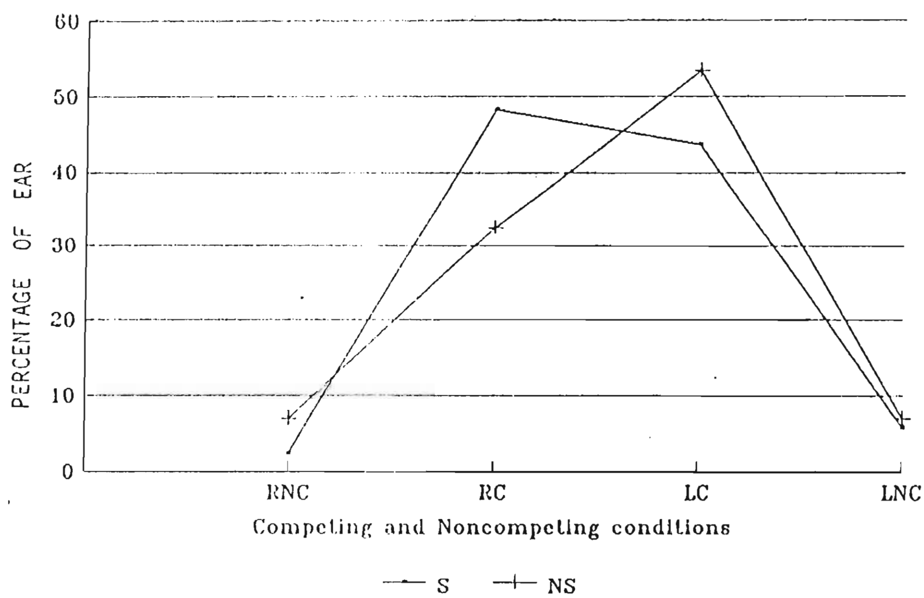

Figure 5 : Percentage of error on competing and noncompeting conditions for stutterers and nonstutterers on the SSW test.

Response Bias

Three aspects were considered : viz. ear effect, order effect and reversals. Analysis of variance indicated no significant

($p<0.05$) ear and order effect for S and NS and for male and female subjects within each group. Therefore, only reversals were considered and these results are presented.

Table 7 : <u>Frequency distribution for reversals for S and NS and males and females within each group</u>

NO. OF REVERSALS	NS	M	F		S	M	F
0	18	8	10		11	6	5
1	7	5	2		5	2	3
2	4	1	3		5	2	3
3	1	1	0		2	1	1
> 4	0	0	0		7	4	3

STUTTERERS/NONSTUTTERERS COMPARISON

- The total number of reversals for NS was 18 whilst for S it was 83.

- 86.6% of NS had one reversal or less. The highest number of reversals for NS was three.

- 53.3% of S had one reversal or less, and 46.6% of S obtained four or more reversals.

MALE/FEMALE COMPARISON

- Males and females NS performed similarly, with males obtaining a total of eight reversals and females a total of ten.
- For the S the males had a higher number of reversals (47) than the females (36).

Table 8 : <u>Summary table at 2 x 2 (Maingroup x Gender) for reversals on the SSW Test</u>

SOURCE	F-RATIO	P
Maingroups (S; NS)	14.394	0.000*
Genders (M & F)	0.010	0.921
Maingroup x Gender	0.010	0.921

STUTTERERS/NONSTUTTERERS COMPARISON

- A significant difference was obtained in the number of reversals ($p<0.05$) between S and NS.

MALE/FEMALE COMPARISONS

- No significant difference ($p>0.05$) was noted between the number of reversals obtained for males and females within each group.

PASS/FAIL CRITERIA AND INTERPRETATION

In order in determine pass/fail criteria on the SSW test the following method was adopted. Error scores were converted to <u>C-SSW scores</u> for all subjects in the study using the method suggested by Katz (1986). The raw data appear in Appendix Q.

The C-SSW scores obtained for NS was compared to the norms provided by Katz (1986). All of the nonstutterers except five scored within normal limits. The researcher observed that the scores for the NS closely resembled the normative data (Katz,1986). It was therefore decided that since NS norms of the present study correlated closely with that provided by Katz (1986), the results of the S could also be compared with that of Katz (1986) to determine pass/fail rate. Furthermore, research with normal adult subjects (Arnst, 1981) has indicated that the norms provided by Katz (1986) are realistic and applicable to normal adults thus providing the motivation to use the Katz norm in the present study.

NB : Norms are presented for each competing condition (Katz, 1986).

For a subjects to pass the SSW test, C-SSW scores were required to be within normal limits for each condition and, one or less reversals were required (Katz, 1986).

For a subject to fail the SSW test, the C-SSW scores were required to be outside of normal limits for one or more conditions, and/or, the subject was to obtain more than one reversal. Using these criteria, 16 stutterers were regarded as having failed the SSW test (8 male and 8 females). Fourteen stutterers passed the test (7 males and 7 females). Three male nonstutterers failed the test and 12 passed, 13 female nonstutterers passed the test and two failed.

5.2.2. DISCUSSION : STAGGERED SPONDAIC WORD TEST

5.2.2.1. Stutterers/Nonstutterers comparison

i. *Analysis of error scores*

Nonstutterers

The analysis of error scores for NS reflected in Table 4 indicates that the mean number of errors for the group is 1.4. This suggests that as a group, the NS made few errors on the SSW test. This is further emphasized by the percentage correct score (99.07%) as seen in Table 4. No nonstutterer scored more than five errors, and the standard deviation of less than one suggests high accuracy and minimal variability in performance for the NS. The results obtained in this study compares favourably with that of Arnst (1981); Newton, Blood, and Blood (1986); and Hawver (1978). The general trend observed with normal adult subjects in previous studies has indicated that the mean number of errors is in the range of 0.8 to 1.45. The results of the present study are in agreement with previous observations that the test is simple for subjects who have no history of central auditory dysfunction and therefore, few errors are made.

The analysis of the number of errors for the right and the left ears for NS revealed that the left ear had more error than the right ear. The analysis of variance for error scores (Table 5) indicated that significant differences ($p<0.05$) for error scores between the ears. The interaction effect as reflected in Table 5 (ears x groups) suggests that this difference was due generated by either the S or NS. The analysis of error scores on Table 4 indicates that the difference was generated by the error scores for the NS. i.e. left and right ears performed significantly ($p<0.05$) differently. The mean number of errors in the left ear (0.87), is higher than in the right (0.56).

Whilst the differences between the ears were significant for the NS group as a whole, the differences between the right and the left ears were small for individual nonstutterers. No more than two errors between the left and right ears were observed for individual nonstutterers. Brunt (1968), cited in Arnst, (1981) suggests that substantial ear difference scores for individual subjects, is usually not evident when stimuli are familiar, highly associated and not completely overlapped as in the SSW test. In the present study, significant error score differences between ears are observed for the group, rather than individual subjects. This could be reflecting that the group as a whole demonstrate right ear dominance. (Brunt & Goetzinger cited in Katz & Arnst, 1982). This trend was also observed for normal subjects by Hall and Jerger (1978).

The analysis of results for NS also indicated that a greater number of errors (Table 4) were made on competing conditions of the test. This is due to the competing portions of the test being more stressful, and hence, more errors are generated. Katz, 1986; Arnst, 1981). However, it should be noted that although most normal adult listeners make more errors on the competing conditions they are usually able to respond correctly on most competing and noncompeting conditions.

ii. *Response bias*

Reversals: The mean number of reversals for NS was 0.6. This was comparable to the mean number of reversals reported by Katz (1986), and Arnst (1981). It has been suggested that for the normal adult, one reversal is considered to be the norm (Katz 1986). The highest number of reversals for an individual nonstutterers was 3 and 86.6% of nonstutterers in the present investigation had one reversal or less. Thus, most nonstutterers did not change the order in which the stimuli were presented. This possibly indicates good temporal sequencing ability. Five nonstutterers scored outside the norm for reversals. Thus, the majority i.e. 25/30 (83.3%) nonstutterers scored within normal limits.

The NS performance on the SSW test appeared to be normal when compared to the literature (Katz, 1986; Arnst, 1981).

Stutterers/Nonstutterers comparison

i. *Error scores*

The analysis of variance (error scores) reflected in Table 5 indicates that in the present study, significant differences existed between S and NS ($p<0.05$). Whilst error score differences between S and NS are statistically significant, the overall percentage correct and percentage error highlights the subtle nature of the differences. Both groups performed with a high degree of accuracy on the SSW test.

The analysis of results indicated in Table 6 suggests that not all of the stutterers performed similarly i.e. a range of error scores was observed for the group. A similar number of stutterers and nonstutterers obtained no errors. Whilst 80% of NS scored four errors or less, this trend was observed for 50% of S. It appears that the significant difference between S and NS was not contributed by all stutterers, but rather by a subgroup of stutterers who performed poorly.

For S the total number of errors in right ear is very similar to the left ear. This is in contrast to the results obtained for NS who as a group, demonstrated a slight REA i.e. a greater number of errors were obtained on the left ear whereas for the S it could be described as NEA (both ears obtained a similar number of errors). S like NS, made the greatest number of errors on the competing conditions of the test as reflected in Table 4. The overall nature of error patterns for the groups is highlighted in

Figure 5. Whilst the pattern for NS indicates a slightly greater percentage of errors on the left competing condition compared with the right competing condition, the pattern for S indicates a similar percentage of errors on the left and right competing conditions.

Analysis of error scores across conditions (Table 4) indicated the greatest performance difference between S and NS was observed on the right competing condition. S scored a greater number of errors (42) on the right competing condition compared with the NS who had 14 errors. This difference could be explained in the light of error scores obtained for NS. In this group more errors were obtained on left competing condition than right competing condition typifying the REA that is usually observed for the normal population. For the S on the other hand , similar numbers of errors were noted on the right competing condition and left competing condition.

In summary, S obtained significantly more errors than NS on the SSW test. NS made more errors on the left ear than the right ear especially on the competing conditions. The S obtained errors a similar number of errors in the left and right ears. The greatest number of errors were made on the competing conditions for both groups.

Response bias

Reversals : S obtained a significantly ($p<0.05$) greater number of reversals than the NS ($P<0.05$). The mean reversals for S was 5.53, whilst for NS it was 0.6. Examination of results (Table 6) indicated that whilst 86.5% of NS had one reversal or less, for S this trend was observed for only 53.3% of subjects. When compared to the norms provided by Katz (1986), 46.6% of the subjects in the S group would fall outside of normal limits. It should be noted that criteria provided by Katz (1986) is stringent. For NS, 14.5% would fall outside of normal limits. This highlights the observation that for stutterers there was variability in performance evident in the range of reversals reflected in Table 7. The highest number of reversals obtained for S was 11 whereas for the NS, the highest number of reversals obtained was three.

Previous research stutterers and nonstutterers on the SSW test

A review of available literature has indicated that whilst some research supported the findings of the present study, others did not. Hall and Jerger (1978), used the SSW test as part of a tes battery and reported (based on percentage correct scores) that the control group had a 2% REA . This trend was not observed for the stutterers who demonstrated NEA. Similar observations were noted in the present study. The presentation of Hall and Jerger's (1978) results was limited to percentage correct scores. A comment on response bias is not evident.

Hawver (1978), also investigated the performances of stutterers and control subjects on the SSW test, and found that the stutterers made significantly greater number of errors on the competing portions of the test compared with the control group. Further support for stutterer/nonstutterer differences were noted in the study by Blood and Blood (1986), which indicated that a subgroup of stutterers performed below the norm on the SSW, therefore, suggesting some type of auditory processing problem. However the study conducted on children and cannot be directly related to the present findings.

Newton, Blood and Blood (1986) have also investigated the performance of stutterers and a control group on the SSW test amongst other tests. The results indicated no significant differences on error scores and on reversals. The results were contrary to that of previous researchers. However,a small sample size was a limitation. Newton et al., have suggested that the SSW test was perhaps not a sensitive measure in identifying central auditory processing problems in stutterers. This is contrary to the findings of the present study which found differences on error scores and reversals.

A survey of literature has indicated that aside from the Newton et al., study, none of the other studies examined reversals in stutterers. Arnst (1981), commented on reversals in the normal population and suggested that whilst most normal subjects display few reversals, some normal subjects may display an unusually high number of reversals. In the normal population this may be representing a shift in listening strategy by that individual. Upon reinstruction, the reversals are eliminated. It is possible that the high number of reversals obtained by some stutterers in the present study could be reflecting a shift in individual listening strategy. Subjects were not reinstructed to change listening strategy in the present study, and therefore a conclusive comment cannot be made as to whether the increased number of reversals for the stutterers was due to a shift in listening strategy or not.

Another interpretation for the increased reversal phenomena is related to a specific area of central nervous system dysfunction. Arnst (1981) reports that the central fissure area or the "reversal strip" is implicated. Lucker (1981) cited in Katz, (1986) reported that children who displayed poor motor planning demonstrate a higher number of reversals. This may, in some way, be applied to stutterers since poor sensorimotor integration as part of a total mechanism responsible for stuttering has been implicated (Kent, 1984). The present researcher is of the opinion that this is a plausible explanation, especially because it considers sensory motor aspects that are reportedly compromised for stutterers (Sussman & McNeilage, 1975a & b). In addition, the present researcher is of the opinion that the ability to process temporal sequences of information maybe compromised for stutterers and this may be contributed to by atypical hemispheric processing strategies. It is possible that compromised temporal sequencing ability may be reflecting the compromised temporal programming pattern suggested by Kent (1984).

Interpretation/Explanation

The results indicated that there was a significant difference in error scores between S and NS. The greatest difference was observed on the right competing condition. Based on these observations two possible explanations are offered.

a. The results, may relate to the atypical cerebral dominance hypothesis. If the results of S are considered, there is evidence to suggest that the typical right ear advantage is not observed to the degree in which it operates in the NS population.

The result could be explained in terms of the Orton-Travis theory which has suggested that stutterers have incomplete cerebral dominance for language processes. This theory could possibly account for some stutterers who performed atypically and obtained higher than usual errors on the right competing condition than the left competing condition. This processing strategy may reflect incomplete dominance of the left hemisphere. The right hemisphere processing theory and bilateral cerebral representation (Moore & Haynes, 1980; Rastatter & Dell 1987a) may also be used to explain the results obtained. Some stutterers made errors on the right and left competing conditions which may indicate bilateral representation for language, whereas fewer errors on the left competing condition may imply more efficient right hemispheric processing strategy used by some stutterers.

b. Interference theory : Hawver (1978), has suggested that the types of errors observed on the SSW test may be described as a continuum of interference. The classification of errors used by Hawver (1978), is different to that used in the present study as a result of the reclassification/description of errors offered in the more recent manual Katz (1986). According to Hawver (1978), total interference in auditory processing is said to occur when repetition occurs (reclassified as linguistic substitution). In this instance, none of the cues of the blocked words were perceived, and therefore it was replaced by a word perceived correctly. For the omission errors, the cues may have been perceived, but not sufficiently to form another word. A third type of error is where some of the cues of the word are interfered with, and a word similar to the correct stimuli is perceived. In this instance what appears to have occurred is that the dichotically presented stimuli may have been separated and held for analysis and subsequent recognition. However, in some instances the separation may not be complete and thereby interfering with the proper processing of stimuli.

In attempting to relate the interference theory to the processes of the central auditory nervous system, Hawver (1978), has suggested that the central auditory nervous transmission times for the stimuli may be different for stutterers and nonstutterers. It is possible that the processing system may require these two stimuli to arrive at the processing centre at a particular time relation to each other, for complete separate processing. If one stimulus takes longer to arrive than is required for optimal processing then its phonetic information may not be separated adequately from the phonetic information of the other stimuli. The cues from both might interact and interfere with proper processing, of one or both stimuli. For S in the present study, interference with processing in the right and left ears was perhaps apparent. It is possible that since the, right hemisphere processing is favoured for some stutterers, the left ear (right hemisphere) processing was not interfered with to the extent that right ear (left hemisphere) processing was compromised. For other stutterers however, the processing in the right and left ears were disrupted and this result could be related to the bilatral cerebral representation model (Rastaller & Dell, 1987a). Since neither ear is dominant, the processing in either ear could be interfered with thereby generating errors in the right and left ears. Thus, the interference theory in combination with theories suggesting right hemisphere processing and bilateral processing best explain the present result for some stutterers on the SSW test.

c. Response bias interpretation : Due to the limited focus on response bias in stuttering literature, an interpretation as to how differences in response bias may be related to stuttering is not formulated. Perhaps, it has yet to be established whether increased number of reversals are a stable feature of stutterers performance or not. The explanations offered by the present researcher suggests that possibly processing at the level of the central fissure is compromised and this is interferes with motor-speech generation. At this stage the researcher is unable to speculate as to how this difficulty (response bias) may be related to cerebral dominance and other related explanations. The present researcher is of the opinion that it may also be related to poor temporal sequencing ability on the central auditory nervous system for some stutterers.

5.2.2.2. <u>Male/female comparisons</u>

Nonstutterers

i. Error scores : The total error scores reflected in Table 4 indicate whilst the males scored more errors than the females. The difference however was not significant $(p>0.05)$

as reflected in Table 5. These results suggest that male and female performance differences are not evident on this measure.

ii Response bias :
Reversals : The males obtained a greater number of reversals compared with females, but the difference was not significant as reflected in Table 8. It can thus be concluded that no significant sex differences were observed for male and female nonstutterers on the SSW test in the present investigation.

Stutterers

i. Error scores : Male stutterers displayed a greater number of errors compared with the females as reflected in Table 4. However, the difference was not significant ($p>0.05$) as indicated in Table 5. The greatest difference between males and females occurred on the left competing condition.

ii. Response bias : Male stutterers displayed a greater number of reversals compared with females stutterers. The result for males wass inflated due to two male subjects having in excess of ten reversals. It could therefore, be stated that no significant differences (error scores and reversals) were noted between male and female subjects within each group.

Comparison with previous research

There is a paucity of research relating to sex differences on the SSW test. McCoy, Butler, and Broekhoff cited in Katz 1982, indicated that for young adults there were no significant sex differences on the SSW test. A similar observation was made in the present study for the NS. For stutterers, it appeared that male performance was poorer than that of the female. The differences are subtle and are not statistically significant.

The greater number of errors obtained by the male stutterers could be reflecting more atypical central auditory processing difficulties compared with female stutterers. Amongst the male subjects individual performance needs to be commented on. The results indicated that the greatest number of errors were made by SM11. Also, six subjects in this group obtained five or more errors. Four female subjects demonstrated a similar trend in performance. This suggests that there was a subgroup of male stutterers who obtained more errors than is usually observed on the SSW test.

Whilst male/female differences for S were evident, it cannot be concluded that these differences were related to the sex of the subject per se. It is possible that other factors such as severity of stuttering , individual processing differences may have contributed to the observed differences. Further research is needed to determine whether sex differences for stutterers are a significant feature on the SSW test. These findings should be viewed as preliminary. It is possible that the SSW is not designed to highlight central auditory processing differences based on the sex of the individual per se.

A greater number of reversals obtained by male subjects could be reflecting a shift in individual listening strategy. It is possible that this result would have been different upon reinstruction. Thus, a conclusive statement in this regard cannot be made.

It thus appears that male stutterers performance were slightly poorer compared to female stutterers performance on the SSW test. The subtle nature of the difference must be emphasized. Further research with the SSW test is needed to make a more conclusive statement about central auditory processing and sex differences, as they relate to stuttering.

SUMMARY

The results on the SSW test indicated significant differences between S and NS on error scores and reversals. However, the overall percentage correct highlights the subtle nature of the differences observed. No significant performance differences were noted between males and females, although male performance was poorer than that of females (for stutterers). The performance of stutterers was varied.

5.3.1 RESULTS : COMPETING SENTENCES TEST

The results are presented as follows :

Table 9 : Summary statistics of CST scores for NS and S and males and females within each group are reflected.

Table 10 : The analysis of variance depicting statistical significance of performance differences between NS & S and males and females are presented.

Figure 6 : Individual performance scores (right and left ears) for each nonstutterers for males and females are plotted.

Figure 7 : Individual performance scores (right and left ears) for each stutterer, for males and females, are plotted.

The figures allow for analysis of individual performances and group performance for S and NS and males and female within each group as they relate to the norm of the CST.

NB : Performance scores are reflected as percent correct scores.

Table 9 : Summary statistics for performance scores for right and left ears on the Competing Sentences Test for S and NS, males and females within each group

	NS		S	
EAR	R	L	R	L
Mean	96.33	94	90.03	89
S.D.	0.615	0.724	0.928	0.995
Range	80 100	80 100	70 100	70 100

	NSM		NSF	
EAR	R	L	R	L
Mean	96	94	96.67	94
S.D.	0.632	0.632	0.617	0.828
Range	80 100	80 100	80 100	80 100

	SM		SF	
EAR	R	L	R	L
Mean	90.67	87.33	90	90.67
S.D.	1.033	0.961	0.845	1.033
Range	70 100	70 100	70 100	70 100

DESCRIPTION OF RESULTS IN TABLE 9

STUTTERERS/NONSTUTTERERS COMPARISONS

The following is observed :

- The mean performance score for right and left ears for NS is higher than for S.
- Right ear performance scores are generally higher than left ear performance scores for S and NS.
- There is little overall variability in performance scores as evidenced by a standard deviation of less tha one.
- The range of performance of S, is marginally greater than for NS for both ears.

MALE/FEMALE COMPARISON

Nonstutterers :

- The mean performance scores for males and females are similar for both ears. There is little variability in performance for males and females as depicted by the range and standard deviation.

Stutterers :

- The mean performance for the right ear are similar for males and females. For the left ear, the female stutterers obtained a higher mean score compared with male stutterers.

Table 10 : Summary table of 2 x 2 x 2 (Maingroups x Gender x Ears analysis of variance for performance scores on the Competing Sentences Test.

BETWEEN SUBJECTS		
SOURCE	F	P
Maingroup (S; NS)	7.802	0.007
Gender (Male & Female)	0.179	0.674
Maingroup x Gender	0.064	0.800
WITHIN SUBJECTS		
SOURCE	F	P
Ears (Right, Left)	4.092	0.048*
Ears x Maingroup	0.304	0.583
Ears x Gender (Male & Female)	0.845	0.362
Ears x Maingroup x Gender	1.657	0.203

* $p<0.05$

The above table reflects the following :

STUTTERERS/NONSTUTTERERS COMPARISON

- No significant performance differences were noted between S and NS ($p>0.05$). However, it should be noted that the probability ($p=0.07$) approached significance.

- No significant interaction effects were noted.

- A significant difference ($p<0.05$) was noted between the performance score of the right and left ears for S and NS combined.

MALE/FEMALE COMPARISON

- No significant ($p>0.05$) performance differences were noted between males and females, for S and NS on the CST.

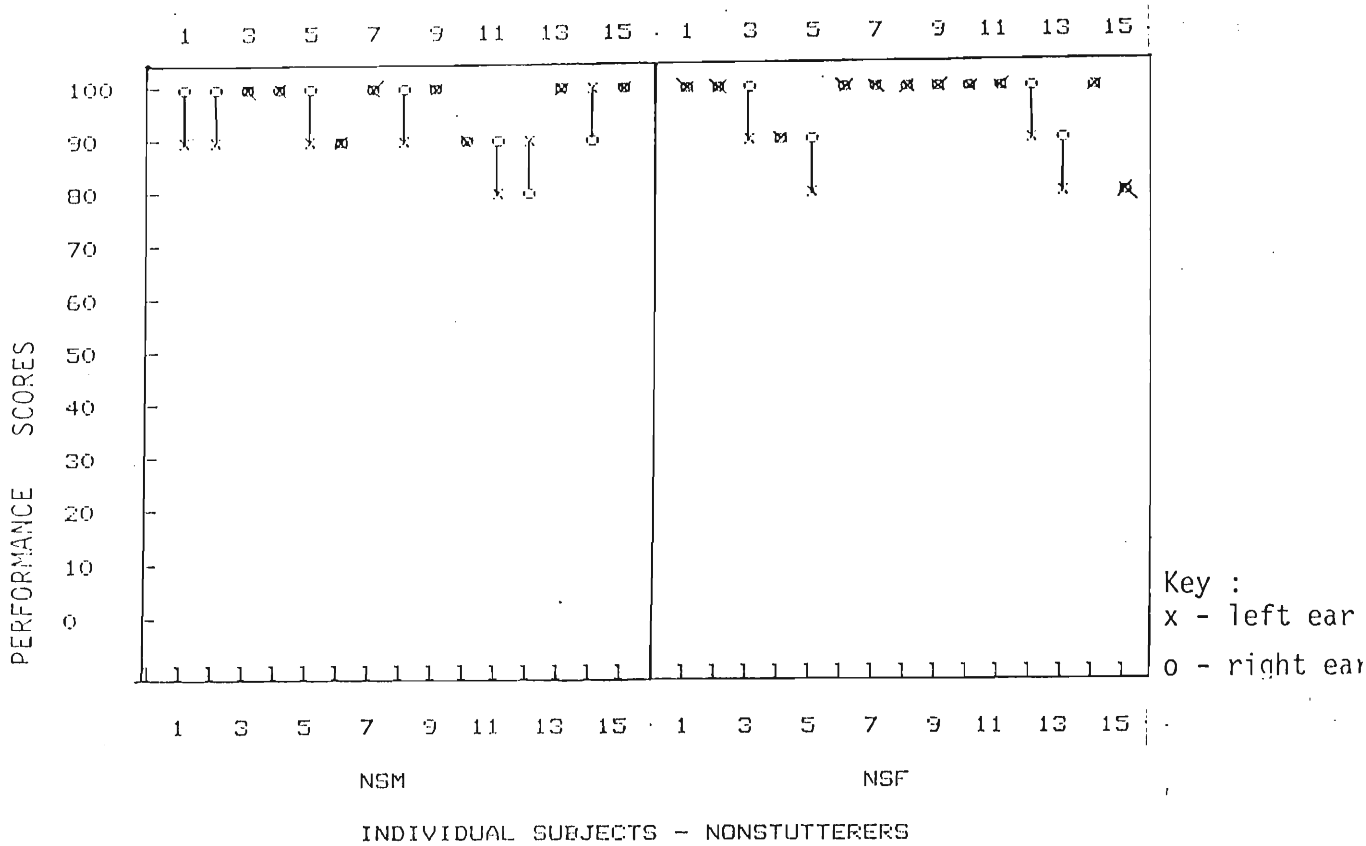

Figure 6 : Performance scores for left and right ears for individual nonstutterers (male and female) on the Competing Sentences Test.

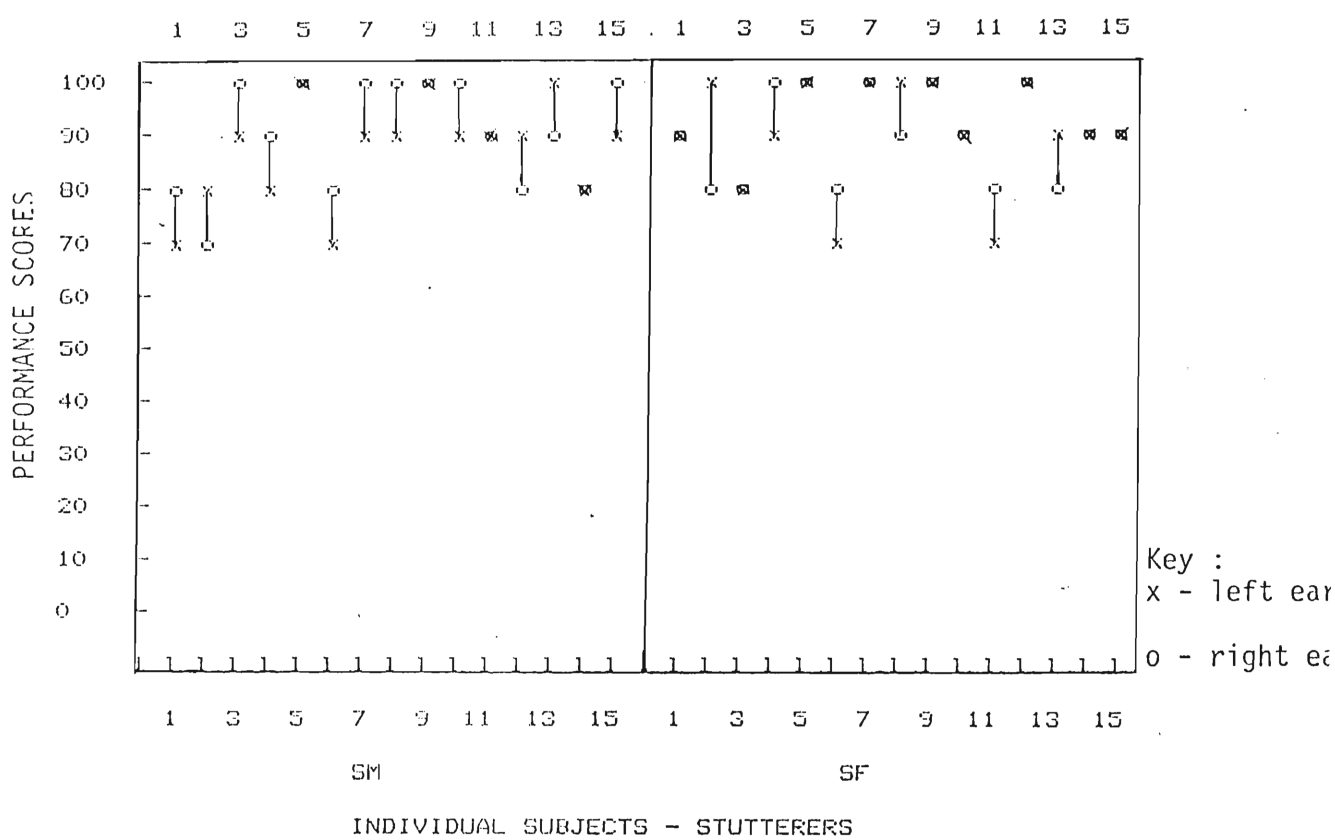

Figure 7 : Performance scores for left and right ears for individual stutterers (male and female) on the Competing Sentences Test.

DESCRIPTION OF FIGURES 6 AND 7

The figures are reflective of individual subjects' performance scores on the CST. The scores are reflected for a total of 60 subjects. NS and S (male and female) scores are grouped in separate figures for ease of reference. Left and right ear scores are presented as they relate to the norm ie. 90% correct. (Willeford, 1985). The 90% norm was used because the NS obtained a mean performance within normal limits for both ears. The figures reflect the following :

STUTTERERS/NONSTUTTERERS COMPARISONS

- A total of 5 nonstutterers scored below the norm as compared with 11 stutterers who scored below the norm.

- A greater number of left ears scored below the norm for nonstutterers, whereas for stutterers a similar number of left and right ears scored below the norm.

MALE/FEMALE COMPARISONS

Nonstutterers :

- A similar number of males (2) and females (3) scored below the norm.
- More left than right ears scored below the norm especially for the female nonstutterers.

Stutterers

- A similar number of males (6) and females (5) scored below the norm.
- Similar number of left and right ears scored below the norm for the male stutterer. For female stutterer group fewer left ears than right ears scored below the norm.

SUMMARY:STUTTERERS/NONSTUTTERERS COMPARISON

No significant performance difference was obtained between S and NS. A subgroup of stutterers did however obtain scores below the norm.

SUMMARY: MALE/FEMALE COMPARISONS

No significant performance differences were noted between males and females within each group.

PASS/FAIL CRITERIA AND INTERPRETATION :

To pass the CST test a subject was required to have scored within the normal limit i.e. 90% correct or better for both ears. A subject was regarded as failing the CST test if one or both ears scored below the norm (Musiek, Geurkink & Kietel, 1982). The result indicated that 11 stutterers failed CST test. Six males stutterers and five female stutterers failed the CST test. Nineteen stutterers passed the test (nine males and ten females). Five nonstutterers failed the test (two males and three males). Twenty five nonstutterers passed the test (13 males and 12 females) and five failed (two males and three females).

5.3.2. DISCUSSION : COMPETING SENTENCES TEST

5.3.2.1. Stutterers/nonstutterers comparison

Nonstutterers

The summary statistics presented in Table 9 indicates that the mean score for NS for the right ear is 96.33 and for the left ear it is 94. A norm of 90% correct performance is reported in the literature. The results obtained indicate that the mean performance for the group could be considered as normal in accordance with norms described by Willeford, 1985; Musiek, Geurkink and Kietel, (1982).

If the individual scores for NS are considered, as indicated in Figure 6, then it is apparent that five of the 30 NS obtained scores below the norm, whilst the majority (25) of NS obtained scores within the the normal range. Futhermore, the range of results and the standard deviations as indicated in Table 9 indicates little variablity in group perfomance for NS. The test results suggest that most nonstutterers had little difficulty on the CST. Previous researchers Willeford, 1985; Musiek et al., 1982, have also suggested that the CST is simple for normal hearing subjects who have no central auditory processing problems.

Performance differences between the right and the left ears have been noted. Analysis of results in Table 10 indicates that for all subjects (S and NS) combined, there is a significant performance difference ($p<0.05$) between ears. An examination of results on Table 9 indicates that the mean performance for the right ear is better than that of the left ear. This suggests that the right ear performance is better than the left ear performances in that there was greater accuracy. The results obtained in this study are similar to a normative study conducted by Ivey in (1969) cited in Willeford, 1985. Ivey reported slightly better performance for the right ear than the left ear in normal hearing young adults. However, it must be emphasized that the difference is minimal, especially considering that the mean performance for both ears was greater than 90%. This feature is especially evident on examination of individual performances reflected in Figure 6. Fifty percent of NS obtained identical performances in the left and right ears.

Thus, the results obtained for the NS suggest that the subjects have little difficulty on the Competing Sentence Test. It could, therefore, be stated that most nonstutterers in the present investigation who were essentially normal listeners performed with a high degree of accuracy, and with little variablity on the CST.

STUTTERERS/NONSTUTTERERS COMPARISON

The analysis of variance reflected in Table 10 indicated that although there were no significant differences between the S and NS although the performance difference approached significance (p=0.07). A review of the mean scores indicate that the overall performance was poorer for S than for NS as reflected in Table 9. Individual scores for S in Figure 7 also clarifies this observation. It is noted that 11 (36.67%) of the 30 stutterers obtained scores below that norm for one or both ears. This is in contrast to the five (16.6%) nonstutterers who obtained scores below the norm. It should be emphasized however that 19 of the 30 stutterers (63.33%) obtained scores within normal limits. It thus appears that subtle overall performance differences occurred between S and NS and this difference may have been generated by a subgroup of 11 stutterers who performed below the norm.

S obtained similar mean scores for the right and the left ears as reflected in Table 9. These findings are subtly different from the NS, whose performances were better in the right ear. For the NS, four of the five subjects scored below the norm for the left ear, whilst two right ears scored below the norm. For S, eight left ears and eight right ears scored below the norm. It was also noted that except for one nonstutterer for whom both ears scored below the norm, the general trend was that only one ear scored below the norm for other nonstutterers. This is reflected in Figure 6. For the S, in four subjects one ear scored below the norm, whilst for the remaining seven stutterers two ears scored below the norm. Therefore, for S it was apparent that most individuals who scored below the norm, had both ears scoring below the norm. This performance trend is not usual for normal subjects (Ivey, 1969 cited in Willeford, 1985) thus suggesting that this subgroup of stutterers experienced difficulty on the CST. The range of differences (in percentage) between the ears was from 0 to 10% in most subjects. For one stutterer the difference was 20%. These performance characteristics are reflected in Figure 7.

To summarize, NS obtained better performance scores than the S. For the S the same number of right and left ears scored below the norm In most instances both ears scored below the norm for S. The slight right ear advantage observed for NS was not evident for S. S performance within the group were varied.

INTERPRETATION/EXPLANATION

The results of the CST in general suggested that the overall performance for most nonstutterers and some stutterers indicated that the test was simple for the normal hearing adult. The majority of nonstutterers and a subgroup of stutterers obtained scores within normal limits. This result is most likely related to the nature of the CST stimuli which consists of sentences that are of similar length and content. The subjects may have relied on contextual clues within the sentence to generate a correct response, despite the reduced intensity level of presentation of the target stimuli and the dichotic presentation.

Wingfield (1975), further describes the perceptual act of listening to sentences as an active process whereby the listener reconstructs the fragments that are heard so that meaniful responses can be generated. A subject is usually able to do this as long as there is minimal intelligibility. For stutterers and nonstutterers in who obtained scores within normal limits in the present study it could be assumed that this process is not compromised in any way. Although there were attempts to stress the central auditory system by presenting the sentences dichotically and reducing the intelligibility of the target sentence, it appears that interaction with language processing mechanisms may have facilitated the realization of the target sentence.

There was however, a subgroup of subjects (predominantly stutterers) who obtained depressed scores on the CST. For many of the stutterers, the most common type of error was that elements of the competing sentence were as reported as part of the primary sentence. Other errors that were less frequent, included omission or substitution of a word in the primary sentence.

The borrowing of words from the competing sentence suggests that the auditory processing of the primary sentence was interfered with by that of the competing message (Welsh, Welsh,Healy & Cooper, 1982). This error feature most likely suggest the existence of a subtle central auditory processing problem. The motivation for suggesting that is is a central auditory processing problem arises from the observation that all subjects in the present study were able to recall a target sentence accurately when the sentence was presented in a noncompeting format. This was done in the familiarization period to rule out possible problems related to memory, since the stimuli in sentence format did, to an extent, rely on memory for accurate retrieval. The processing problems only surfaced when the sentences were presented dichotically with reduced intelligibility so as to challenge the central auditory nervous system. It also suggests that the process of binaural separation/selective attention was compromised since the processing of competing sentence interefered with the processing of the target sentence. This suggests compromised central auditory processing, since selective attention is reportedly the function of the cortical auditory processing system (Duchan & Katz, 1983). A further observation was that stutterers appeared to generate proper temporal sequences although words in the sentence may have been omitted or substituted. The investigator is of the opinion that knowledge of syntactic structures probably governed the responses. Therefore, to some extent subjects reliance on the language processing system may have facilitated the ability to produced words in sequence. Welsh et al., (1982) supported this explanation, and further suggested that the pathway from subcortical association fibres to the cortical regions were compromised. However, the subtle nature of the differences must be emphasized, and that they apply to only a subgroup of stutterers must be acknowledged. This result appears to be in contrast to the SSW test where word sequences were not predictable, and therefore were changed with greater frequency (reversals).

The error patterns observed for some stutterers could be explained by the interference theory suggested by Hawver (1978). The theory has been described previously (p. 223) and therfore will not be repeated. The extent to which the central auditory processing system may be compromised and its relationship to stuttering is open to speculation. Explanations offered previously by Kent (1984), relating to how problems of central auditory processing may relate to stuttering, may also apply here.

The differences in ear preferences observed between S and NS have also been noted on the CST. The slight REA evident for the majority of nonstutterers is not evident in all stutterers. Furthermore, not all stutterers showed a similar trend in ear preference. A subgroup type analysis revealed that there were three subgroup types who demonstrated REA, LEA and NEA. Within these groups there were subjects for whom the performances of both ears were below the norm. It is possible that ear advantage or the lack thereof as observed on this measure may relate to stuttering as suggested in the Orton-Travis and related theories. However, the CST does not provide convincing evidence to this effect as ear differences appear to be small for most subjects. The greatest difference in ear performance subject was 30%, and this occurred for a single S (SF2) subject only. Therefore, the Orton- Travis theory as described previously, cannot be applied with confidence to the results obtained on this measure.

It was concluded that whilst there were performance differences between S and NS on the CST , these differences were subtle and nonsignificant. The findings of this study suggest CST is not capable of stressing the auditory system sufficiently to reveal the nature of S and NS auditory processing differences, as observed with other measures such as the DCV test and SSW test. The test was in effect simple for most nonstutterers and stutterers.

The result of the CST needs to be considered as part of a battery of tests so that overall processing patterns for S and NS, group and individual subjects could be examined. A discussion to this effect is forthcomming in part B.

5.3.2.2. Male/female comparisons

Nonstutterers

No significant performance differences were observed between male and female NS as reflected in Table 10. An examination of summary statistics reflects similar trends.

Stutterers

No significant performance differences were observed between male and female S as reflected in Table 10. The summary statistics confirm these findings.

This finding appears contrary to the literature cited by Govender (1989) which support the contention that sex differences are evident on physiological measures such as those evoked by the BSER. It also contradicts findings by McGlone(1981) which, though not conclusive, has also supported the contention that sex differences may exist on central auditory tests. In an attempt to reconcile these discrepancies the present researcher suggests that that tasks involving meaningful stimuli are usually processed with ease because signal redundancies exist (Rintelman, 1985), and therefore gross performance differences are not observed. Thus, on measures such as the CST where stimuli is semantic in nature, it is unlikely that sex differences would be apparent, especially if these differences are subtle. It is likely that auditory processing of semantic information is more similar than different for males and females, and that the CST is perhaps not stringent enough to highlight the nature of central auditory processing differences, if there are any.

The results of the CST revealed no significant performance of S and NS, and between males and females within each group.

5.4.1 RESULTS : SYNTHETIC SENTENCE IDENTIFICATION - IPSILATERAL COMPETING MESSAGE

The format of results are as follows :

Table 11 : Summary statistics of performance scores for S and NS and males and females within each group are presented for right and left ears for four MCR conditions.

Table 12 : The table reflects the analysis of variance of performance scores for Maingroups (S; NS), Gender (M; F) and Ears (R; L) scores on -20dBMCR condition.

Table 13 : The table reflects the analysis of variance for performance scores for Maingroups (S; NS) Gender (M; F) and Ear (R; L) scores on the -10dBMCR condition.

Table 14 : The table reflects analysis of variance of performance scores for Maingroups (S; NS), Gender (M; F) and Ear (R; L) scores on the 0dBMCR condition.

Table 15 : The table reflects analysis of variance of performances scores for Maingroups (S; NS), Gender (M; F) and Ear (R; L) scores on +10dBMCR condition.

Table 11 : <u>Summary statistics of performances scores for S and NS and males and females within each group (right and left ears) for each MCR condition on the SSI-ICM test</u>

		NS		S	
		R	L	R	L
-20dBMCR	Mean	57.67	53.33	49	50.67
	S.D.	8.98	9.73	14.7	14.37
	Range	40 70	40 80	20 70	30 70
-10dBMCR	Mean	83.33	80.67	72.67	76.67
	S.D.	9.59	9.80	11.72	11.24
	Range	70 100	70 100	40 90	50 90
0dBMCR	Mean	95	95	94.33	96.33
	S.D.	4.72	5.29	5.68	5.561
	Range	80 100	80 100	90 100	80 100
+10dBMCR	Mean	99.33	100	99.67	100
	S.D.	1.04	0	1.83	0
	Range	90 100	90 100	90 100	100

cont/....

		NSM		NSF	
		R	L	R	L
-20dBMCR	Mean	57.33	56.00	58	54.67
	S.D.	8.84	11.83	9.41	7.43
	Range	40 70	40 80	40 70	40 70
-10dBMCR	Mean	84.67	80.67	82	80.67
	S.D.	8.34	9.612	10.82	10.33
	Range	70 100	70 100	70 100	70 100
0dBMCR	Mean	95.33	95.33	94.67	94.67
	S.D.	5.16	6.40	6.40	6.40
	Range	90 100	80 100	90 100	90 100
+10dBMCR	Mean	98.67	100	100	100
	S.D.	3.52	0	0	0
	Range	90 100	100	100	100

cont/...

		SM		SF	
		R	L	R	L
-20dBMCR	Mean	48	50.67	50	50.67
	S.D.	14.24	16.24	15.58	12.8
	Range	20 70	20 70	20 70	30 70
-10dBMCR	Mean	73.33	76.67	72	76.67
	S.D.	10.47	9.759	13.2	12.91
	Range	50 90	60 90	40 80	50 80
0dBMCR	Mean	9.4	96.67	94.67	96
	S.D.	6.33	4.88	5.16	6.33
	Range	80 100	90 100	90 100	80 100
+10dBMCR	Mean	100	100	99.33	100
	S.D.	0	0	1.83	0
	Range	100	100	90 100	100

<u>DESCRIPTION OF RESULTS REFLECTED IN TABLE 11</u>

<u>STUTTERERS/NONSTUTTERERS COMPARISON</u>

- The mean performance scores for S and NS for right and left ears improve as the MCR decreases.
- The mean performance scores for all MCR conditions are higher for NS than for S.
- The greatest mean performance score difference between S and NS was noted at -20dBMCR and -10dBMCR.
- The mean performance scores for S and NS for right and left ears are similar. However, NS have a better mean right ear

performance score, whilst S have a better mean left ear score on all of the MCR's.

- Variability in performance scores in both for S and NS are noted, especially on the -20dBMCR and -10dBMCR. The standard deviation and range of performance scores provide information to this effect.

MALE/FEMALE COMPARISON

Nonstutterers :

- Similar mean performances scores are evident for males and females on all MCRs.

- The right ear performance for males and females is consistently higher at -20dBMCR and -10dBMCR.

- The mean performance scores for right and left ears for males and females increase, with a decrease in MCR.

Stutterers :

- Male and female mean performance scores were similar for all MCR's for left and right ears.

Table 12 : Summary table of 2 x 2 x 2 (Maingroups x Gender x Ears) analysis of variance, with repeated measures on the factor last for SSI-ICM test scores at -20dBMCR

BETWEEN SUBJECTS		
SOURCE	F	P
Maingroups (S; NS)	3.744	0.058
Genders (M & F)	2.680	0.107
Maingroup x Gender	0.022	0.882
WITHIN SUBJECTS		
SOURCE	F	P
Ears (R; L)	0.020	0.000*
Ears x Maingroup	0.020	0.001*
Ears x Gender	1.658	0.203
Ears x Maingroup x Gender	0.020	0.887

* $p<0.05$

Table 13 : Summary table of 2 x 2 x 2 (Maingroups x Gender x Ears) analysis of variance, with repeated measures on the last factor, for SSI-ICM test scores at -10dBMCR

BETWEEN SUBJECTS		
SOURCE	F	P
Maingroups (S; NS)	10.762	0.002*
Genders (M & F)	2.126	0.150
Maingroup x Gender	0.531	0.469
WITHIN SUBJECTS		
SOURCE	F	P
Ears (R; L)	0.097	0.757
Ears x Maingroup	0.873	0.354
Ears x Gender	1.552	0.218
Ears x Maingroup x Gender	0.388	0.536

* $p<0.05$

Table 14 : Summary table of 2 x 2 x 2 (Maingroups x Gender x Ears) analysis of variance, with repeated measures on the last factor, for SSI-ICM test scores at 0dBMCR

BETWEEN SUBJECTS		
SOURCE	F	P
Maingroups (S; NS)	0.780	0.381
Gender (M & F)	0.000	1.000
Maingroup x Gender	0.347	0.558
WITHIN SUBJECTS		
SOURCE	F	P
Ears (R; L)	0.966	0.330
Ears x Maingroup	0.107	0.744
Ears x Gender	0.429	0.515
Ears x Maingroup x Gender	0.429	0.515

Table 15 : Summary table of 2 x 2 (Maingroups x Gender x Ears) analysis of variance, with repeated measures on the last factor, for SSI-ICM test scores of +10dBMCR

BETWEEN SUBJECTS		
SOURCE	F	P
Maingroups (S; NS)	0.327	0.569
Genders (M & F)	0.327	0.569
Maingroup x Gender	0.327	0.569
WITHIN SUBJECTS		
SOURCE	F	P
Ears (R; L)	2.947	0.092
Ears x Maingroup	0.327	0.569
Ears x Gender	0.327	0.569
Ears x Maingroup x Gender	0.327	0.569

DESCRIPTION OF RESULTS : ANALYSIS OF VARIANCE : (Tables 12, 13, 14, 15).

STUTTERERS/NONSTUTTERERS COMPARISON

- Significant performance differences between S and NS were noted on the -10dBMCR ($p<0.05$) for left and right ear scores combined.
- The performance differences between S and NS (left and right) at -20dBMCR approached significance ($p=0.058$, left and right ear scores combined).

Within subjects : Significant right/left ear performance differencies were obtained at -20dBMCR. Maingroup X Ear interaction indicated that the performance difference between the ears was generated by either the S or NS. The results in Table 11 indicated that this difference was contributed by the NS.

The interaction effect was only evident at the -20dBMCR condition. No significant performance difference were evident between S and NS at 0dBMCR and +10dBMCR. Thus, significant performance differences between S and NS were apparent on stressful test conditions.

MALE/FEMALE COMPARISON

- No significant differences were obtained for performance scores for males and females within each group across all MCR's.

- No significant interaction effects were noted.

Thus for the SSI-ICM test

1. Significant performance differences were obtained between S and NS noted on the -10dBMCR condition.

2. No significant male/female performance differences were obtained within each group.

PASS/FAIL CRITERIA AND INTERPRETATION

The mean performance scores (R & L ears combined) of the NS was used as a basis for comparison. For a subject to have passed the SSI-ICM test, performance scores were required to be above the (mean - 2 standard deviation) for each MCR condition, for both ears. For a subject to have failed the SSI-ICM test, the performance score was to be below the(mean -2 standard deviation) for any or both ears on any one or more MCR conditions.

The criterion for each MCR was as follows :

-20dB - below 50

-10dB - below 70

0dB - below 90

+10dB - below 90

Using the above criteria 12 stutterers (six males and six female) failed the test and 18 (nine male and nine female) passed. Three nonstutterers (two male and one female) failed the test and 27 (13 males and 14 females) passed the SSI-ICM test.

5.4.2. DISCUSSION : SYNTHETIC SENTENCE IDENTIFICATION - IPSILA-ERAL COMPETING MESSAGE

5.4.2.1. Stutterers/nonstutterers comparison

Nonstutterers

The results obtained for the nonstutterers indicated the following trends :

No significant between ear differences ($p>0.05$) were evident on the various MCR's except on -20dBMCR as indicated in Tables 12, 13, 14, and 15. However, the mean right ear scores appeared to be higher than the left ear scores especially at -20 and -10 dBMCR as indicated in Table 11. It appears that although significant ear difference scores on this measure were not apparent on all MCR's, subtle differences were evident.

Wynne and Boehmler (1982) reported that no significant ear differences for the normal subjects in their experiment. Hall and Jerger (1978), commented on a slight right ear preference (as observed in this study) for the control group. The higher mean scores for the right ear implies the possibility that a subtle right ear processing advantage is evident at subcortical level for NS.

Performance at various MCR conditions : The mean performance scores for the left and the right ears were lowest at -20dBMCR. As the MCR's decreased, the mean performance scores increased bilaterally. This is evident from comparison of the mean performance scores for left and right ears at -20 dBMCR which is 56%, whilst the mean performance scores for left and right ears at +10dBMCR is approximates 100% The standard deviation and range of performance was greatest on the higher MCR's, suggesting greater variability in performance under more difficult conditions (reflected in Table 11). Similar trends in variability have been observed in other studies (Ventry & Spitzer, 1980; Wynne & Boehmler, 1982; Toscher & Rupp, 1978). Thus, the SSI-ICM test was capable of stressing the central auditory system on the -20 and -10dBMCR conditions in normal listeners.

It can also be stated that the performance on the SSI-ICM test varies depending on the MCR. Hall and Jerger (1978), commented that the unique advantage of the SSI-ICM test was that the difficulty of the test could be selectively controlled by varying the MCR. The MCR at -10 and -20dB places an unusual demand on the speech decoding capabilities of the central auditory system, and is sensitive to subtle central auditory processing disorders.

The performance of NS in the present study compare favourably to the performance of subjects in the control groups in some studies cited by Willeford, 1985; Ventry and Spitzer, (1980). However, when compared with other previous studies the performance of the NS in the present study differs (Hall & Jerger, 1978; Toscher & Rupp 1978; Wynne & Boehmler, 1982). These studies generally reported better performances for normal subjects at -20 and -10 dBMCR compared with the mean performance of the NS in the present study. The norms reported by Hall and Jerger (1978), appear to be unusually high suggesting that the normal group performance was consistently in the upper range. The Hall and Jerger study has been criticized on this account (Nuck et al., 1987). A similar trend was observed in the study by Toscher and Rupp (1978).

In the study by Wynne and Boehmler (1982) the mean correct scores for the -20 dBMCR condition was 91%, whilst for the present study it was 56%. These differences may have been related to two factors. Firstly, the control subjects in the Wynne and Boemhler (1982) study were chosen specifically because they were exceptionally fluent speakers. Since fluency and central auditory processing have been positively correlated

(Wynne & Boehmler, 1982), the present researcher suggests that this factor may have contributed to the unusually high scores obtained. The subjects' exceptional speech fluency and excellent central auditory processing skills may have contributed to high scores on the SSI-ICM test since fluency and central auditory processing are correlated (Mirabile, Porter & Hughes, 1978). Secondly, the subjects were only tested on the -20 dBMCR, and a total of 50 trials were provided. It is possible that after a period subjects adapted to the procedure and therefore made few errors. This is contrast to the present study which used 10 presentations at each MCR. The present researcher concurs with the suggestion of Nuck, et al., (1987) who state that the performance scores for the normal fluent speakers were unusually high in the Wynne and Boehmler study.

For comparison in the present study the results of NS are considered the norm, because should the results of S in the present study be compared to norms by Hall and Jerger (1978), the S would be at a disadvantage. Furthermore, NS performance scores are more suitable as the norm because the S and NS have been closely matched on many variables (age, sex, linguistic background) that may influence test performance.

Stutterer/nonstutterer comparison

The summary statistics reflected in Table 11 indicate that the left and right ear performances for S and NS within each group are comparable, and thereby suggest that overall performance differences between ears are generally not evident. This observation is confirmed by the statistical analysis in Tables 13, 14 and 15 which indicated no significant ears differences ($p>0.05$)

for NS and S for all MCR'S. Examination of individual scores for L and R ears for S and NS indicated only small between ear differences. The observation of nonsignificant ear differences has been reported in the literature (Wynne & Boehmler, 1982). The present researcher suggests that since the subjects in the present investigation did not have any identified lesion of the central auditory pathway per se, it is unlikely that one ear would score significantly different from the other. This speculation arises from information cited by Willeford, (1985), which indicates that when lesions occur in the central auditory system, the ipsilateral or contralateral ear performance may be compromised.

Whilst ear differences scores were generally not significantly different for S and NS, S appeared to have obtained higher mean left ear scores than mean right ears scores at various MCRs suggesting a left ear processing advantage. This is in contrast to that of the NS, who obtained higher mean right than mean left ear scores. These results appear to suggest subtle processing differences between S and NS. The results also appears to indicate that the right ear processing advantage observed for NS on other test measures, also applies to this measure, though the mean performance difference between the ears on the SSI-ICM test is not as robust as on dichotic tests. The right and left ear processing advantages for the NS and S groups may be reflecting a subcortical processing asymmetry as suggested by Sidtis (1982.) It is considered to be the consequence of subcortical asymmetry since the SSI-ICM test is purported to provide an appraisal of functioning of brainstem level. The present investigator concurs with this speculation but suggests that the results of central auditory processing test battery needs to be considered before a conclusive statement is made. A comparison of this nature is forthcomming in the composite discussion of test results.

The results of the SSI-ICM test indicates a *significant* performance difference ($p<0.05$) between S and NS at the -10dBMCR as reflected in Table 3, with differences at the -20 dBMCR as reflected in Table 12 approaching significance ($p=0.058$). These results suggest that the performance difference (left and right ears combined) between the S and NS were apparent at the more stressful conditions. A review of individual scores for stutterers indicated that not all stutterers performed poorly on the SSI-ICM test. A subgroup of 12 stutterers scored below the norm and it was the performance of this subgroup that contributed to the significant nature of performance differences between S and NS. Eighteen stutterers performed normally, highlighting that all stutterers did not perform similarly on this test. No significant performance differences ($p>0.05$) were observed at 0dBMCR, and +10dBMCR as reflected in Tables 14 and 15. These conditions are less stressful and most individuals obtain normal results at these MCRs (Willeford, 1985).

It would be expected that the performance differences between the NS and S would be most significant at the -20 dBMCR condition, which was the most stresssful condition, rather the -10dBMCR condition. The results of this study did not reveal this expected pattern of result and this perhaps could be explained in the light of the performance of NS at -20 dBMCR. On this condition both S and NS obtained lower scores compared to other

MCR conditions. However, although the scores for the NS were higher than that of the S as reflected in Table 11, the differences were not great enough to be considered statistically significant. At the -10dBMCR however, the performances of the NS improved greatly compared to the S. The mean right and left ear performance for the NS was approximately 82%, whereas for the S it was approximately 75%. The performance differences were thus greater between S and NS on the -10dBMCR condition generating a statistically significant ($p<0.05$) difference. Hall and Jerger (1978), state that both the -20 and -10dBMCR conditions are demanding, and this is confirmed by the results of this study, especially for S.

Whilst the research reviewed does report that performance differences on the various MCRs differ, the underlying processes that may be stressed are not delineated. The present investigator suggests that the following description may offer insight as to the nature of the stress created in the brainstem, that could account for poorer performance stressful MCRs for S and NS. At -20 and -10dBMCR conditions of the SSI- ICM test, the stress is introduced in three ways. Firstly, the sentences are synthetic in nature, and therefore, more difficult to process since the dependence is on the auditory processing skills as opposed to language skills. Secondly, the competition is presented at a higher intensity than the target sentence, and therefore reducing the overall intelligibility of the primary message. Thirdly, the primary and secondary signals are introduced to the same ear thus, reducing the redundancy available in the auditory, and reducing the influence of the binaural processing system in processing auditory information.

The nett effect of the stress results in poor performance of the auditory system at brainstem level as evidenced on the SSI-ICM test. The present researcher suggests that for the group of stutterers who performed poorly on the SSI-ICM test, since the binaural processing advantages were not available, the inability of the brainstem auditory system to "squelch" unnecessary information (Protti, 1983) became apparent and this is reflected in poor performance on the SSI-ICM test. Whilst subtle processing difficulties may generally operate for some stutterers, these difficulties may only be realized when the system is stressed. Thus, it appears that since stutterers are not able to "squelch" unnecessary signals, this may interfere with the realization of the target signal.

There have been other studies that have reported findings similar to the present study. Hall and Jerger (1978) investigated the performance of stutterers and normal subjects on a battery of tests, which included the SSI-ICM test. The results indicated that stutterers obtained lower scores than the normal subjects on -20, -10 and 0dBMCR conditions. Stutterers showed an 8% loss in the right ear and a 9% loss in the left ear compared to the control group. Based on these results, Hall and Jerger concluded that on difficult listening conditions a difference in performance between stutterers and normal subjects groups emerged. No comment is regarding the statistical significance of differences between the groups. It was concluded by Hall and Jerger(1978) that the SSI-ICM test was sensitive to a subtle central auditory dysfunction generated primarily at the brainstem level of dysfunction. As stated previously the Hall and Jerger study is often criticized by other researchers including the present investigator because the performance of the control group was unusually high. Although the stutterers as a group scored within normal limits according to norms (Jerger, 1978) their performance was considered to be different from that of the control group. The significance of the result is therefore questionable. Hageman and Greene (1989), further described the breakdown as being at the level of the brainstem, or reticular activating system. The processes compromised involved that of attention allocation, effort and arousal, rather than higher levels of auditory function.

Toscher and Rupp (1978) also investigated the performance of stutterers on the SSI-ICM test. The results indicated that stutterers performed significantly differently from nonstutterers on the -20dBMCR and -10dBMCR. These results correlate closely with the results obtained in the present study. It was suggested by Toscher and Rupp (1978) that the result of the investigation was compatible with the hypothesis that a dysfunction in central auditory apparatus is one of the underlying causes of stuttering. The present researcher is of the opinion that causal statement about central auditory processing as etiology in stuttering is a possibility but that more evidence to this effect is needed before a definitive statement can be made.

Wynne and Boehmler (1982), investigated the performance of the fluent and disfluent normal speakers on the SSI-ICM test. The results of their study can, to an extent, can be applied to the stuttering population though not entirely. Whilst Wynne and Boehmler (1982) have investigated essentially normal speakers, the disfluent speakers with part-word repetitions were selected for the evaluation. Since stutterers also demonstrate part-word repetitions as a symptom of stuttering some of the processes that generate the disfluency may overlap with that of stuttering. In the light of this similarity the results of the Wynne and Boehmler (1982) study is considered supportive of the present study.

Wynne and Boehmler (1982), investigated performances of fluent and disfluent normal speakers on the -20dBMCR of the SSI-ICM test and concluded that there was a statistically significant difference between the fluent and disfluent speakers on the SSI-ICM test, therefore supporting the hypothesis that that disfluent normal speakers demonstrate poorer performance on the SSI-ICM test compared with fluent normal speakers. If one envisages a continuum of disfluency then it is possible to conceive the notion that normal disfluent speakers may share part of the continuum where greater disfluency occurs, with stutterers. The fluent speakers may be on the opposite end on the continuum where there is little disfluency. It is therefore likely that because stutterers and normally disfluent individuals are at the same end of the continuum where there is greater disfluency, that stutterers and normally disfluent speakers may demonstrate similar central auditory processing problems, since Wynne and Boehmler (1982) have identified a positive relationship between disfluency and central auditory processing problems. Nuck et al., (1987) also provide evidence to support this contention.

Based on the results of the present study it is suggested that S performed significantly differently from NS at the -10dBMCR condition thereby supporting the contention that central auditory processing differences may be evident in at least a subgroup of stutterers.

Whilst the review of the previous literature has highlighted stutterers and nonstutterers performance differences on the SSI-ICM test, a study by Hannley and Dorman (1982), failed to find significant differences between stutterers and normal subjects on the SSI-ICM test. However, it is acknowledged by the researchers that the 20 stutterers investigated had completed a fluency training programme, and therefore may have performed more like normal subjects.

Explanation/interpretation

The following discussion pertains to theoretical explanations offered for the poorer performance of S compared to the NS, on the SSI-ICM test (-10 and -20dBMCR) and the relationship to stuttering.

a. Normal performance of stutterers on the SSI-ICM test : For this subgroup it is possible that no central auditory processing problems exists at this level of processing (brainstem). It is also possible that the test may not be stressful enough to reveal performance differences should they exist. The Hageman and Greene (1986) study used a seemingly more stressful test on stutterers and suggested that it was able to reveal subtle performance differences. It is possible that a measure such as that suggested by Hageman and Greene (1989) may reveal subtle performance differences for stutterers, should they exist.

b. Toscher and Rupp (1978) offered an explanation which suggested that observed differences between stutterers and nonstutterers could be attributed to differences in neural function, neurophysiological organization or both. The explanation unfortunately is not developed further.

c. Wynne and Boehmler (1982) provided a theoretical explanation describing how part-word repetitions may relate to central auditory dysfunction. In providing an explanation relating to the nature of part-word repetitions, they suggest that part-word repetitions may not be a function of language formulation as much as they are due to the function of central auditory nervous system activities. It was suggested that the part-word repetitions were a more sensitive indicator of speech flow breakdown than other categories of disfluencies. The theory has been described in Chapter Two of the present study and is therefore not repeated.

In linking this philosophy to the occurance of part-word repititions the following explanation is offered. If the central auditory encoding process is momentarily interrupted, then the correct encoded motoric pattern may not be available to generate the syllable pulse. Should the motoric pattern be unavailable whilst the basic temporal pulsed pattern of speech production is maintained, then the resulting behaviour would be a repetition of the previously encoded pattern, which is realized as a part-word repetition. In relating this process to stutterers, Wynne and Boehmler (1982) suggest that a central auditory deficit may lead to frequent part-word repetition which in turn contributes to the development of a communication disorder of clinical significance i.e. stuttering. The present investigator is of the opinion that this is a likely possibility.

d. The early models described by Mysak (1960) and Martin (1970) may also contribute to an explanation as to how stuttering is related to central auditory processing problems, as evidenced on the present measure. The theory of stuttering as a perceptual deficit suggested by Martin (1970) could be related to the findings of the present study. Martin suggested that the stutterer sets stringent criterion for the perception of signals. As a result the perception of the signal maybe delayed or blocked thus generating error signals in the auditory feedback system. Whilst the present investigator disagrees with Martin (1970) that anxiety is the basis for the poor perception, the setting of a strict criterion may apply to the subgroup of stutterers who had difficulty on the SSI-ICM test.

For this group the processing may be compromised in the following manner :
When the signal and noise (e.g. competing message) are present, then the combined input will have the intensity of signal and noise (primary and competing signal). To decide whether the signal is present, does not only depend on the intensity, but also on the criterion set by the listener. It is possible, that for this group, a rather stringent criterion is set (by stutterers) at the -20 and -10dBMCR. The intensity on the MCRs might not have reached the criterion, and the perception of the primary signal is blocked. The individual will therefore not respond or will respond incorrectly on the presentation of the target sentence. This processing deficiency disturbs the feedback in the

central auditory nervous system and may generate dysfluency. The way in which the error signal generates dysfluency has been described by Fairbanks (1964) and Mysak (1960). The models have been described in Chapter Two.

5.4.2.2 <u>Male/female comparisons</u>

Nonstutterers and stutterers

The summary statistics reflected in Table 11 indicate that similar mean performance scores were noted for right and left ear for all MCRs for males and females within each group. The statistical analysis indicated that there were no significant differences ($p>0.05$) between males and females on all MCRs for S and NS as reflected in Tables 12, 13, 14, and 15.

The failure to find performance differences between males and females on this measure is evident in the present investigation. There is a paucity of research into performance differences based on sex. The result of the present study could be compared to the results generated by Nuck, Blood and Blood (1987) who compared normal male and female fluent and dysfluent subjects on the SSI-ICM test. The results indicated no significant performance differences between males and females at -10 and -20dBMCR conditions.

The present investigator suggests that the SSI-ICM test may not be capable of showing up sex differences or, that infact, no sex differences exist. These findings should be viewed as preliminary and further research is necessary to confirm or reject the findings of the present. It is likely that other measures may be more capable of hightlighting sex differences at the brainstem level of processing, should they exist.

SUMMARY

The results of the SSI-ICM test indicated that there were significant performance differences between S and NS on stressful MCR conditions. No significant male/female performance differences were noted for S and NS.

5.5.1 RESULTS : ACOUSTIC REFLEX LATENCY TEST (ARLT)

The test results are presented as follows :

Table 16 : Summary statistics (of acoustic reflex latency) are presented for NS and S, males and females within each group at 500Hz, 1000Hz and 2000Hz (Ipsilateral (I) and contralateral (C) stimulation).

Table 17 : The F-ratio and probability values indicating significance of differences between S and NS, and males and females are presented.

NB : Preliminary analysis of variance indicated no significant left/right ($p>0.05$) ear latency differences. Therefore the data for left and right ears were collapsed. Ipsilateral - contralateral scores also indicated no significant overall differences ($p>0.05$). However, since there were significant ipsilateral/contralateral differences per frequency, the results have not been combined in the presentation.

A one-way analysis of variance was conducted as it was the most suitable method of providing manageable analysis of data, relating to the objectives of the study.

NB : Latency measures are in milliseconds (ms)

Table 16 : Summary statistics for reflex latency (ipsilateral and contralateral stimulation) are presented for S and NS, and males and females (within each group) at 500Hz, 1000Hz and 2000Hz

		NS		S	
		I	C	I	C
500Hz	Mean	102.43	103.87	105.53	110.53
	S.D.	13.28	14.3	27.82	26.96
	Range	74 - 146	78 - 136	10 - 174	20 - 164
1000Hz	Mean	105.84	106.33	115.22	115.55
	S.D.	14.12	15.59	30.75	34.37
	Range	82 - 146	80 - 148	10 - 184	10 - 198
2000Hz	Mean	129.41	128.84	140	140.07
	S.D.	22.68	26.32	34.21	35.17
	Range	96 - 186	74 - 186	14 - 196	18 - 200
		NSM		NSF	
		I	C	I	C
500Hz	Mean	106.4	110.53	98.58	97.42
	S.D.	13.9	12.33	11.52	13.29
	Range	90 - 146	90 - 136	74 - 120	78 - 120
1000Hz	Mean	107.33	110.88	104.38	102.10
	S.D.	12.93	16.82	15.25	13.23
	Range	84 - 134	80 - 148	82 - 146	82 - 130
2000Hz	Mean	134.86	133.57	124.13	124.26
	S.D.	23.34	26.15	21.07	26.09
	Range	102 - 186	74 - 186	96 - 176	86 - 184

cont/......

		SM		SF	
		I	C	I	C
500Hz	Mean	102.86	105.73	108.2	115.33
	S.D.	29.32	30.68	26.46	22.12
	Range	10 - 148	20 - 148	68 - 174	82 - 164
1000Hz	Mean	111.83	108.87	118.6	122.23
	S.D.	34.54	38.58	26.58	28.68
	Range	10 - 158	10 - 162	72 - 184	74 - 198
2000Hz	Mean	133.4	133.00	146.6	147.13
	S.D.	37.71	37.53	29.47	31.69
	Range	14 - 186	18 - 184	82 - 196	74 - 200

Description of Results : Table 16

i. General trends for S and NS

The ARL (in msec) increased as the frequency increased. The mean latency for I and C stimulation were similar at each frequency. The standard deviation was high on latency measures for all frequencies (I & C). Substantial variability in performance scores in both groups was evident.

STUTTERERS/NONSTUTTERERS COMPARISON

- The mean latency for S was consistently higher on ipsilateral and contralateral stimulation than for NS, at all frequencies.
- The standard deviation for S was consistently higher, than for NS suggesting greater variability in performance for the S compared with NS.

MALE/FEMALE COMPARISONS

Nonstutterers

- Female NS obtained mean latency consistently shorter than the male NS at all frequencies (I & C).

Stutterers

- Female S obtained longer mean latency compared with SM at all frequencies (I & C).

Table 17 : Summary table of analysis of variance for S and NS males and females, on latency measures at 500, 1000 and 2000Hz

SOURCE	MAINGROUPS S; NS			
	I		C	
Hz	F-RATIO	P	F-RATIO	P
500	0.619	0.43	2.896	0.09
1000	4.676	0.03*	3.58	0.06
2000	4.04	0.047*	3.96	0.049*
SOURCE	GENDER (M/F) (NONSTUTTERERS)			
	I		C	
Hz	F-RATIO	P	F-RATIO	P
500	5.74	0.02*	15.94	0.00*
1000	0.660	0.42	5.145	0.027*
2000	3.56	0.06	1.936	0.17
SOURCE	GENDER (M/F) (STUTTERERS)			
	I		C	
Hz	F-RATIO	P	F-RATIO	P
500	0.547	0.46	1.93	0.17
1000	0.723	0.39	2.32	0.133
2000	2.282	0.14	2.48	0.12

* $P<0.05$

Description of result Table 17 :

STUTTERERS/NONSTUTTERERS COMPARISON

- Significance latency differences were noted for S and NS on the following condition :

  1000Hz (I)

  2000Hz (I & C)

- No significant latency differences were observed at 500Hz (I & C)

MALE/FEMALE COMPARISON

Nonstutterers

- Significant latency differences were noted between males and females on the following conditions :

    500Hz (I & C)

    1000Hz (I) and approached significance on (C)

    2000Hz (I & C)

Stutterers

- No significant latency differences were obtained between males and females for all frequencies (I & C).

Normative Data Pass/fail and interpretation of results :

For the purposes of the present investigation the results of S are compared with that of the NS. In an attempt to define the normal range of performance using NS data the (mean +/-2 standard deviation) (Clemis & Sarno, 1980a) was determined.

Normative range : for ipsilateral and contralateral conditions was as follows :

	I	C
500 Hz	129 - 76	132 - 75
1000Hz	134 - 78	137 - 75
2000Hz	174 - 84	181 - 76

A subject failed the ARLT if at least two ears scored outside the normal range for ipsilateral and/or contralateral conditions for at least two stimulus frequencies. The analysis of result indicated that nine stutterers scored outside of the normal range. Six male stutterers and three female stutterers scored outside of the normal range. Twenty one stutterers (nine males and 12 females) passed the test. All the nonstutterers passed the test.

5.5.2. DISCUSSION : ACOUSTIC REFLEX LATENCY TEST

The presentation format is as follows :

A discussion of general result trends is presented. A discussion pertaining to the objectives of the study follows thereafter.

GENERAL TRENDS

Frequency (Hz) of stimulus : The results of the present study indicated that as the stimulus frequency increased, so did the reflex latency as reflected in Table 16. A comparison of the mean latency for 500Hz (I and C) for S and NS and 1000Hz were similar to each other. The latency at 2000Hz is longer compared to the latency obtained at 1000Hz and 500 Hz. This result suggests that the latency is frequency dependent.

This trend has also been noted by other researchers (Clemis & Sarno, 1980; Gorga et al., 1983; Church & Cudahy, 1984 Ferrita and Martin 1974). Since latency is frequency dependent, the results of the present study are presented per frequency.

Clemis and Sarno (1980a) attempt to explain the frequency dependent nature of the acoustic reflex latency to the tonotopic organization of the auditory system. It is suggested that the high frequency fibres are at the outermost part of the acoustic nerve and therefore takes more time to respond compared with the lower frequency stimuli. The reflex latency however, is a function of processing in the central system (Clemis & Sarno, 1980a and b; Church & Cudahy, 1984).

NB: The latency of the acoustic reflex is also intensity dependent. In the present study the intensity of the stimulus was kept constant i.e. at 10 dB SL re: acoustic reflex threshold. Since the intensity parameter was kept at a relative constant value, and it was not considered a variable in the present investigation.

Variability on test measure

The standard deviation obtained for S and NS subjects suggest that there was substantial intersubject variability as reflected in Table 16. Observation of individual latency measures indicated that intra-subject variability was also evident (see Appendix U for raw data). This trend was noted when the results of left and right ears were compared for individual subjects. In addition, this feature was apparent when the ipsilateral/contralateral performances for individual subjects are considered. Clemis and Sarno (1980a) reported similar standard deviations as in the present study for the normal subjects, and greater variability in pathological ears such as those with retrocochlear tumors. The increased latency trend was apparent in the stuttering group. Clemis and Sarno (1980a), suggest that the significant amount of intra and inter-subject variability reflect the variability inherent in the combined points along the auditory pathway from the external auditory canal to the level of the lower brainstem. Thus, the variability noted on the test measure for normal subjects in not unusual as physiological pathways between subjects are not identical.

Norms

For the purposes of the present study, the results of the S are compared with the NS. It is of interest to relate the norms of the present study to those of other studies to determine if the performance of the NS in this study relate to normal subjects in other studies.

Jerger, Oliver and Stach (1986), provide a summary of results obtained for onset latency on various studies. The range results for the present study are in general agreement with those reported in other studies. However, increased mean latency for 2000 Hz is not as apparent in other studies as in this study. This feature (i.e. increased mean latency at 2000Hz) however, has been specifically commented on in other studies (Clemis & Sarno, 1980a and b; Mangham et al., 1982) thereby suggesting that increased mean latency at 2000Hz than other frequencies is characteristic in the normal population.

It was concluded that the results for mean latencies of NS in the present study are in general agreement with other studies.

5.5.2.1. Stutterers/nonstutterers comparison

The most striking observation relating to the mean latency for S and NS was that the latency for the S was consistently longer compared to NS as reflected in Table 16. This trend was observed for all test frequencies, and for ipsilateral and contralateral measurements. The differences between the S and NS were significant ($p<0.05$) at the 2000Hz (I and C) and 1000Hz (I). No significant differences ($p>0.05$) were noted between S and NS on latency measures at 500Hz.

The analysis of variance per frequency, reflected in Table 17 suggests that 500Hz stimulus may not be sensitive to S and NS latency differences. The 500Hz is not always selected for testing by other researchers because oscillatory behaviour for the acoustic reflex is unique to 500Hz signals (Church & Cudahy, 1984). In describing oscillatory behaviour, Church and Cudahy (1984), suggest that the points of maximum and minimum slope occur as a result of the *initial response peak*. Thus, the time taken to reach from the minimum to the maximum peak is very short suggesting the reflex mechanism is responding with unusual rapidity. The effect of oscillatory behaviour is that it greatly reduces the latency. This phenomena was striking for at least three stutterers . Thus, when compared to the NS the differences were not significant at 500Hz.

Significant latency differences between S and NS did, however occur, at 1000 and 2000Hz as reflected in Table 17. The differences were observed on ipsilateral stimulation for both frequencies, whereas for 2000Hz the differences were also observed on contralateral stimulation. In the light of the overall result of the study which suggested no significant difference for latency measures generated by ipsilateral and contralateral stimulation, the present investigator suggests that these findings may have been generated by random variability. This explanation is favoured having noted the findings by Clemis and Sarno (1980a) who also did not find significant latency differences for ipsilateral and contralateral stimulation. An alternative suggestion is that the latency differences are more likely to be generated by ipsilateral rather than by contralateral stimulation. This finding is not commented on in the literature, and perhaps needs to be researched further before other speculation is offered. It is possible that ipsilateral and contralateral pathways process signals at different rates.

Nature of differences S and NS : The results in Table 16 indicate that the mean latency for S was consistently longer than for the NS. In the normal acoustic reflex system, Church and Cudahy (1984) define the ARL in a range between 75msec and 100msec and a similar range was noted for NS in the present study. Church and Cudahy (1984) suggest that the time interval between the onset of the acoustic reflex activating stimulus and the onset of the postive change in impedance in the middle ear is what is considered the latency of the reflex. The same definition of latency applies to the present study. Although, in terms of impedance change nothing appears to happens until about 70-90 msec after the onset of the stimulus, Church and Cudahy (1984) suggest that a great deal of physiological activity takes place. In attempting to detail the nature of the response, the results of EMG findings were described by Church and Cudahy (1984). It is suggested that the start of the stapedial muscle action potential occurs after an initial onset latency of 12 msec. In this time the acoustic stimulus is processed by the cochlea,, and relayed through the polysynaptic reflex arc to the stapedius muscle which then develops enough electrical activity to be detected by EMG. The time taken for this type of processing to occur with S is extended for the group as a whole in the present investigation.

The longer mean latencies have been reported to occur in pathological conditions related to retrocochler lesions (Clemis &

Sarno, 1980b; Jerger & Hayes, 1983). Since the subjects in the present study did not have eight-nerve lesion (as indicated by the tone decay test) it is suggested that the differences generated may be reflective of processing mediated at the level of the lower brainstem. Support for this finding for S on the ARLT is not available in the literature, and should be viewed as a preliminary.

Analysis of individual results indicated that some stutterers (SM5, SM6, SF1) had shorter latencies compared with the norm. For these subjects it appears that the reflex mechanism acts very quickly upon presentation of the stimulus. A fast response has been related to oscillatory as suggested for Church and Cudahy (1984). Whilst this phenomena is likely at 500Hz it does not explain the results obtained at 1000Hz and 2000Hz. The present investigator agrees with Church and Cudahy (1984) who suggest that a very short latency may be indicating that the reflex mechanism responds very quickly, therefore suggesting poor temporal management of sound in the central auditory system.

The overall result of the Taylor study is in contrast to the finding of the present study. Taylor (1990), reported that the mean latency for stutterers was shorter than of normal subjects but did not comment on the existence of oscillatory behaviour. It is possible that this behaviour may have influenced the outcome of results, by reducing the mean latency for the group. Furthermore, Taylor (1990), used only five subjects and the result could have been influenced by inter-subject variability characteristic of the ARLT.

The latency of stutterers on other electrophysiological measures mediated at brainstem level also requires consideration. It is perhaps suitable to compare the results of the ARLT with that of the BSER because the generator sites for the responses up to the level of the superior olivary complex are similar. Furthermore, a study by Clemis and Sarno (1980b) indicated that the ARLT and the BSER results are comparable on retrocochlear measures. The BSER has been investigated for stutterers and the findings of previous studies may be used to support or contradict the findings of the present study.

The study by Newell et al., (1982), supports the findings of the present study in two general respects. Firstly, the stutterers brainstem latencies were more variable. Secondly, only a subgroup of stutterers contributed to overall group differences. The variabilty of intersubject performance highlights the contention that stutterers as a group are heterogeneous with respect to their performance on central auditory measures.

With respect to the prolonged latency on BSER measures, several researchers have reported that a subgroup of stutterers display longer latencies (Stager, 1990; Papanicolaou et al., 1986; Blood & Blood 1984). These researchers have also suggested that the abnormal latencies observed are those generated at the level of the superior olivary complex in the lower brainstem. These findings could thus be viewed as support for findings for a subgroup of stutterers who have prolonged lateny in the present study.

Thus, it could be stated that for a subgroup of stutterers who had longer or shorter ARL compared with the norm, it is possible that they process auditory information at the level of the lower brain stem differently from nonstutterers. Various models have been previously suggested as to how a dysfunction at the level of the brainstem may relate to stuttering. The explanation offered by Stager (1990) appears quite plausible in the light of the results obtained in this study. Stager suggests that since some of the auditory and vocalization neural mechanisms are common to the lower brainstem , a disruption in the auditory mechanism could contribute to generating dysfluency. Further research is needed to describe the actual process that may operate in generating the dysfluency and the present researcher is of the opinion that further research may unravel the nature of auditory processes that are compromised for S.

A second suggestion offered by Stager (1990) relates directly to the present study. Stager (1990) has suggested that a delay or disruption in the auditory signal in the central auditory nervous system could disrupt the synchrony of information at the point where speech and auditory mechanisms interact. It is also likely that a delay in processing the auditory signal (Martin, 1970) results in the generation of an error signal in the auditory mechanism which provides a basis for dysfluency (Fairbanks, 1954; Mysak, 1960).

For stutterers who scored within the normal range it is likely that they , process auditory information normally at least up to the level of the lower brainstem. It is possible that processing problems beyond this level exists. Also, it is possible that the ARLT may not be a sensitive measure in revealing processing differences at the lower brainstem.

5.5.2.2. Male/female comparison

Nonstutterers

Females obtained a shorter mean latency than males. This indicates that the females NS had a faster neural conduction time (Clemis & Sarno, 1980) than the males. The sex differences were significant at 500Hz, 1000Hz and at 2000Hz on ipsilateral and contralateral stimulation. A survey of the available literature indicated that male/female ARLs have not been investigated. Thus , the results of the present study may be viewed as preliminary. A study of sex differences on other auditory measures will be reviewed, as they provide support for sex differences on auditory measures other than the ARL in the normal subjects.

Jerger and Hall (1980) have suggested that performance differences between males and females are noted on behavioural and impedance audiometry. Females seem to perform better on most measures compared with males. A summary of research cited by Govender (1989) indicated sex related differences on pure-tone testing, speech testing and impedance. Of significance to the present study are the sex differences as they relate to BSER. Govender (1989) cites studies by Stockard, Stockard, and Sharbrough,(1978); McClelland and McCrae, (1979) and Kjaer (1979) who have reported that females have significantly shorter absolute or relative latencies compared with males. These differences have been related to the lower brainstem generator sites as well as higher brainstem generator sites. Govender (1989), also investigated sex differences on the BSER. The significance of the Govender (1989) study for the present study, is that the subjects were chosen from the same age range and race group. Govender (1989), confirmed the findings of previous studies, and reported that females had shorter latencies than males. To account for the sex differences, speculative arguments have been put forth in the literature cited by Govender (1989). The most common explanations relate to the following :

- anatomical differences : the short latency for females have been attributed to anatomical differences in the corresponding segments of the auditory pathway. Females have a smaller average head and brain size.

- Variables such as body temperature and hormonal status have been cited as contributory factors.

- Govender (1989) suggested that a combination of factors may contribute to the observed sex difference. These include brain size and mass influencing volume conduction, differences in neural transmitter substrates, differences metabolic rates as well as differences in conduction times of impulses.

The present investigator agrees with the explanations put forth by previous researchers. Since the ARLT in the present investigation used an impedance method to obtain reflex latencies, the size of the external auditory meatus and the physical and physiological differences in the middle ear may have influenced results, The physical characteristics of the subjects were not controlled for in the present investigation, it is likely that these may be responsible for generating male/female differences.

Stutterers

The results of the present investigation indicates that male and female stutterers had similar latencies across the frequency range tested as reflected in Table 16. Statistical analysis (Table 17) revealed that there were no significant latency difference between male and female stutterers. The results in Table 16 indicate that females obtained longer mean latencies compared to males. Analysis of individual results indicates that three females compared to six males obtained latencies outside of the normal range. Two males (SM5,SM6) and one female (SF1) had shorter latencies compared with the norm.

The findings cannot be related to other studies, since research on sex differences with stutterers has not been investigated on the ARLT. Drawing from the research on BSER on stutterers Newman et al., (1985) found no significant differences in the neural conduction time for stutterers and subjects in the control group, but reported that females had a shorter latency compared to the males. This finding is in contrast to the findings of present study which suggested that there were sex differences for NS, but not for S. There is no available explanation for this observation. The present investigator therefore offers the following speculation.

Firstly, one needs to consider how the longer neural conduction times may contribute to stuttering. The explanation offered by Stager (1990), also applies here.

Secondly, it is possible that some stutterers (males and females) are similarly disadvantaged with respect to auditory processing at the brainstem level, and that this contributes to stuttering. In the present investigation some female stutterers have a latency that is longer than that of the female nonstutterers. It is possible that (in terms of explaining the sex ratio) females whose auditory systems have longer conduction time are more predisposed to stuttering. Since the average female appears to have a shorter conduction time, the susceptibility for disfluency is not great. Therefore, only a small number of females are predisposed to stuttering. For males however, slight increases in neural conduction time may predisppose them to stuttering and hence auditory problems.

For some stutterers who obtained short latencies it is possible- that they have poor temporal management of sound (Church & Cudahy, 1984) and that this may predispose them to stuttering. Previous models (kent, 1984; Stager,1990) suggesting how poor temporal management of sound may relate to stuttering may also apply here.

It should be emphasized that these findings are only preliminary and more research needs to be done before a conclusive statement can be made about acoustic reflex latencies and stuttering. Larger samples of male and female stutterers and nonstutterers are necessary to determine if the latency characteristics of stutterers determined in the present study are stable features.

SECTION B

5.6.1 COMPOSITE RESULTS

The results are presented as follows :

Figure 8 : The percentage pass/fail performance of stutterers and nonstutterers on individual tests in the battery are reflected.

Table 18 : Pass/fail performance for each nonstutterer (male and female) is plotted for individual tests in the battery.

Table 19 : Pass/fail performance for each stutterer (male and female) is plotted for individual tests in the battery.

<u>Pass/fail criteria for the test battery was as follows</u> :

A subject was required to have passed all individual tests to have passed the test battery. A subject was required to have failed one or more individual tests to have failed the test battery. Pass/fail criteria was derived from research by Musiek, Geurkink and Keitel, (1982) and Musiek and Geurkink, (1980).

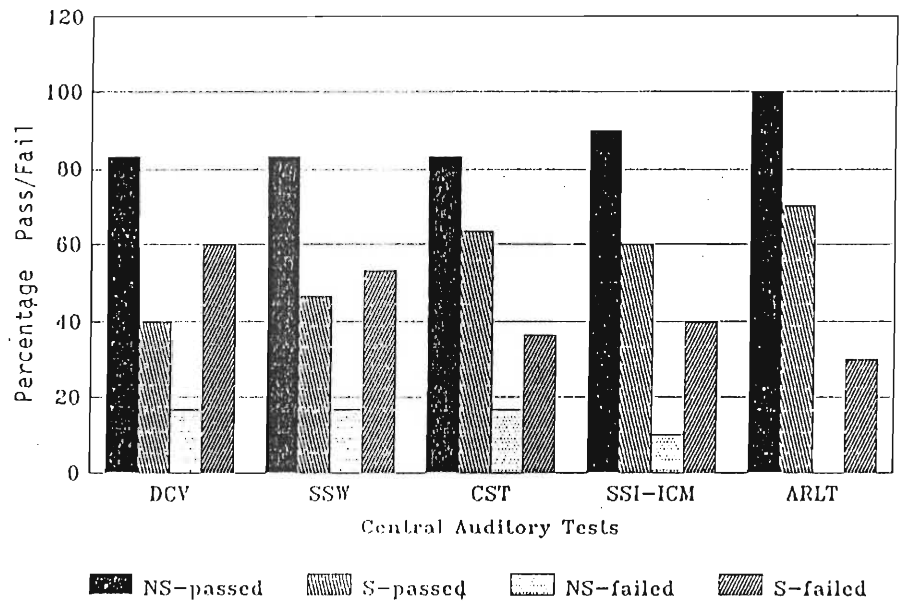

Figure 8 : Pass/fail rates in percentage for stutterers and nonstutterers on individual tests in the batterv.

<u>The results in Figure 8 indicate the following</u> :

<u>Pass/Fail Rates</u>

- on the DCV test : 25 (83.3%) nonstutterers passed the test battery compared with 12 (40%)

stutterers who passed the test. 5 (16.67%) nonstutterers failed the test compared with 18 (60%) stutterers who failed.

- on the SSW test : 25 (83.3%) nonstutterers passed the test whilst 14 (46.6%) stutterers passed the test. 5 (16.67%) nonstutterers failed compared with 16 (53.3%) stutterers who failed the test.
- on the CST test : 25 (83.3%) nonstutterers passed the test compared with 19 (63.3%) stutterers who passed. 11 (36.6%) stutterers failed the CST compared with 5 (16.67%) nonstutterers who failed failed the test.
- on the SSI-ICM test : 27 (90%) nonstutterers passed the test compared with 18 (60%) stutterers who passed. 12 (40%) stutterers failed the the test whereas 3 (10%) nonstutterers failed.
- on the ARLT test : All of the 30 (100%) nonstutterers passed 21 (70%) stutterers passed. 9 (30%) stutterers failed.

The results indicated that generally in excess of 80% nonstutterers passed the tests whilst performance for stutterers varied on individual tests as reflected above.

SUMMARY

The higest failure rate for stutterers was on the DCV test (60%) whilst the highest pass rate for stutterers was on the CST (63.3%). Nonstutterers consistently obtained better pass rates compared with stutterers. Nonstutterers and stutterers obtained better pass rates on monotic than dichotic tests. The average difference in pass/fail rates between stutterers and nonstutterers was approximately 30% with the difference greatest on the DCV test (43.3%) and lowest on the CST (20%).

Table 18 : Nonstutterers (male and female) performance on individual tests included in the battery

SUBJECT	DCV	SSW	CST	SSI-ICM	ARLT	INTERPRETATION
NSM1	P	P	P	P	P	Passed all
NSM2	P	P	P	P	P	Passed all
NSM3	P	P	P	F	P	Failed on monotic
NSM4	P	P	P	P	P	Passed all
NSM5	F	P	P	P	P	Failed on dichotic
NSM6	P	P	P	F	P	Failed on monotic
NSM7	P	F	P	P	P	Failed on dichotic
NSM8	P	P	P	P	P	Passed all
NSM9	P	F	P	P	P	Failed dichotic
NSM10	P	P	P	P	P	Passed all
NSM11	P	P	F	P	P	Failed on dichotic
NSM12	F	F	F	P	P	Failed dichotic
NSM13	P	P	P	P	P	Passed all
NSM14	P	P	P	P	P	Passed all
NSM15	F	P	P	P	P	Failed dichotic

cont/.....

SUBJECT	DCV	SSW	CST	SSI-ICM	ARLT	INTERPRETATION
NSF1	P	P	P	P	P	Passed all
NSF2	P	F	P	P	P	Failed dichotic
NSF3	P	P	P	P	P	Passed all
NSF4	P	P	P	P	P	Passed all
NSF5	P	P	F	F	P	Failed dichotic and monotic
NSF6	P	P	P	P	P	Passed all
NSF7	P	P	P	P	P	Passed all
NSF8	F	P	P	P	P	Failed dichotic
NSF9	F	P	P	P	P	Failed dichotic
NSF10	P	F	P	P	P	Failed dichoitc
NSF11	P	P	P	P	P	Passed all
NSF12	P	P	P	P	P	Passed all
NSF13	P	P	F	P	P	Failed dichotic
NSF14	P	P	P	P	P	Passed all
NSF15	P	P	F	P	P	Failed dichotic

Key : P - Passed

F - Failed

<u>Results reflected in Table 18 indicates the following</u> :<u>Nonstutterers</u>

- 15 (50%) nonstutterers were regarded as having failed the test battery and 15 (50%) passed.
- the majority of nonstutterers 13 (86.6%) who failed on the test battery, failed on a single test measure.
- 2 nonstutterers failed 2 or more tests.

- 5 nonstutterers failed the DCV test, SSW test and CST test. 3 nonstutterers failed the SSI-ICM test and none failed the ARLT test.

MALE/FEMALE COMPARISON

Nonstutterers

- a similar number of males (8) and females (7) failed the battery, and similar numbers passed the battery.

Table 19 : Performance of individual stutterers on the test battery

SUBJECT	DCV	SSW	CST	SSI-ICM	ARLT	INTERPRETATION
SM1	F	F	F	P	P	Failed dichotic tests only
SM2	F	F	F	F	P	Failed dichotic and monotic
SM3	P	P	P	P	P	Passed all tests
SM4	F	P	F	F	F	Failed dichotic and monotic
SM5	P	F	P	F	F	Failed dichotic and monotic predominatly brainstem level tests
SM6	F	F	F	P	F	Failed dichotic and monotic
SM7	F	P	P	P	P	Failed dichotic
SM8	F	P	P	P	F	Failed dichotic and monotic
SM9	F	P	P	F	F	Failed dichotic and monotic
SM10	P	P	P	P	P	Passed all tests
SM11	P	F	P	F	P	Failed dichotic and monotic
SM12	F	P	F	P	P	Failed dichotic
SM13	F	F	P	P	P	Failed dichotic
SM14	F	F	F	F	P	Failed dichotic and monotic
SM15	P	F	P	P	F	Failed dichotic and monotic

cont/.....

SUBJECT	DCV	SSW	CST	SSI-ICM	ARLT	INTERPRETATION
SF1	P	F	P	F	F	Failed dichotic and monotic predominatly brainstem
SF2	F	F	F	P	P	Failed dichotic
SF3	F	F	F	P	P	Failed dichotic
SF4	P	P	P	P	P	Passed all tests
SF5	F	F	P	F	P	Failed dichotic and monotic
SF6	F	F	F	F	P	Failed dichotic and monotic
SF7	P	P	P	P	P	Passed all tests
SF8	F	F	P	F	F	Failed dichotic and monotic
SF9	P	P	P	P	P	Passed all tests
SF10	F	F	P	F	P	Failed dichotic and monotic
SF11	F	F	F	P	P	Failed dichotic
SF12	P	P	P	P	P	Passed all
SF13	F	P	F	F	F	Failed dichotic and monotic
SF14	P	P	P	P	P	Passed all
SF15	P	P	P	P	P	Passed all

Key : P - Passed

F - Failed

The results reflected in Table 19 indicate the following :

- 8 (26.6%) stutterers passed all tests.
- The majority of stutterers (22; 91%) who failed the battery, failed on 2 or more tests.
- 7 (23.3%) stutterers failed dichotic tests only.
- 15 (50%) stutterers failed dichotic and monotic tests of which 2 stutterers failed predominatly monotic tests.

The results indicate that not all stutterers displayed central auditory processing problems. The performance of the stutterers could best described as varied.

MALE/FEMALE COMPARISON

- 6 female stutterers compared with 2 male stutterers passed all tests.
- More males than females failed individual tests in the battery. Thus, female stutterers appeared to perform better than male stutterers.

5.6.2. COMPOSITE DISCUSSION

The discussion that follows relates to the following :

- Pass/fail rates of stutterers and nonstutterers on individual central auditory tests
- Performance profile for individual stutterers and nonstutterers on the test battery.
- Comparison with previous research
- Theoretical integration of findings.
- Male/female comparisons for stutterers and nonstutterers within each group.

5.6.2.1. Pass/fail rates of stutterers and nonstutterers on individual central auditory tests

The pass/fail criteria for individual tests have been described with previous test results and are therefore not repeated.

Nonstutterers

The results reflected in Figure 8 indicate that in excess of 80% of nonstutterers passed each test. A 100% pass rate was observed on the ARLT , and 90% pass rate on the SSI-ICM test. This result indicated that the majority of nonstutterers did not experience processing problems on these measures. The average pass rate on dichotic tests was lower (83.3%) than the monotic tests (95%) possibly reflecting that dichotic tests were more stringent and sensitive measures of central auditory processing. The fail rate for nonstutterers was less than 20% on the individual tests. These results appear to reflect a normal distribution of performance for nonstutterers. The results for the stutterers are in contrast to that for nonstutterers. A description of results to this effect follows.

Stutterers

The results reflected in Figure 8 indicate that the greatest number of stutterers (18) 60% failed on the DCV test compared with other tests. Twelve (40%) stutterers passed on the DCV test. On the SSW test 16 (53.3%) stutterers failed the test whilst 46.6% passed and on the CST 63.3% passed the tests whilst 36.6% failed. The results on dichotic tests suggest that the DCV test was a more robust measure compared with the SSW test and CST in revealing atypical processing for stutterers. The CST had a greater pass rate compared with the other two dichotic measures suggesting that it may not be as sensitive as the SSW and DCV tests in revealing central auditory processing problems. The average pass rate for stutterers on the dichotic tests was approximately 50%.

On the monotic tests, a greater number of stutterers 21 (70%) passed the ARLT compared with 18 (60%) stutterers who passed the the SSI-ICM test. This suggests that the SSI-ICM test was possibly more sensitive to brainstem level problems than the ARLT since more stutterers failed the test compared with the ARLT. The average pass rate for stutterers on monotic tests was 60%

Stutterers/ Nonstutterers comparison

The pass/fail rate results indicate that whilst in excess of 80% of nonstutterers passed individual tests, the results for the stutterers were more varied. The highest pass rate for the stutterers was on the CST (63.3%) and the ARLT (70%). These results are in contrast to the relatively low pass rates for stutterers on the DCV test (40%) and the SSW test (46.6%). The greatest performance diference between S and NS was observed on the DCV test on which 83.3% of nonstutterers passed the test compared to 40% of stutterers who passed the test. The pass/fail rate differences between S and NS was, on average, in excess of 30% on the test battery. It was only on the CST that the difference was 20% once again highlighting that the performance of NS was consistently higher than for S on all tests. The results suggest that the DCV test and the SSW test were most sensitive in highlighting S/NS performance diferences. However, the SSI-ICM test and ARLT however, could also be regarded as a sensitive measures since a 30% difference in pass/fail rates for S and NS were observed. These results confirm statistical analysis of variance on individual tests which indicated that the CST was the only test in the battery which did not reveal significant S/NS differences.

Dichotic tests : The DCV test was the most sensitive measure in revealing S/NS differences and two explanations are offered in this regard. Firstly, the nature of the stimuli i.e. CVs may have contributed to the sensitive nature of the test. DCVs stimuli are meaningless and are very closely aligned in dichotic format thereby stressing the central auditory processing mechanisms. Compared with other dichotic stimuli which carry semantic information (words and sentences), the DCVs are more difficult to process since subjects cannot rely on the semantic aspect of processing for accurate recall. Secondly, the DCV test is a sensitive test because it provides an indication of ear advantage and hence cerebral dominance for speech perception, which is purported to be atypical in stutterers (Blood & Blood, 1989b). Hence, it appears to provide a sensitive measure of processes that are likely to be compromised for stutterers.

SSW test also highlighted performance differences between stutterers. Meaningful word stimuli were used and subjects could to an extent depend on the semantic cues for accurate recall. In addition to providing some information about atypical cerebral dominance, the processes challenged in the SSW test include binaural integration and temporal sequencing, and the results for the stutterers suggested that these processes may be compromised more so than for nonstutterers. On the CST, the predictable nature of meaningful stimuli possibly increased the redundancy in the central auditory nervous system thus causing less stress. For stutterers, it is likely that the auditory processing difficulties become apparent when the system is stressed sufficiently. Although stress was created by using a dichotic format and reducing the intensity of the target signal, it was possibly not sufficient to reveal breakdown in performance.

Monotic tests : The SSI-ICM test appeared to be a more sensitive measure of brainstem level dysfunction compared with the ARLT. The comparison between the tests however, need to be approached with caution since one measure uses speech stimuli and the other is an electrophysiological measure. It is possible that the SSI-ICM test was more sentive as it was able to stress the system by using an ipsilateral competing message as well as reducing the intensity of the target signal. In doing so, the redundancy in the auditory system was reduced thereby creating stress. The ARLT uses pure-tone stimuli to investigate the latency of the system. It is possible that the stress created in the central auditory system was not sufficient to reveal central auditory processing problems for some stutterers. It is also possible that central auditory processing is not compromised at all levels of processing for all stutterers, and that that even if stress were created that stutterers may still perform normally since they do not have a central auditory processing problem at that level of processing, which in this instance is the brain stem. A similar explanation could apply to the levels of processing challenged by the CST.

Thus, pass/fail rate on tests may not depend only on the extent of stress created in the central auditory system but also on the intactness of the individuals processing at various levels of the central auditory nervous system challenged by the tests.

5.6.2.2. <u>Performance profile for individual stutterers and nonstutterers on the central auditory test battery</u>

A performance profile of individual nonstutterers and stutterers are presented in Tables 18 and 19 respectively. The results are described for subjects as they pertain to dichotic tests (sensitive primarily to cortical level processing functions) and SSI-ICM test and ARLT which are reportedly sensitive to brainstem level processing difficulties. The tests have been categorized in this manner to facilitate ease of analysis. and discussion.

Using the above-mentioned categories four types of performance trends were isolated. These include :

i. Normal performance on all tests

ii. Failure on monotic (brainstem level sensitive tests) i.e. SSI-ICM test and ARLT.

iii. Failure on dichotic tests only.

iv. Failure on monotic (brainstem level) tests and dichotic tests.

Nonstutterers

The results for the nonstutterers indicate that 15 (50%) nonstutterers passed all tests. Two nonstutterers failed on monotic tests and 12 nonstutterers failed on dichotic tests only whilst two nonstutterers failed on dichotic and monotic tests. Since the majority (86.6%) of nonstutterers who failed typically failed one test only, the results on the test battery do not provide collaborative support for substantial auditory processing difficulties for the nonstutterers. Only one nonstutterer (SM12) failed three measures. The results thus indicated that 15 (50%) nonstutterers failed the test battery. This relatively high failure rate for nonstutterers is possibly due to the following :

i. Stringent pass/fail criteria : Stringent criteria were used to determine pass/fail performance on individual tests as well as the test battery as suggested by Musiek et al., (1982). Thus, any slight variation from the norm on individual tests would have caused the subject to fail the test, and hence the test battery. However, the stringent criteria was retained so that subtle performance differences would not be missed. Furthermore, since a variety of functions are challenged by the central test battery, exclusion of poor performance on one test may lead the researcher to erroneously suggest that the individual performed normally on the battery when this was not true.

ii. This finding is perhaps not unexpected when one considers that the nature of the tasks are unusual and stresses the central auditory system in a manner that is not encountered in daily listening. The researcher noted that stutterers' and nonstutterers' subjective opinions were that the tests were stressful. The subject NSM12 who in particular performed atypically on the three dichotic tests reported that the tests were stressful.

iii. Fluency and performance on a central test battery appear to be positively correlated in the light of findings by Wynne and Boehmler (1982) and Nuck et al (1987). Both researchers reported that normally nonfluent subjects perform significantly poorer than subjects who are very fluent. It is possible that speech of the nonstutterers who failed the battery in the present study may not have been completely fluent. It is likely that the subject who failed three tests in the battery has central auditory processing differences related to normal nonfluency. However, the normal nonfluency was not measured in the present study and therefore a conclusive statement cannot be made.

iv. Central auditory processing difficulties are often noted in learning disabled individuals (Roeser et al., 1983) in individuals with temporal lobe epilepsy (Todebrush, 1982) and with multiple sclerosis (Hicks, 1982). The subjects in the present study did not report any of the conditions described. The central auditory processing problem could therefore not be linked to any specific dysfunction in this instance.

Stutterers

Eight stutterers passed all tests in the test battery. None of the stutterers failed brainstem level measures only. However, the results for two (6.6%) (SM5 and SF1) stutterers could be described as predominantly failing brainstem level measures since these individuals failed mainly brainstem level tests and only one dichotic test. These individuals failed the SSW test in particular and Hall and Jerger (1978) suggest that when this combination of results occur then it is likely the the problem is with processing at the brainstem level since the SSW test may also be indicative of brainstem level dysfunction, although performance deficits are traditionally considered to be cortical in nature (Hendershot, Wood & Karnuta, 1981).

Seven (23.3%) stutterers failed dichotic tests and passed brainstem level tests. The majority of stutterers who failed the DCV test also failed the SSW test. 15 (50%) stutterers failed monotic (brainstem level) and dichotic (cortical) measures. The results indicates the following :

The frequency with which stutterers failed the individual tests in the battery appears to provide collaborative evidence for central auditory processing poblems. Stutterers failed an average of three tests in the battery. Not all stutterers performed similarly thus reflecting the heterogeneous nature of stutterers' performance on central auditory processing measures.

A subgroup type description can aptly describe the performance characteristics of the stutterers. Whilst one subgroup performed normally on all central auditory tests , another sugroup failed tests dichotic and brainstem level tests. Yet another subgroup failed only on dichotic tasks. The majority of stutterers (50%) failed on brainstem and on dichotic tasks whilst only 6.6% failed predominantly on brainstem level tests.

Stutterers/Nonstutterers comparisons

The pass fail rates on the test battery indicated that 15(50%) nonstutterers failed the test battery whilst 22 (73.3%) stutterers failed the battery. The crucial difference in performance between S and NS was that 86.6% of nonstutterers who failed the test battery failed on one measure only. This is in contrast to the stutterers who failed the test battery. Whilst 9% of stutterers failed one test only and 91% failed two or more tests. Thus the stutterers failed a greater frequency of tests than nonstutterers. Statistical analysis indicated significant differences in pass/fail performance between stutterers and nonstutterers (χ^2=19.867; p<0.05; df=1) on the test battery. The performance of the nonstutterers could be considered as being within a normal distribution when the pass/fail rates are considered on individual measures. For the nonstutterers who failed on individual tests, errors were few. The results of the present study thus provided collaborative evidence suggesting central auditory processing problems for some stutterers compared with nonstutterers.

5.6.2.3. Theoretical integration of findings for stutterers

The explanations that follow are as per subgroup of performance for stutterers.

a. Normal performance on all tests : For stutterers who performed normally on the test battery two interpretations of the results are offered.

i. It is possible that this subgroup of stutterers demonstrated no problems on central auditory processing tasks. For this group, it is likely that processes other than auditory processes are compromised, thereby generating stuttering. This suggestion appears plausible when one considers the range of theoretical perspectives that have been offered to describe the nature of stuttering. Eisenson and Ogilvie (1983) offer the traditional division of theories into stuttering as a manifestation of a personality disorder, stuttering as a learned behaviour, and stuttering as a physiological defect. The present study considered only one aspect of the physiological mechanism, and it is possible that other physiological processes may be compromised for stutterers. In addition, the explanations that stuttering is a neurotic disorder and a learned behaviour are also possible. These alternate explanations that may provide insight into the nature of the stuttering for those stutterers who performed within normal limits on all measures in the present study. Noting the heterogeneous nature of stuttering it is possible that a combination of factors need to be considered to explain the nature of the disorder.

ii. It is possible that the tests used in the present investigation were not sensitive enough to assess subtle nature of auditory processing difficulties. Perhaps other measurements techniques and more stressful tests would be capable of generating performance differences between this group of stutterers and normal subjects.

b. Failure on monotic/brainstem level tests : One of the outstanding observations made in the present study was that none of the stutterers failed only monotic brainstem level tests. Only two stutterers could be described as having failed predominantly brainstem level tests. For these subjects it is likely that the brainstem level of function is compromised for auditory processing. A processing model explaining how atypical brainstem processing may relate to stuttering may be considered. The models suggested by Stager (1990) and Wynne and Boehmler (1982) as well as those described by Mysak (1960) and Martin (1970) can be applied to explaining these findings. A restatement of these theories is not necessary at this stage as they have already been described in explaining results for individual tests. The results of the present investigation indicated that it was unlikely that stutterer would fail on brainstem level tests in isolation. However, there is a possibility that for a subgroup of stutterers only brainstem level processing difficulties may occur, though this trend was not strongly apparent in present investigation.

These findings are in contrast with previous literature (Stager, 1990; Hageman & Greene,1989) which suggest that brainstem level processing differences were evident for stutterers. It should be noted that previous studies have typically used single measures that have only assessed brainstem level auditory functioning. In doing so other levels of functioning that may also have been compromised were not considered.

c. Stutterers failure on dichotic tests only : This subgroup of stutterers passed brainstem level tests but experienced problems predominantly on dichotic tasks. The majority of the stutterers in this category failed as a result of their performance on the DCV test i.e. they obtained atypical ear advantages. Stutterers also failed the SSW test and CST though performances were better on these measures compared with the DCV test.

If one considers the processes/functions compromised for stutterers on the dichotic tests it is apparent that for each type of stimulus a different process was examined. However, it should be noted that the processes are likely to overlap and that ear advantage/cerebral dominance did influence the processing of the various stimuli to differing degrees. The processes challenged by dichotic tests are higher level (cortical) integrative functions, as opposed to lower level (brainstem) attentive/arousal factors (Hageman & Greene, 1989; Hendershot et al., 1981).

For the stutterers who failed on the dichotic tests, the explanations linking stuttering and central auditory processing include the Orton-Travis theory, right hemisphere processing theory inteference theory. These theories and explanations have been described previously and are therefore not repeated.

d. Failure on monotic and dichotic tests. The results indicated that for atleast 50% of stutterers processing problems were noted on the dichotic as well on monotic (brainstem level) tests. This pattern of results indicate that processing difficulties appeared to have occured at cortical and brainstem levels. The explanations offered by the present researcher to explain the performance in this subgroup of stutterers were derived from Yeudall's neuropsychological theory. The theory is based on the premise that the activation balance between the cerebral hemispheres of the brain favours the nondominant hemisphere in stutterers whilst the dominant hemisphere is favoured in normal subjects. Evidence to this effect in the present study is generated by some stutterers atypical ear advantage on the DCV test. More importantly however, is that stuttering is considered a multilevel neurological phenomenon that involves that involves cortical and subcortical structures (Yeudall, 1985).

In describing the flow of sensory information (auditory information included) Yeudall suggests that the information is relayed to the brainstem and then to the posterior association regions of each hemisphere. The present researcher suggests that it is likely that the processing of information at the level of the brainstem may be compromised for some stutterers. As a result the auditory information channeled to the midbrain and thalamic levels may have already been influenced by processing problems at the lower levels of the brainstem.

In explaining the process further, Yeudall (1985) suggests that a process of differential weighting applies at the midbrain and thalamic levels so that the information is "gated" to one hemisphere or the other depending on the nature of the incoming stimuli. The information is then processed in the context of the individuals memory systems as well as other regulatory brain structures which serve to modify the flow of information to regions of the cerebral cortex. The present researcher suggests that for some stutterers the auditory information may be channeled to the right hemisphere which is typically unsuited speech type stimuli and in an interactive process generates dysfluency.

Based on the results of the present study it is suggested that whilst the cortical function is atypical, that processing difficulties at brainstem level may form the basis for processing problems that that are evident at cortical level especially for this subgroup of stutterers. The influence of subcortical function is suggested by Musiek and Pinheiro (1985) who report that asymmetrical brainstem pathways may contribute to cortical asymmetries. In the present investigation this feature was evident on the performances of some stutterers on the SSI-ICM test who performed better with left than right ears and who had atypical ear advantage on the DCV test. The present researcher suggests that subcortical and cortical auditory systems be viewed as part of an integrated system that may be generating auditory processing difficulties for stutterers. The central auditory processing system possibly forms part of a complex mechanism which may generate dysfluency.

The overall result for stutterers suggest heterogeneity in processing of auditory information. This result further confirms the general hypothesis that stuttering is not a unitary disorder. It is in keeping with Yeudall's description of stuttering as a broad spectrum disorder with a wide range of symptoms that are dependent on specific neural systems that are dysfunctional. In this instance the processing in the central auditory system may be compromised in various combinations that may be related to the ultimate generation of dysfluent behaviour.

5.6.2.4. <u>Comparison with previous studies</u>

The results of individual tests have been compared with previous research. What remains is to compare the results of the test battery with previous research. It should be noted that the results can only be compared with studies that have used test batteries. The literature in general does not comment on analysis of tests for individual subjects and, therefore, comparison of this nature is not possible.

Amongst the early studies which used a battery of test to examine stutterers performance on central auditory tasks was that of Hall and Jerger (1978). The study revealed that three measures were sensitive in detecting differences between stutterers and normal speakers. These measures included the SSW test, the SSI-ICM test and the acoustic reflex amplitude function. The results obtained for the SSW test and the SSI-ICM test support the results of the present study. This pattern of results led Jerger and Hall (1978) to conclude that for stutterers the brainstem level of function was compromised. These findings are in contrast to the findings of the present study which did find processing problems at the brainstem level but in combination with cortical levels of processing. Only a small percentage of stutterers in the present study had predominantly brainstem level processing difficulties. The Hall and Jerger (1978) study did not use the DCV test as part of the test battery and was therefore not sensitive to cortical level function.

Toscher and Rupp (1978) used the SSI-ICM and the SSI-CCM tests which could be considered as a battery. The results led Toscher and Rupp to suggest that since the SSI-ICM test was sensitive to auditory processing differences for stutterers they had difficulties within brainstem level processing. However, it should be noted that that the SSI -CCM test was not considered sensitive measure for processing problems in stutterers. The findings of Toscher and Rupp concurred with that of Hall and Jerger (1978). The present researcher is of the opinion that because sensitive measures of cortical level processing were not included as part of the test battery the conclusion relating stuttering only to brainstem level function was shortsighted. Similar criticisms apply to studies done by Hageman and Greene, 1989; Stager, 1990 who used single test measures, and have on the basis of the result commented on possible site of processing difficulties. The present researcher is of the opinion that only with a battery of tests that stress the entire auditory processing system can a comment be made on the nature of processing difficulties for stutterers.

Whilst the studies reviewed thus far have typically cited the brainstem as the possible level of auditory processing difficulty, the test battery used by Hawver (1978) revealed findings to the contrary. The time-compressed and filtered speech tests that were included in the battery that purported to be sensitive to brainstem level processing problems did not reveal any significant processing difficulties between stutterers and the normal control group. However, the dichotic tests appeared to be more sensitive in revealing processing differences between stutterers and control group subjects. The result of the Hawver study provided support for the present study for the performance of at least one group of stutterers in the present investigation. Hawver (1978) does not comment on individual performance on tests.

Other studies have not provided support for central auditory processing problems in stutterers although a test batttery was used. Pinsky and MCAdam (1980) used a variety of techniques and did not find performance differences between stutterers and the normal control group. However, a small sample was used and it is possible that lack of significant differences could be related to this factor. In addition , group analysis of data as opposed to individual analysis may have revealed results to the contrary.

The reasons that the present study showed greater subgroupings of stutterers who had auditory processing difficulties are related to two issues :

i. All the stutterers in the present study reported family history of stuttering. Janssen et al.,(1990) have suggested that those stutterers with a family history of stuttering may be individuals whose dysfluency may be a manifestation of an inherited neuromotor disorder. The present researcher suggests that auditory processing difficulties may contribute to the stuttering disorder. Perhaps of significance for this study is Jannsen et al., (1990) suggestion that to increase the power of studies to detect differences that it is necessary to divide subjects on the basis of family history and sex. In doing so, differences that were more subtle in other studies became more apparent in the present study. However, even with this group of stutterers, performance on central auditory processing tests were heterogeneous in nature suggesting that other factors may need to be considered in further differentiation of subgroups.

ii. Data analysis : The choice of statistical analysis i.e. phi-coeficient on the DCV test was more stringent than those used in other studies (Hawver, 1978; Rosenfield & Goodglass, 1980). This led to the outcome where more stutterers were classified as having atypical ear advantages than would otherwise have been reported when using other methods of analysis.

The present researcher analysed group and individual data and this type of analysis highlighted the heterogeneous nature of performance of stutterers on the central auditory test battery. Comparison with previous research highlights two major points : - The need to used a test battery that is able to assess a wide range of auditory processes at cortical and subcortical levels.

- The need for analysis of data per individual is necessary because the stutterers as a group are heterogenous by nature.

5.6.2.5. <u>Male/ female comparisons</u>

Nonstutterers

The analysis of results on individual tests indicated no significant differences between males and females except on the ARLT. The results reflected in Table 18 indicated that similar pass/ fail rates for males and females. It therefore appears the results on the test battery confirm the findings of individual tests which revealed no significant differences (χ^2=0.133, df=1, p>0.05) between males and females on all measures except the ARLT. The significant sex difference on the ARLT suggests that males and females may reflect perform differently on electrophysiological measures (ARLT, and BSER) but that there are negligible processing differences on tests using speech stimuli presented in complex forms.

Stutterers

Whilst no significant differences were observed on individual tests, it appeared that female stutterers performed better than the male stutterers. On analysis of individuals performance profiles on the test battery (Table 19) it was noted that six female stutterers compared to two males passed all tests suggesting that in the present study, female performance was less compromised. Statistical analysis indicated that this difference was significant ($\chi^2 = 8.66$, df=1, $p<0.05$). Two explanations are offered to this effect.

i. Processes other than central auditory processes may be compromised for the female stutterers who passed the test battery. It is possible that the tests used were not capable of stressing the central auditory nervous system sufficiently to highlight problems, should they exist.

ii. It is possible that females are less susceptible to auditory processing difficulties that may contribute to stuttering and thus are less predisposed to stuttering than males. For the females who displayed auditory processing problems it is likely that this predisposition contributes to stuttering.

Theoretical speculation related to male/female performance differences for stutterers were presented for individual tests and are therefore not repeated. However, a summary of relevant explanations is provided.

a. Dichotic tests : The study indicated that male stutterers performed marginally poorer than female stutterers on the ditchotic tests in the battery. Their performance differed with respect to ear advantage on the DCV test and on error scores and reversals on the SSW test.

Yeudall (1985) cites research evidence that has suggested that in females the left hemisphere grows larger and sooner than that of the male and that this may contribute to lateralization of language being established sooner in females. Flor-Henry further expanded this contention in (1983) and has suggested that from infancy gender differences in lateralization of language is different for males and females, thus leading to males being more vulnerable than females to atypical cerebral lateralization. The results of the DCV test in the present study support this contention for the stutterers i.e. female stutterers demonstrated typical patterns of dominance to a greater extent than male stutterers. Developmentally more males appear to be predisposed to atypical cerebral lateralization than females and hence, more males than females are dysfluent. This is a rather simplistic explanation for the sex ratio and needs to be considered in combination with other explanations for the sex ratio to provide a more comprehensive picture.

b. Monotic tests : Male and female stutterers performed similarly on the SSI-ICM test but their performances differed on the ARLT. Six males compared with three females failed the test. For male stutterers the performance on the ARLT appeared to be more varied, with some males having obtained prolonged latencies and others having obtained shortened latencies. For females, the trend appeared to be that of prolonged latency. These results appear to suggest that males and females may differ in their abilities to process sound at brainstemstem level. Yeudall's (1985) suggestion that shorter brainstem latencies in male stutterers may be influenced by the depletion of brainstem norepinephrine could explain the sex differences observed in the present study.

The findings of the present study should be viewed as preliminary and only further research will confirm whether the performance differences observed between males and females is a stable trend.

5.7. <u>**TEST-RETEST RELIABILITY**</u>

The test-retest reliability was conducted to determine whether the results generated in the study were reliable or not. The Pearson-R correlation used to correlate test-retest data indicated that generally there was a relatively high positive correlation (raw data in Appendix V) on most test-retest measures with the exception of the ARLT. It should be noted however, that on the ARLT the subjects scored in the same <u>range</u> of scores as on the first test performance. Variability on physiological measures such as this is not unusual (Clemis & Sarno, 1980a; Church & Cudahy, 1984). This suggests that further research using ARLT should consider the range of scores that are normal rather than actual acores in correlation measures. It could therefore be stated that the test-retest reliability was high in this investigation suggesting that the test measures were relatively stable in assessing central auditory performance in the sample selected.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

6.1. SUMMARY

The objectives of the investigation were firstly, to compare the performance of stutterers and nonstutterers on a battery of central auditory tests and secondly, to compare the performances of males and females within each group. The subjects included sixty adults with a mean age of 25.5 years of whom thirty were stutterers (15 males and 15 females), and thirty were nonstutterers (15 males and 15 females). The stutterers and nonstutterers were chosen according to predetermined criteria. The test battery included the Dichotic Consonant-Vowel Test, the Staggered Spondaic Word Test, Competing Sentences Test, Synthetic Sentence Indentification Test-Ipsilateral Competing Message, and the Acoustic Reflex Latency Test.

6.1.1. STUTTERER/NONSTUTTERER COMPARISONS

The performance of stutterers and nonstutterers were compared on each of the above-mentioned tests. The results indicated the following :

i. Dichotic Consonant-Vowel Test : No significant performance differences were noted between S and NS with regard to accuracy and double correct scores, although the NS scored marginally better than the S. Performance differences between S and NS were noted with respect to ear advantages. The majority of nonstutterers (80%) obtained REA which typically reflects performance in normal-hearing right-handed adults. Ear advantages for 60 % of stutterers were regarded as atypical (NEA and LEA) and 40% of stutterers obtained REA. These results indicated that a subgroup of stutterers processed dichotic CVs atypically suggesting that stutterers may have atypical cerebral dominance for auditory processing of speech sounds. Atypical cerebral dominance for speech/language processing has been linked to stuttering (Kent, 1984; Rastatter & Dell, 1987 a & b).

ii. Staggered Spondaic Word Test : The analysis of variance indicated that S and NS performed significantly differently with respect to error scores and reversals. The NS made the greatest number of errors on the left competing condition whilst S made a similar number of errors on the right competing condition and the left competing condition. A slight REA was noted for NS whilst this trend was not evident for S. The percentage correct score on the SSW test indicated that the mean overall difference between S and NS were of a subtle nature. A subgroup of stutterers performed normally on the test whilst another subgroup had errors and reversals than is usually observed on the test (Katz, 1986).

The results appear to support the contention that some stutterers process auditory information differently from nonstutterers. It is concievable that the interference theory as put forth by Hawver (1978) may be relevant to explain present findings for the subgroup of stutterers who performed poorly on SSW test.

iii. Competing Sentences Test : No significant performance differences ($p>0.05$) were noted between the performance of S and NS on the Competing Sentences Test. However, S made a greater number of errors compared with the NS. The NS made fewer errors on the right ear whereas this trend was not evident for S. A subgroup of stutterers made more errors than is usually evident on the CST. This implied that there were no significant central auditory processing differences between S and NS on CST. The CST was possibly not capable of stressing the auditory system sufficiently to reveal S/NS differences since it uses sentence stimuli and subjects are able to rely on semantic cues for processing.

iv. Synthetic Sentence Identification test - Ipsilateral competing message. S and NS performed significantly ($p<0.05$) differently on the -10dBMCR condition of the test, and the performance difference approached significance at the -20dBMCR condition. A better right ear performance was observed for the NS whereas this trend was not evident for S. Both groups made fewer errors on the 0dBMCR and -10dBMCR conditions. A subgroup of stutterers performed within the normal range whilst another subgroup of stutterers obtained scores that were considered to be outside of the normal range.

The SSI-ICM test is purported to be sensitive to brainstem level auditory processing difficulties. Therefore, for the subgroup of stutterers who performed poorly on this measure a suggestion of a brainstem level processing problem is likely in the light of research by Hall and Jerger, 1978, and Hageman and Greene, 1989; Stager, 1990 Theoretical links between stuttering and central auditory processing problems at brainstem level by Stager, 1990 and Martin (1970) and the present researcher shares these theoretical perspectives.

v. Acoustic Reflex Latency Test : Statistical analysis of latency measures indicated significant differences between S and NS at 1000Hz and 2000Hz. S obtained longer latencies than NS at these stimulus frequencies suggesting that results indicated longer neural conduction times for S than NS. However it should be noted that only a subgroup of stutterers obtained latencies outside of the normal range implying that for this subgroup poor temporal management of signals was evident and that this processing difference may be related to stuttering (Stager,1990)

The analysis of results for the individual tests indicated that S and NS performed significantly differently on four of the five central auditory tests implying that the test battery is sensitive to stutterer/nonstutterers differences. Stutterers' performance was varied on the central auditory tests.

Pass/fail performance on the test battery

The analysis of pass/fail rates on the test battery indicated the following :

i. In excess of 80% of nonstutterers passed all tests included on the test battery. Stutterers performance was more variable. On average a pass rate of 50% was obtained for stutterer on tests in the battery.

ii. The greatest pass/fail rate difference between S and NS was noted on the DCV test on which 83.3% of nonstutterers passed compared with 40% of stutterers. This suggested that the DCV test was a sensitive measure in the battery revealing stutterer/nonstutterer differences.

iii. The lowest pass/fail rate difference between S and NS was observed on the CST.

iv. Nonstutterers obtained consistently higher pass rates compared with stutterers.

Analysis of individual performance profiles on the test battery

The analysis of results indicated that 50% of nonstutterers failed the test battery whilst 73.3% of stutterers failed the test battery.Statistical analysis indicated that a significant difference ($p<0.05$) between the performance of stutterers and nonstutterers on the test battery. The crucial difference was that 86.6% of stutterers who failed the test battery on a single test. This is in contrast to the results for stutterers whereby 91% who failed the battery failed on two or more tests thus providing collaborative support for central auditory processing problems for stutterers as compared to nonstutterers.

The analysis of results for individual stutterers on the test battery revealed the emergence of four types of performance profiles. A subgroup of stutterers (26.6%) performed normally, whilst another subgroup of stutterers (23.3%) failed on the dichotic (cortical) tests only. The majority of stutterers (53.3%) failed the dichotic (cortical) and monotic (brainstem level) test. Within this group, a small percentage of stutterers (6.6%) failed predominantly on monotic tests (brainstem level).

The result indicates that the auditory processing performance of stutterers was heterogeneous in nature since all stutterers did not perform similarly. The result of the study supports the contention that stutterers compared with nonstutterers demonstrated central auditory processing problems. Various models and theories have been put forth to relate the nature of auditory processing problems to stuttering. Among these are the Orton-Travis theory, bilateral language representation model (Rastatter & Dell, 1987a), right hemisphere processing model (Moore & Haynes, 1980), stuttering as a temporal processing disorder (Kent,1984), and the neuropsychological theory of Yeudall, (1985). These models/theories have attempted to account for stuttering as a disorder related to cerebral dominance. Other models (Mysak, 1960; Martin, 1970; Wynne & Boehmler, 1982; Stager, 1990) have attempted to explain stuttering as a disorder in the auditory feedback mechanism.

These models may best describe the performance of subgroups of stutterers in the present investigation. The present researcher is of the opinion that the role of auditory processing in stutterers needs to consider stuttering as a multilevel neurological phenomenon that may involve atypical processing at cortical, cortical and subcortical, and subcortical levels. This view has also been expressed by Yeudall. (1985) This suggestion is based on the heterogeneous nature of central auditory processing performance in the group of stuttterers investigated.

For the stutterers who passed all tests physiological and psychological factors may contribute to the stuttering disorder.

6.1.2. <u>MALE/ FEMALE COMPARISONS</u>

The analysis of variance on each of the five test tests indicated that for nonstutterers no significant performance differences were observed between males and females except on ARLT. The pass/fail performance on the test battery confirmed that males and females performed similarly on the test battery.

For S, no significant sex differences were observed on each of the five tests used in the investigation. However, it was noted that female stutterers performed significantly better than male stutterers on each test i.e. fewer female stutterers failed tests compared to male stutterers. On the test battery considered as a whole, six female stutterers compared with two males stutterers passed all tests implying superior performance of the female stutterers in the present investigation.

There is a paucity of research on male/female differences for stutterers on central auditory processing tests. The present investigator speculates that male/female differences in stutterers to may be explained in the light of developmental trends in hemispheric dominance. More males are susceptible compared with females to atypical cerebral dominance. It is possible that a larger number of males than females retain the atypical cerebral dominance related to stuttering. This may contribute to an explanation of the sex ratio. Another suggestion is that hormonal imbalances in male and female stutterers may predispose males and females differentially to stuttering. Males generally appear to be a greater risk for developmental disorders, including stuttering.

6.2. **CONCLUSION**

The following conclusions were drawn :

i. Stutterers performed significantly ($p<0.05$) poorer than nonstutterers on individual test parameters (except the CST) and on the test battery.

ii. There were no significant ($p> 0.05$) performance differences between male and female nonstutterers on various parameters of individual tests (except on the ARLT), and on the test battery.

For stutterers, whilst males performed poorer than females on individual test parameters , the performance differences were nonsignificant ($p>0.05$). However, on the test battery males performed significantly ($p<0.05$) poorer than females.

6.3. **RESEARCH AND THEORETICAL IMPLICATIONS OF THE STUDY**

i. Stuttering as a heterogeneous disorder: The results of the present study concurs with the contention put forth by stuttering theorists (Van Riper, 1982; Starkweather, 1987) who support the view that stuttering is a heterogeneous disorder in contast to a unitary disorder. The evidence to this effect has been noted on stutterers' responses on central auditory processsing tasks. In the light of the results obtained in the present study, it is plausible to surmise that the underlying central processes related to stuttering may be different for individual stutterers thereby generatimg different symptoms, severity and responses to treatment. Hence, the heterogeneous nature of the stuttering disorder is an important consideration in the analysis and interpretation of results in stuttering research.

ii. Differentiation of subgroups of stutterers: In keeping with the popular belief that stutterers are a heterogeneous popu-lation, research using subgroups of stutterers is recommended (Rentschler, 1984). The present study carried forth this recommendation and selected a subgroup of stutterers who, amongst other criteria had a family history of stuttering. The result of the present study indicated that in using a subgroup of stutterers where the possibility of an inherited predisposition to stuttering is likely, S and NS differences that were more apparent compared with most other studies in which careful differentiation of subgroups was not considered. These finding appear to support the contention that stutterers with a family history of stuttering have neuromotor deficits as suggested by Jannsen et al., (1990). It contributes to this view by suggesting that some stutterers in the present investigation demonstrate a central auditory processing deficit as part of a greater/general neuromotor deficit.

The present investigator suggests that further differentiation of subgroups amongst stutterers is necessary. One possibility is to differentiate stutterers on the basis of central auditory processing abilities e.g. seperate stutterers who obtain atypical ear advantages from those who failed brainstem level tests. Another possibility would be to correlate the symptomatology of stuttering with the nature of central processing performance. Whilst this aspect was not investigated in the present study, it is possible that stutterers with part-word repititions may perform poorly on tasks involving brainstem level processing anomalies as may be implied from research by Wynne and Boehmhler (1982). It is also possible that prolongations and blocks may be correlated with processing deficits at brainstem or other levels of functioning in the central auditory nervous system.

iii. A battery of tests to investigate central auditory processing: The present study has demonstrated the value of using a sensitive test battery. It has also indicated that the Competing Sentences Test is not a sensitive measure in revealing stutterer/nonstutterer differences. The present researcher is of the opinion that further development of stressful central auditory tests (eg. Revised Token Test with competing message, Hageman and Greene, 1989) may be more sensitive in revealing stutterers/nonstutterer performance differences. Also further investigation of the ARLT measure is recommended. The present researcher suggests that further investigation of the sex differences on acoustic reflex latency in necessary to determine whether trends found in the present study are stable features.

It is further suggested that a normative data base be developed for populations studied to facilitate comparison. The battery could also include the BSER measures which have been found it to be sensitive to stutterer/nonstutterer differences (Stager,1990). The results may form a vital part of the test battery as they are relatively objective in nature.

iv. Analysis of data : The present investigator analysed data generated on central auditory tests using group and individual analysis procedures. This method was considered useful because it was able to consider individual results. The present researcher is of the opinion that a step further would be to group stutterers according to performances on tests, and compare with other stutterers who do not demonstrate central auditory processing problems. In this research design, stutterers could be compared to other stutterers and thereby having a closely matched experimental and central group. In this way further analysis of processing underlying stuttering may be achieved.

v. Male/female comparisons. As mentioned on previous occasions, there appears to be a paucity of research related to sex differences in stuttering. The findings of the present investigation revealed no significant differences between male and female stutterers on individual tests in the battery. However, when the battery is considered as a whole, three times as many females than males passed all tests. Male stutterers performances were general poorer compared to female stutterers. It is posible that this difference may contribute to an understanding of the sex ratio. However, more research using a test battery (including electrophysiological measures) is needed to ascertain whether this difference is a stable and significant trend.

vi. The search for an understanding of processes underlying stuttering is under constant investigation and speculation. It is likely that with greater understanding of how a compromised central auditory processing system may be related to stuttering that a more comprehensive picture will emerge. Thus, further research into the nature of central auditory processing using larger samples of male and female stutterers and more carefully differentiated subgroups is warranted.

vii. The results of the present study revealed that 50% of normal subjects failed on the test battery primarily because of failure on a single test. It is possible that normal nonfluency is related to this type of performance characteristic. Except for studies by Wynne and Boehmler (1982) and Nuck et al., (1987) there is no available information about the relationship between normal nonfluency and performance on central auditory processing tests. Further investigation to this effect may lead researchers to consider renorming data by taking into account fluency characteristics of normal speakers.

6.4. CLINICAL IMPLICATIONS

i. The notion of stuttering as a heterogeneous disorder implies clinically that all stutterers should not be treated similarly. This suggestion is not new. The range of available methods used to treat stutterers provides testimony to this effect and is supported by Ham (1986).

ii. Researchers have questioned how stutterers who show atypical cerebral dominance could be treated. Yeudall (1985) suggested that hemispheric imbalances may be treated using medication eg. haliperidol. Yeudall's investigation using medication to treat stutterers indicated that following an improvement in fluency, it was also noted that there was greater blood flow in the left hemisphere on cerebral blood flow experiments compared to pretreatment measures. This implied that a change in fluency status is linked with changes in cerebral processing.

Further evidence to this effect were gathered in behavioural interventions (Boberg, Yeudall, Schopflocher, & Bo-Lassen, 1983; Moore, 1984b). Boberg et al., gathered alpha aysmmetry data from the anterior and posterior brain sites in pre-and post treatment phases for stutterers. In the pretreatment phase the stutterers showed less alpha over the right posterior frontal region for verbal tasks. This implied right hemisphere processing. A reversal of this trend was noted in the post-treatment phase. This suggested that increased fluency accompanying treatment shifts alpha suppression from the right hemisphere to the left hemisphere. Moore (1984b), in a single subject design reported results similar to Boberg et al., (1983) thereby indicating that fluency and cerebral dominance are related. It follows then that fluency shaping therapy for stutterers is related to more typical left than to right hemisphere processing strategy.

iii. Stuttering therapies include fluency shaping therapies (Starkwaether, 1987). The present researcher is of the opinion that the techiques facilitating the prolongation of speech possibly provides a modified auditory signal in the processing mechanism which facilitates fluency production. Other techniques using auditory masking and delayed auditory feedback techniques to enhance fluency, influences the auditory feedback mechanism, and hence generates fluency.

The present researcher is of the opinion that the speech and hearing mechanisms should be considered as part of an integrated mechanism and hence, manipulation of input to the hearing mechanism may impact on the speech mechanism. Parents of dysfluent children are usually advised to provide a speech model that is slow and prolonged. It is possible that these features modify the speech input to the auditory system. Hence, the auditory signal is simplified and the child may be able to process the information better, hence contributing to fluent speech. Thus, it would be of importance to compare the influence of fluency-enhancing conditions on stutterers who do, and do not demonstrate central auditory processing problems.

6.5. LIMITATIONS OF THE STUDY

The following aspects are considered to be limitations of the present study.

i. Sample size : A total sample of 60 subjects were chosen. Thirty experimental and 30 control subjects were selected with 15 male and female subjects within each group. Due to extreme difficulty in locating female subjects the sample size could not be increased therefore limiting the generalizability of the findings of the present study.

ii. Test selection : The study included a battery of five tests. It would have been preferable to include other measures e.g. the BSER test to form a more comprehensive assessment. However, in this instance it would have prolonged the testing time and subjects were not available for further testing.

iii. Data analysis : The ARLT data analysis was limited to single-way analysis of variance. This method was chosen as it provided information relating directly to the aims of the study. It is possible that multivariate analysis of variance may reveal other significant interactions (e.g. sex x I or C stimulation), not considered in the present investigation.

iv. Normative data : The researcher observed that high variability on acoustic reflex latency measures. It would have been preferable to generate a larger normative data base to use for comparison. However, this was not possible due to time constraints. It would have also been advisable to establish normative data for males and females separately.

v. Retest reliability : In the present investigation only nine subjects were retested. It would have been preferable to retest a larger sample to determine the stability of results. However, subjects were not available for further testing. It would also have been preferable to retest subjects after six months to reduce the practice effect. This was not possible due to time constraints.

vi. Assessment of nonfluency : In the light of findings generated in the present research, it would have been advantageous to have assessed thoroughly the fluency of nonstutterers as well as nonstutterers.

vii. Number of trials : It would have been preferable to increase the number of trials for each test to determine the stability and reliability of results. However, this would have prolonged testing time and the practice effect and fatigue may have influenced test results. Also, subjects were not available for further testing and therefore the number of trials could not be increased.

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APPENDIX A

CONSENT FORM

Dear Subject

A study aiming to investigate auditory (hearing) skills in stutterers and nonstutterers is to be conducted. Kindly indicate whether or not you are willing to participate in such a project. All of the information, including the test results will be treated in strictest confidence by the researcher. Your consent to participate in the experiment will be greatly appreciated.

☐ – I am willing to participate in the experiment

☐ – I am not willing to participate in the experiment

APPENDIX B

QUESTIONNAIRE

A. BIOGRAPHICAL DATA

1. SURNAME : ______________________
2. FIRST NAMES : ______________________
3. BIRTHDATE : __________ 4. C.A. : __________
4. SEX : ______________________
5. CONTACT ADDRESS : ______________________
6. TELEPHONE NUMBER : Home : __________ Work : __________

B. GENERAL

1. Is English your first language [YES] [NO]

2. Are you

[left handed] [right handed] [ambidexterous]

3. Have you ever had previous experience with specialized Audio testing? [YES] [NO]

4. Do you have any speech or language problems ?

[YES] [NO]

If yes, indicate which of the following :

a. Articulation
b. Language
c. Stuttering
d. Voice
e. Other

5. Academic History :

Education status : State highest standard passed

____

Have you failed any year at school.

| YES | | NO |

Did/Do experience any academic/learning problems.

| YES | | NO |

Elaborate :

____

____

C. Fluency History

1. Do you stutter ?

| YES | | NO |

2. At what age did you first start to stutter ?

____

3. Have you received or are receiving any treatment ?

| YES | | NO |

If yes, state :

the date of last treatment ____________________

duration of treatment ____________________

effect of treatment of fluency ____________________

4. Is there any history of stuttering in your family

| YES | | NO |

If yes, describe the familial relationships and the ages of the family members who stutter .

Father YES NO

Mother YES NO

Brother YES NO

Indicate number : ____________

Sister YES NO

Indicate number : ____________

Child YES NO

Indicate Nunber : ____________ Sex : ____________

Nephew YES NO

If yes, indicate number and relationship :

____

Niece YES NO

If yes, indicate number and relationship :

____

Grandfather YES NO

If yes, indicate number, maternal and paternal :

____

Grandmother YES NO

If yes, indicate number, maternal and paternal :

____

Uncle YES NO

If yes, indicate number, maternal and paternal :

____

Aunt YES NO

If yes, indicate number, maternal and paternal :

____

Other, indicate relationship :

____

____

____

____

____

D. Audiological Information

1. Do you have any hearing problems ?

YES NO

If yes, describe the nature of your hearing difficulties.

____

____

____

2. Can you hear equally well with both ears ?

YES NO

If no, state which is your preferred ear.

LEFT RIGHT

If yes, describe the ear/s affected

LEFT RIGHT

the type of noise : ______________________

the effect on ability of hear : ______________________

severity : ______________________

duration : ______________________

6. Are you exposed routinely to loud noises :

YES NO

If yes, describe the :

length of exposure : ______________________

frequency of exposure : ______________________

effect on hearing : ______________________

7. Are you oversenitive to loud noises ? i.e. do you have that these noises cause unsual discomfort or irritation?

YES NO

8. Do you generally have difficulty with hearing and following conversations?

YES NO

If yes, describe the nature of your difficulties

____

____

E. MEDICAL HISTORY

1. Do you have any of the following medical/neurological problems /symptoms

[YES] [NO]

Indicate which of the following

- Trauma (head and/or neck) [ ]
- Epilepsy [ ]
- Encephalitis [ ]
- Drug addication [ ]
- Alcoholism [ ]
- Tumours [ ]
- Multiple sclerosis [ ]
- Infections of the ear, noise and throat [ ]
- Visual [ ]
- Dizziness [ ]
- Recurrent headaches [ ]

- Psychological/Psychiatric [ ]
- Other [ ]

If yes, state the nature, duration and treatment

____

____

____

3. Are you on any medication/drug ?

[YES] [NO]

If yes, specify the name and dosage.

____

____

4. Do you drink alcohol ?

[YES] [NO]

If yes do you drink

Rarely [ ]

Occasionally [ ]

Frequency [ ]

5. When last did you consume alcohol ?

less than [24] hours [48] hours, more than [48]

APPENDIX C

HANDEDNESS INVENTORY (Annet's - Adapted & modified by Lazarus, 1983; 1985)

NAME :............................ SEX:........... AGE:.......

INDICATE HAND PREFERENCE	ALWAYS LEFT	USUALLY LEFT	NO PREFERENCE	USUALLY RIGHT	ALWAYS RIGHT
1. To write a letter legibly	....	....	....	....	....
2. To throw a ball to hit a target.	....	....	....	....	....
3. To play a game requiring the use of a racquet	....	....	....	....	....
4. At the top of a broom to sweep dust from the floor.	....	....	....	....	....
5. At the top of a spade to move sand	....	....	....	....	....
6. To hold a match when striking it..	....	....	....	....	....
7. To hold a scissors to cut paper.	....	....	....	....	....
8. To hold thread to guide through the	....	....	....	....	....
9. To deal playing cards	....	....	....	....	....
10. To hammer a nail into wood.	....	....	....	....	....
11. To hold a tooth-brush while clean-ing teeth.	....	....	....	....	....
12. To unscrew the lid of a jar.	....	....	....	....	....

13. Are either of your parents left handed? If yes, which ....

14. How many siblings do you have? Male:....... Female:.........

15. What is your birth order? First:.... Middle:.... Last:.......

16. Which eye do you use when using only one eye to look through a telescope?.................

17. Have you ever suffered any severe head trauma? ....

APPENDIX D

READING PASSAGE

In terms of the current restructing of the University Executive, interim changes in the portfolios of the two Vice-Rectors have been announced, as have some new appointments.

From 1 September, Professor Tom Bennett, as Vice-Rector (Academic), will be responsible for Research and Academic Services.

The position of Vice-Rector (Development) will be filled by Prof. John Butler Adam, who has been Director of the Institute for Social and Economic Research since 1983. In his new post, which he will hold initially for four years, Professor Butler-Adam will be responsible for Faculty Affairs, Academic Planning, the Deans, Teaching Departments and the University Library. He will also be responsible for liaison with COMSA and the SRC.

He sees his role as having a very large coordinating and facilitating component. "I intend to work very closely with colleagues who run research, academic and service departments", he says, "to develop with them a sense of the importance of the work that we will do together for the University and the broader community."

APPENDIX E

UNIVERSITY OF DURBAN-WESTVILLE
DEPARTMENT OF SPEECH AND HEARING THERAPY

CID SPONDEES

Airplane
Sunset
Armchair
Duckpond
Toothbrush
Eardrum
Greyhound
Schoolboy
Mousetrap
Northwest
Iceberg
Horseshoe
Farewell
Grandson
Pancake
Railroad
Playground
Hardware
Mousetrap
Oatmeal
Hotdog
Hothouse

Greyhound
Schoolboy
Inkwell
Whitewash
pancake
mousetrap
eardrum
Headlight
birthday
duckpond
sidewalk
hotdog
padlock
mushroom
hardware
workshop
horseshoe
armchair
baseball
stairway
coyboy
iceberg

northwest
railroad
playground
airplane
woodwork
oatmeal
toothbrush
farewell
grandson
drawbridge
doormat
hothouse
daybreak
sunset
workshop
schoolboy
padlock
railroad
northwest
armchair
eardrum
headlight

EAR:	P T A	S R T
RIGHT:		
LEFT:		

APPENDIX F

W-22 WORD LISTS

PB-50—LIST 1

1. ace
2. ache
3. an
4. as
5. bathe
6. bells
7. carve
8. chew
9. could
10. dad
11. day
12. deaf
13. earn (urn)
14. east
15. felt
16. give
17. high
18. him
19. hunt
20. isle (aisle)
21. it
22. jam
23. knees
24. law
25. low
26. me
27. mew
28. none (nun)
29. not (knot)
30. or (oar)
31. owl
32. poor
33. ran
34. see (sea)
35. she
36. skin
37. stove
38. them
39. there (their)
40. thing
41. toe
42. true
43. twins
44. yard
45. up
46. us
47. wet
48. what
49. wire
50. you (ewe)

PB-50—LIST 2

1. ail (ale)
2. air (heir)
3. and
4. bin (been)
5. by (buy)
6. cap
7. cars
8. chest
9. die (dye)
10. does
11. dumb
12. ease
13. eat
14. else
15. flat
16. gave
17. ham
18. hit
19. hurt
20. ice
21. ill
22. jaw
23. key
24. knee
25. live (verb)
26. move
27. new (knew)
28. now
29. oak
30. odd
31. off
32. one (won)
33. own
34. pew
35. rooms
36. send
37. show
38. smart
39. star
40. tare (tear)
41. that
42. then
43. thin
44. too (two, to)
45. tree
46. way (weigh)
47. well
48. with
49. yore (your)
50. young

PB-50—LIST 3

1. add (ad)
2. aim
3. are
4. ate (eight)
5. bill
6. book
7. camp
8. chair
9. cute
10. do
11. done (dun)
12. dull
13. ears
14. end
15. farm
16. glove
17. hand
18. have
19. he
20. if
21. is
22. jar
23. king
24. knit
25. lie (lye)
26. may
27. nest
28. no (know)
29. oil
30. on
31. out
32. owes
33. pie
34. raw
35. say
36. shove
37. smooth
38. start
39. tan
40. ten
41. this
42. though
43. three
44. tie
45. use (yews)
46. we
47. west
48. when
49. wool
50. year

PB-50—LIST 4

1. aid
2. all (awl)
3. am
4. arm
5. art
6. at
7. bee (be)
8. bread (bred)
9. can
10. chin
11. clothes
12. cook
13. darn
14. dolls
15. dust
16. ear
17. eyes (ayes)
18. few
19. go
20. hang
21. his
22. in (inn)
23. jump
24. leave
25. men
26. my
27. near
28. net
29. nuts
30. of
31. ought (aught)
32. our (hour)
33. pale (pail)
34. save
35. shoe
36. so (sew)
37. stiff
38. tea (tee)
39. than
40. they
41. through
42. tin
43. toy
44. where
45. who
46. why
47. will
48. wood (would)
49. yes
50. yet

PB-50—LIST 5

1. add
2. bake
3. bathe
4. beck
5. black
6. bronze
7. cheat
8. choose
9. curse
10. drive
11. feed
12. flap
13. good
14. Greek
15. grudge
16. high
17. hill
18. inch
19. kid
20. lend
21. love
22. mast
23. nose
24. odds
25. owls
26. pass
27. pipe
28. puff
29. punt
30. rear
31. rind
32. rode
33. roe
34. scare
35. shine
36. shove
37. shy
38. sick
39. solve
40. thick
41. thud
42. trade
43. true
44. tug
45. vase
46. watch
47. wink
48. wrath
49. yawn
50. zone

APPENDIX G

UNIVERSITY OF DURBAN-WESTVILLE

AUDIOMETRIC EXAMINATION

DEPARTMENT OF SPEECH AND HEARING THERAPY

NAME .... PATIENT NO. ....

AUDIOLOGIST .... DATE ....

PURE TONE AUDIOGRAM

Hearing Level in dB (ISO 1964)

Right Ear

	125	250	500	1 K	2 K	4 K	8 K	Hz
0								
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								
110								
120								

Left Ear

	125	250	500	1 K	2 K	4 K	8 K	Hz
0								0
10								10
20								20
30								30
40								40
50								50
60								60
70								70
80								80
90								90
100								100
110								110
120								120

NBN dB Masking

AC								AC							
BC								BC							

AUDIOMETRIC WEBER

250	500	1 K	2 K	4 K	Hz

R–Right C–Central L–Left

TEST RELIABILITY

GOOD	FAIR	POOR

SPEECH AUDIOGRAM

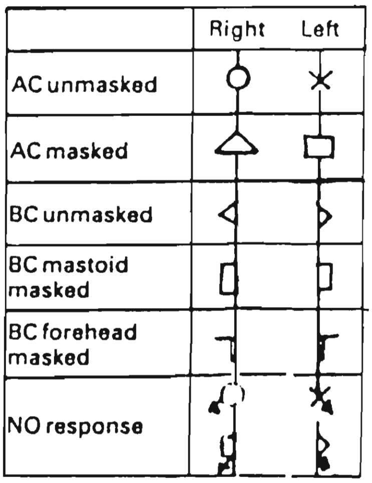
WORD DISCRIMINATION SCORE (% Correct)

	10	20	30	40	50	60	70	80	90	100	110	120	dB
100													
90													
80													
70													
60													
50													
40													
30													
20													
10													
0													

WN MASKING

												dB

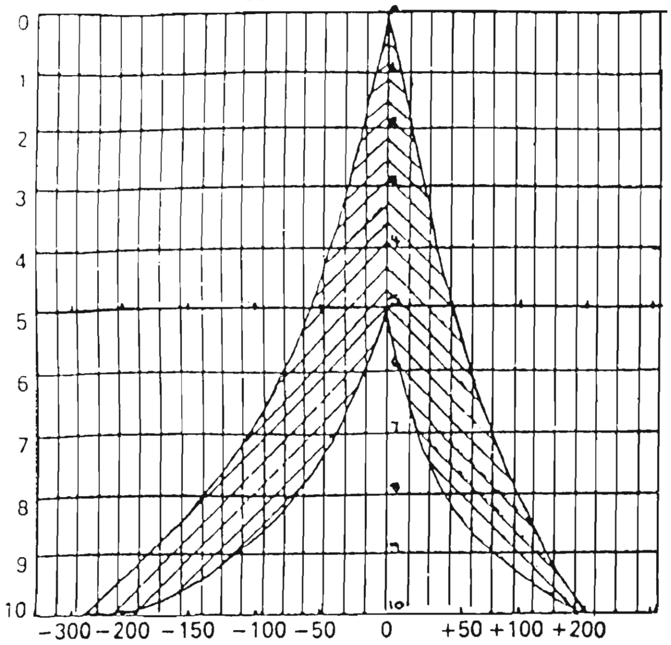
AUDIOGRAM KEY



EAR	PT	SRT	% max disc	MCL	DL	Dynamic range
Right						
Left						

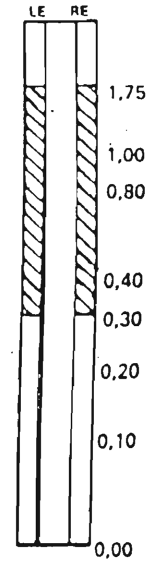
IMMITANCE TESTS

TYMPANOGRAM
PRESSURE IN mm WATER



C O M P L I A N C E

STATIC COMPLIANCE



MIDDLE EAR PRESSURE

R ____________________ mmW

L ____________________ mmW

PHYSICAL VOLUME TEST:

R ____________________ cc

L ____________________ cc

ACOUSTIC REFLEX TEST

Right ear: Reflex threshold PT C	I	C	I	PT	PT-ART	Reflex Decay	Hz	Left ear: Reflex threshold PT C	I	C	I	PT	PR-ART	Reflex Decay
							250							
							500							
							1 K							
							2 K							
							4 K							

SPECIAL TESTS

ABLB

Hz	Right	Left

SISI

Hz	Right	Left

BÉKÉSY

	Description
Right	
Right	
Left	
Left	
Left	

DIFFERENCE LIMEN TEST

Hz	Right	Left

TONE DECAY/60 sec

Hz	Right	Le

REMARKS: Otoscopic Pass

Fail

Stores Cat. No. 23-40051/F 210/P 64330/N.W 9832/17.11 83/L

4.2.7 Tympanometry - Sample Printouts

GSI 33
Middle-Ear Analyzer

NAME: ______________________

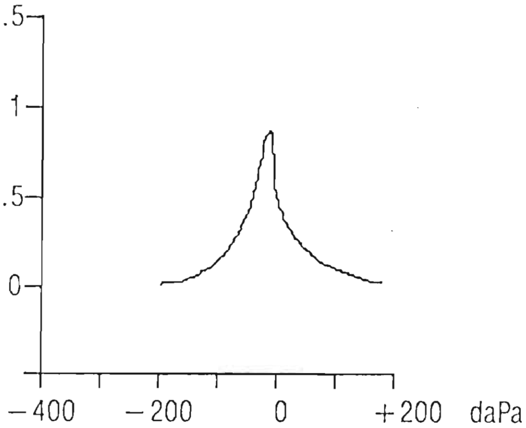
I.D. #: ______________________

ADDRESS: ______________________

OPERATOR: ______________________

DATE: ____________ EARTIP: ____________

TYMP DIAGNOSTIC TEST 1
ml Ytm 226 Hz L

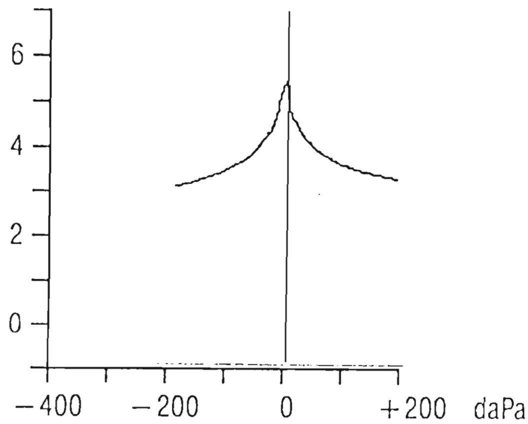


← 50 daPa/s

EARCANAL VOLUME: 1.0

	daPa	ml
TYMP 1:	−5	0.9
TYMP 2:		
TYMP 3:		
GRADIENT:	0.7	

TYMP DIAGNOSTIC TEST 2
mmho Ya 678 Hz L



← 50 daPa/s

C1: 3.3

	daPa	mmho
TYMP 1:	0	5.6
TYMP 2:		
TYMP 3:		

CURSOR: dapa = 0
TYMP #1 = 5.59 mmho

APPENDIX I

ACOUSTIC REFLEX LATENCY TESTING : RECORDING FORM

Right Ear

		I C
500 Hz	ON	
1000 Hz	ON	
2000 Hz	ON	

Left Ear

		I C
500 Hz	ON	
1000 Hz	ON	
2000 Hz	ON	

APPENDIX J

DITEC™

DICHOTIC CV

0 msec Lead

RAND H Left Track CH. 1	RAND H Right Track CH. 2	RAND I Left Track CH. 1	RAND I Right Track CH. 2
PA	KA	PA	BA
DA	KA	KA	PA
KA	TA	GA	TA
PA	BA	DA	PA
KA	DA	KA	DA
GA	KA	BA	TA
TA	KA	GA	PA
TA	GA	DA	GA
BA	DA	BA	KA
GA	TA	PA	DA
TA	BA	BA	GA
KA	BA	PA	GA
GA	PA	TA	BA
GA	BA	KA	GA
DA	PA	KA	TA
DA	GA	TA	DA
KA	PA	GA	KA
PA	TA	TA	PA
DA	TA	BA	PA
BA	PA	DA	KA
BA	GA	TA	GA
DA	BA	GA	BA
AG	DA	DA	TA
TA	DA	KA	BA
KA	GA	GA	DA
BA	TA	DA	BA
PA	GA	PA	KA
PA	DA	TA	KA
BA	KA	BA	DA
TA	PA	PA	TA
R ______	______	______	______
Correct ______	______	______	______

ME______________________ B.D.________ Age______ Date________

DITEC of St. Louis St. Louis, MO 63119

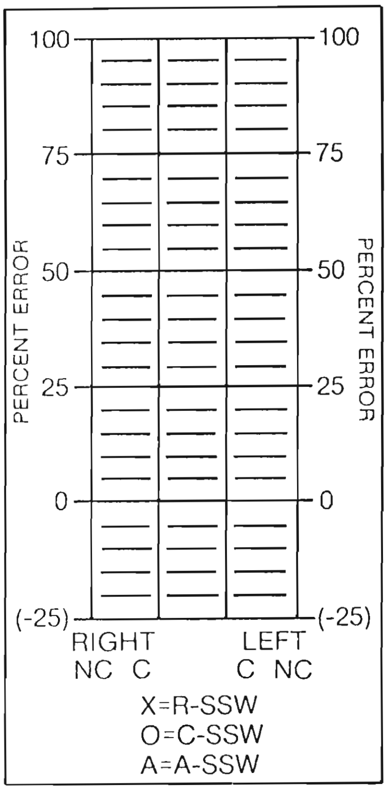
STANDARD SSW TEST-LIST EC

APPENDIX K

Name ______________________ Date ____________ REF LEF

AGE ________ Sex: M F Handed: R L A Tester ______________________

1. R-SSW Enter totals from page 3				
CONDITION	**RNC**	**RC**	**LC**	**LNC**
Total Errors				
Multiplier	x	x	x	x
R-SSW %Error				
EAR	**RE**		**LE**	
R-SSW %Error				
TOTAL		**T**		
R-SSW % Error				



2. C-SSW Enter R-SSW % error				
CONDITION	**RNC**	**RC**	**LC**	**LNC**
R-SSW % Error				
-WDS % Error	–	–	–	–
C-SSW % Error				
EAR	**RE**		**LE**	
C-SSW % Error				
TOTAL		**T**		
C-SSW % Error				

3. A - SSW Enter least biased errors from page 3				
CONDITION	**RNC**	**RC**	**LC**	**LNC**
Least Biased Errors				
Multiplier	x	x	x	x
Least Biased % Errors				
-WDS % Error	–	–	–	–
A-SSW % Error				
EAR	**RE**		**LE**	
A-SSW % Error				
TOTAL		**T**		
A-SSW % Error				

SSW SUMMARY
Score
Response Bias
Reversals _____ SIG NS
Sig-Order _____/_____ H/L L/H
Sig-Ear _____/_____ L/H H/L
Type A LC RC
Other: ______________

COMMENTS: ______________________

AUDIOMETRIC SUMMARY	3-FREQ SP AVG	SRT	WDS	SSW HL
RE				
LE				

Multipliers		
#ITEMS	R-SSW	A-SSW
20 ____	5 ____	10 ____
25 ____	4 ____	8 ____
30 ____	3.3 ____	6.7 ____
40 ____	2.5 ____	5 ____
If other: ____		
( )	____	____

TEC ANALYSIS	C-SSW Total	C-SSW Ear	C-SSW Cond.	A-SSW Total	A-SSW Ear	A-SSW Cond.
#						
CAT						
	Combined TEC			Combined TEC		

PRECISION ACOUSTICS
411 N.E. 87th. Avenue, Suite B
Vancouver, WA. 98664
(206) 892-9367

PRACTICE ITEMS

a.	air	plane	wet	paint
c.	north	west	stair	way

b.	cow	boy	white	bread
d.	oat	meal	flash	light

Left First / Right First	L-NC (A) R-NC	L-C (B) R-C	R-C (C) L-C	R-NC (D) L-NC	Rev	WRONG
1.	up	stairs	down	town	R	
3.	day	light	lunch	time	R	
5.	corn	bread	oat	meal	R	
7.	flood	gate	flash	light	R	
9.	meat	sauce	base	ball	R	
11.	house	fly	wood	work	R	
13.	sun	day	shoe	shine	R	
15.	back	door	play	ground	R	
17.	snow	white	foot	ball	R	
19.	blue	jay	black	bird	R	
SUM						

	R-NC (E) L-NC	R-C (F) L-C	L-C (G) R-C	L-NC (H) R-NC	Rev	WRONG
2.	out	side	in	law	R	
4.	wash	tub	black	board	R	
6.	bed	spread	mush	room	R	
8.	sea	shore	out	side	R	
10.	black	board	air	mail	R	
12.	green	bean	home	land	R	
14.	white	walls	dog	house	R	
16.	school	boy	church	bell	R	
18.	band	saw	first	aid	R	
20.	ice	land	sweet	cream	R	
SUM						

COMMENTS: ____________________

	(A)	(B)	(C)	(D)	Rev	WRONG
21.	hair	net	tooth	brush	R	
23.	ash	tray	tin	can	R	
25.	key	chain	suit	case	R	
27.	corn	starch	soap	flakes	R	
29.	day	break	lamp	light	R	
31.	bird	cage	crow's	nest	R	
33.	book	shelf	drug	store	R	
35.	hand	ball	milk	shake	R	
37.	for	give	milk	man	R	
39.	race	horse	street	car	R	
SUM Page 3						
SUM Page 2						
TOTAL		(CARDINAL NUMBERS)				
Left First	L-NC	L-C	R-C	R-NC		
	(A)	(B)	(C)	(D)		
Right First	R-NC	R-C	L-C	L-NC		

	(E)	(F)	(G)	(H)	Rev	WRONG
22.	fruit	juice	cup	cake	R	
24.	nite	light	yard	stick	R	
26.	play	ground	bat	boy	R	
28.	birth	day	first	place	R	
30.	door	knob	cow	bell	R	
32.	week	end	work	day	R	
34.	wood	work	beach	craft	R	
36.	fish	net	sky	line	R	
38.	sheep	skin	bull	dog	R	
40.	green	house	string	bean	R	
SUM Page 3						
SUM Page 2						
TOTAL		(CARDINAL NUMBERS)				
	R-NC	R-C	L-C	L-NC		
	(E)	(F)	(G)	(H)		
	L-NC	L-C	R-C	R-NC		

EAR EFFECT		
Total Errors	REF	LEF
☐ Sig. ☐ N. Sig.		

REVERSALS
TOTAL =

ORDER EFFECT			
1	2	3	4
(A+E)	(B+F)	(C+G)	(D+H)
TOTAL		TOTAL	
1st SPONDEE		2nd SPONDEE	
☐ Sig		☐ N. Sig	

COMBINED TOTALS				
	RNC	RC	LC	LNC
(A) - (D) or (E) - (H)				
(H) - (E) or (D) - (A)				
GRAND TOTALS				

Enter these figures on Page

APPENDIX L

COMPETING SENTENCES : SCORING RECORDING FORM

Practice Items Monotic	1. It was a long ride by car. I thought we would never get there. 2. He went to the South on his vacation. I get two weeks off in the Summer.	
Practice Items Dichotic	3. He read the whole book in one week. I think they made the book into a movie. 4. I put the letter in the mail box. You must write to her more often. 5. He drank all of the milk. I like my coffee black. 6. He watched the cartoon on TV. I like the Bugs Bunny cartoon. 7. He was very late to class yesterday I went to the cafeteria at noon. 8. The airplane flew very low. The jet took off smoothly. 9. I have the best teacher in school. He was a student here before me.	
Target Ear Right	10. I saw the funny clown. The circus was very good. 11. This is a long freight train. The caboose is always last. 12. I don't like to go to school either Recess is my favorite time. 13. My car is very fast. Put gas in the tank. 14. They say candy is bad for your teeth. I do not like to eat dinner alone. 15. Put a clean bandage on that cut. That scratch may get infected.	

cont/........

	16. That movie was on TV. I say it when it was a play 17. I saw lots of different kinds of animals. There are lions and tigers in the zoo. 18. It is dangerous to swim there. He likes to swim the backstroke. 19. He is only resting. I had to take a nap.	
Target Ear Left	20. I had a wonderful Christmas. He's off for Easter week. 21. I think hide and seek is a lot of fun. The children played tag for a long time. 22. They went to the zoo Sunday. I was able to go to the park. 23. My sister is older than I am. Your uncle is not over there. 24. There is a color television over there. 25. He's too old to play with toys. I like to run my model train. 26. There was fried chicken for dinner. I had a sandwich for lunch. 27. Dessert was a chocolate sundae. I put strawberries on my ice cream. 28. Mother made pancakes for breakfast. I like maple syrup on my waffles. 29. Nobody is at home. They won't answer the phone. 30. Its raining very hard. There's a lot of snow on the ground	

APPENDIX L

COMPETING SENTENCES : SCORING RECORDING FORM

Practice Items Monotic	1. It was a long ride by car. I thought we would never get there. 2. He went to the South on his vacation. I get two weeks off in the Summer.	
Practice Items Dichotic	3. He read the whole book in one week. I think they made the book into a movie. 4. I put the letter in the mail box. You must write to her more often. 5. He drank all of the milk. I like my coffee black. 6. He watched the cartoon on TV. I like the Bugs Bunny cartoon. 7. He was very late to class yesterday I went to the cafeteria at noon. 8. The airplane flew very low. The jet took off smoothly. 9. I have the best teacher in school. He was a student here before me.	
Target Ear Right	10. I saw the funny clown. The circus was very good. 11. This is a long freight train. The caboose is always last. 12. I don't like to go to school either Recess is my favorite time. 13. My car is very fast. Put gas in the tank. 14. They say candy is bad for your teeth. I do not like to eat dinner alone. 15. Put a clean bandage on that cut. That scratch may get infected.	

cont/........

	16. That movie was on TV. I say it when it was a play 17. I saw lots of different kinds of animals. There are lions and tigers in the zoo. 18. It is dangerous to swim there. He likes to swim the backstroke. 19. He is only resting. I had to take a nap.	
Target Ear Left	20. I had a wonderful Christmas. He's off for Easter week. 21. I think hide and seek is a lot of fun. The children played tag for a long time. 22. They went to the zoo Sunday. I was able to go to the park. 23. My sister is older than I am. Your uncle is not over there. 24. There is a color television over there. 25. He's too old to play with toys. I like to run my model train. 26. There was fried chicken for dinner. I had a sandwich for lunch. 27. Dessert was a chocolate sundae. I put strawberries on my ice cream. 28. Mother made pancakes for breakfast. I like maple syrup on my waffles. 29. Nobody is at home. They won't answer the phone. 30. Its raining very hard. There's a lot of snow on the ground	

APPENDIX M

SSI-ICM

													MCR	CORR
SSI-ICM	R	A	1	2	5	3	4	7	8	9	10	6	-20	
	R	B	3	7	9	6	5	8	10	1	2	4	-10	
	R	C	2	10	3	6	7	5	1	8	9	4	0	
	R	D	2	1	6	10	3	9	8	5	7	4	+10	
	L	E	7	4	1	10	6	5	8	2	9	3	-20	
	L	F	10	2	3	8	7	1	9	6	4	5	-10	
	L	G	7	4	3	9	1	8	10	6	2	5	0	
	L	H	1	2	9	4	8	10	6	5	3	7	+10	
	R	I	3	5	4	8	1	6	9	7	10	2	0	
	L	J	2	6	10	4	5	9	1	3	8	7	0	

APPENDIX N

RAW SCORES DICHOTIC CONSONANT VOWEL TEST

Subj.	R	L	R+L	DC
NSM1	47	30	77	22
2	54	34	88	29
3	43	30	73	25
4	43	30	73	29
5	36	40	76	21
6	44	31	75	22
7	46	32	78	27
8	44	31	75	22
9	38	27	65	22
10	40	28	68	20
11	41	29	70	22
12	30	44	74	26
13	43	29	72	28
14	41	26	67	24
15	36	35	71	25
NSF1	48	35	83	25
2	42	30	72	24
3	44	26	70	21
4	37	24	61	21
5	36	22	58	20
6	37	23	60	22
7	47	33	80	24
8	32	41	73	22
9	36	39	75	22
10	42	30	72	21
11	42	41	83	26
12	49	30	79	27
13	40	28	68	21
14	39	24	63	25
15	45	31	76	24

Subj.	R	L	R+L	DC
SM1	38	37	75	22
2	24	36	60	20
3	42	28	70	27
4	40	42	82	28
5	51	40	91	31
6	38	32	70	22
7	36	32	68	25
8	41	36	77	25
9	30	40	70	18
10	39	26	65	22
11	38	26	64	18
12	30	42	72	23
13	36	36	72	22
14	26	39	65	19
15	46	35	81	26
SF1	43	30	73	21
2	25	36	61	19
3	32	38	70	20
4	44	32	76	24
5	39	32	71	24
6	38	36	74	25
7	40	28	68	23
8	29	42	71	23
9	43	30	73	25
10	34	40	74	21
11	30	42	72	19
12	40	28	68	20
13	37	36	73	20
14	48	36	84	29
15	49	34	83	30

APPENDIX O

PHI-COEFFICIENT AND EAR ADVANTAGE FOR INDIVIDUAL SUBJECTS IN THE EXPERIMENT

SUBJECT	PHI-COEF	EAR ADVANTAGE
NSM 1	0.295	REA
NSM 2	0.377	REA
NSM 3	0.222	REA
NSM 4	0.222	REA
NSM 5	-0.069	NEA
NSM 6	0.224	REA
NSM 7	0.245	REA
NSM 8	0.224	REA
NSM 9	0.184	REA
NSM 10	0.202	REA
NSM 11	0.203	REA
NSM 12	-0.240	LEA
NSM 13	0.238	REA
NSM 14	0.252	REA
NSM 15	0.017	NEA

cont/....

SUBJECT	PHI-COEF	EAR ADVANTAGE
NSF 1	0.235	REA
NSF 2	0.204	REA
NSF 3	0.304	REA
NSF 4	0.217	REA
NSF 5	0.233	REA
NSF 6	0.233	REA
NSF 7	0.247	REA
NSF 8	-0.154	NEA
NSF 9	-0.052	NEA
NSF 10	0.204	REA
NSF 11	0.018	NEA
NSF 12	0.334	REA
NSF 13	0.202	REA
NSF 14	0.250	REA
NSF 15	0.242	REA

cont/.....

SUBJECT	PHI-COEF	EAR ADVANTAGE
SM 1	0.017	NEA
SM 2	-0.200	LEA
SM 3	0.237	REA
SM 4	-0.036	NEA
SM 5	0.214	REA
SM 6	0.101	NEA
SM 7	0.067	NEA
SM 8	0.087	NEA
SM 9	-0.169	NEA
SM 10	0.217	REA
SM 11	0.200	REA
SM 12	-0.204	LEA
SM 13	0.000	NEA
SM 14	0.217	LEA
SM 15	0.196	REA

cont/......

SUBJECT	PHI-COEF	EAR ADVANTAGE
SF 1	0.222	REA
SF 2	0.183	LEA
SF 3	0.101	NEA
SF 4	0.208	REA
SF 5	0.119	NEA
SF 6	0.034	NEA
SF 7	0.202	REA
SF 8	-0.220	LEA
SF 9	0.222	REA
SF 10	-0.103	NEA
SF 11	-0.204	LEA
SF 12	0.202	REA
SF 13	0.017	NEA
SF 14	0.218	REA
SF 15	0.271	REA

APPENDIX P

RAW DATA : STAGGERED SPONDAIC WORD TEST

SUBJECT	EAR EFFECT		ORDER EFFECT		COMBINED TOTALS				REVERSALS
	REF	LEF	1	2	RNC	RC	LC	LNC	
NSF1	1	1	1	1	0	0	2	0	1
NSF2	1	0	1	0	0	1	0	0	2
NSF3	0	0	0	0	0	0	0	0	0
NSF4	0	0	0	0	0	0	0	0	2
NSF5	1	2	1	2	0	1	2	0	0
NSF6	2	0	1	1	1	0	1	0	0
NSF7	0	1	0	1	0	1	0	0	0
NSF8	2	1	1	2	0	1	1	1	0
NSF9	1	2	1	2	0	1	2	0	0
NSF10	0	1	1	0	0	0	1	0	2
NSF11	0	0	0	0	0	0	0	0	0
NSF12	1	1	1	1	0	0	2	0	0
NSF13	0	2	0	2	1	1	0	0	1
NSF14	0	0	0	0	0	0	0	0	0
NSF15	0	0	0	0	0	0	0	0	0

cont/.....

SUBJECT	EAR EFFECT		ORDER EFFECT		COMBINED TOTALS				REVERSALS
	REF	LEF	1	2	RNC	RC	LC	LNC	
NSM1	1	0	0	1	0	0	1	0	1
NSM2	0	1	1	0	0	0	1	0	1
NSM3	2	1	1	2	0	0	2	1	0
NSM4	1	1	2	0	0	1	1	0	0
NSM5	0	0	0	0	0	0	0	0	0
NSM6	0	0	0	0	0	0	0	0	0
NSM7	0	2	0	2	0	2	0	0	0
NSM8	0	1	1	0	0	0	1	0	0
NSM9	2	1	1	2	0	0	2	1	3
NSM10	0	0	0	0	0	0	0	0	1
NSM11	0	1	0	1	0	1	0	0	1
NSM12	3	2	3	2	1	2	2	0	2
NSM13	0	0	0	0	0	0	0	0	0
NSM14	1	1	2	0	0	1	1	0	0
NSM15	1	1	2	0	0	1	1	0	1

cont/....

SUBJECT	EAR EFFECT		ORDER EFFECT		COMBINED TOTALS				REVERSALS
	REF	LEF	1	2	RNC	RC	LC	LNC	
SM1	4	2	2	4	0	4	2	0	10
SM2	2	4	4	2	0	4	2	0	8
SM3	2	2	1	3	0	1	2	1	0
SM4	0	0	0	0	0	0	0	0	0
SM5	1	0	1	0	0	1	0	0	2
SM6	3	2	2	3	0	2	2	1	7
SM7	0	0	0	0	0	0	0	0	0
SM8	0	0	0	0	0	0	0	0	0
SM9	0	0	0	0	0	0	0	0	0
SM10	2	2	3	1	1	0	3	0	1
SM11	5	6	7	4	0	3	7	1	2
SM12	0	0	0	0	0	0	0	0	0
SM13	3	2	2	3	0	4	1	0	3
SM14	2	3	2	3	0	3	2	0	1
SM15	1	0	0	1	0	0	1	0	11

cont/.....

SUBJECT	EAR EFFECT		ORDER EFFECT		COMBINED TOTALS				REVERSALS
	REF	LEF	1	2	RNC	RC	LC	LNC	
SF1	2	3	4	1	0	3	2	0	2
SF2	2	1	1	2	0	2	1	0	1
SF3	2	3	2	3	0	3	2	0	6
SF5	2	2	1	3	0	1	3	0	3
SF4	0	0	0	0	0	0	0	0	0
SF6	3	0	1	2	0	1	2	0	10
SF7	0	0	0	0	0	0	0	0	0
SF8	3	5	5	3	1	3	3	1	2
SF9	0	0	0	0	0	0	0	0	0
SF10	4	3	3	4	0	4	2	1	2
SF11	1	1	1	1	0	2	0	0	8
SF12	0	0	0	0	0	0	0	0	0
SF13	1	0	0	1	0	0	1	0	1
SF14	0	1	0	1	0	1	0	0	1
SF15	0	0	0	0	0	0	0	0	0

R-SSW

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
NSF1	0	0	5	0	0	2.5	1
NSF2	0	2	0	0	1	0	1
NSF3	0	0	0	0	0	0	0
NSF4	0	0	0	0	0	0	0
NSF5	0	2	5	0	1	2.5	2
NSF6	2	0	2	0	1	1	1
NSF7	0	2	0	0	1	0	1
NSF8	0	2	2	3	1	2.5	2
NSF9	0	2	5	0	1	2.5	2
NSF10	0	0	2	0	0	1	1
NSF11	0	0	0	0	0	0	0
NSF12	0	0	5	0	0	2.5	1
NSF13	2	2	0	0	2	0	1
NSF14	0	0	0	0	0	0	0
NSF15	0	0	0	0	0	0	0

cont/......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
NSM1	0	0	2	0	0	1	1
NSM2	0	0	2	0	0	1	1
NSM3	0	0	5	2	0	3.5	2
NSM4	0	2	2	0	1	1	1
NSM5	0	0	0	0	0	0	0
NSM6	0	0	0	0	0	0	0
NSM7	0	5	0	0	2.5	0	1
NSM8	0	0	2	0	0	1	1
NSM9	0	0	5	2	0	3.5	2
NSM10	0	0	0	0	0	0	0
NSM11	0	2	0	0	1	0	1
NSM12	2	5	5	0	3.5	2.5	3
NSM13	0	0	0	0	0	0	0
NSM14	0	2	2	0	1	1	1
NSM15	0	2	2	0	1	1	1

cont/.......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
SM1	0	10	5	0	5	2.5	4
SM2	0	10	5	0	5	2.5	4
SM3	0	2	5	2	1	3.5	2
SM4	0	0	0	0	0	0	0
SM5	0	2	0	0	1	0	1
SM6	0	5	5	2	2.5	3.5	3
SM7	0	0	0	0	0	0	0
SM8	0	0	0	0	0	0	0
SM9	0	0	0	0	0	0	0
SM10	2	0	8	0	1	4	3
SM11	0	8	28	2	4	15	10
SM12	0	0	0	0	0	0	0
SM13	0	10	2	0	5	1	3
SM14	0	8	5	0	4	2.5	3
SM15	0	0	2	0	0	1	1

cont/......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
SF1	0	8	5	0	4	2.5	3
SF2	0	5	2	0	2.5	1	2
SF3	0	8	5	0	4	2.5	3
SF5	0	2	8	0	1	4	3
SF4	0	0	0	0	0	0	0
SF6	0	2	5	0	1	2.5	2
SF7	0	0	0	0	0	0	0
SF8	2	8	8	2	5	5	5
SF9	0	0	0	0	0	0	0
SF10	0	10	5	0	5	2.5	4
SF11	0	5	0	0	2.5	0	1
SF12	0	0	0	0	0	0	0
SF13	0	0	2	0	0	1	1
SF14	0	2	0	0	1	0	1
SF15	0	0	0	0	0	0	0

C-SSW

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
NSF1	0	0	5	0	0	2.5	1
NSF2	0	2	0	0	1	0	1
NSF3	0	0	0	0	0	0	0
NSF4	0	0	0	0	0	0	0
NSF5	0	2	5	0	1	2.5	2
NSF6	2	0	2	0	1	1	1
NSF7	0	2	0	0	1	0	1
NSF8	0	2	2	3	1	2.5	2
NSF9	0	2	5	0	1	2.5	2
NSF10	0	0	2	0	0	1	1
NSF11	0	0	0	0	0	0	0
NSF12	0	0	5	0	0	2.5	1
NSF13	2	2	0	0	2	0	1
NSF14	0	0	0	0	0	0	0
NSF15	0	0	0	0	0	0	0

cont/......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
NSM1	0	0	2	0	0	1	1
NSM2	0	0	2	0	0	1	1
NSM3	0	0	5	2	0	3.5	2
NSM4	0	2	2	0	1	1	1
NSM5	0	0	0	0	0	0	0
NSM6	0	0	0	0	0	0	0
NSM7	0	5	0	0	2.5	0	1
NSM8	0	0	2	0	0	1	1
NSM9	0	0	5	2	0	3.5	2
NSM10	0	0	0	0	0	0	0
NSM11	0	2	0	0	1	0	1
NSM12	2	5	5	0	3.5	2.5	3
NSM13	0	0	0	0	0	0	0
NSM14	0	2	2	0	1	1	1
NSM15	0	2	2	0	1	1	1

cont/.......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
SM1	0	10	5	0	5	2.5	4
SM2	0	10	5	0	5	2.5	4
SM3	-4	-2	5	2	-3	3.5	0
SM4	0	0	0	0	0	0	0
SM5	0	2	0	0	1	0	1
SM6	0	5	1	-2	2.5	-0.5	1
SM7	0	0	0	0	0	0	0
SM8	0	0	0	0	0	0	0
SM9	0	0	0	0	0	0	0
SM10	-2	-4	8	0	-3	4	1
SM11	0	8	28	2	4	15	10
SM12	0	0	0	0	0	0	0
SM13	0	10	2	0	5	1	3
SM14	0	8	5	0	4	2.5	3
SM15	0	0	-2	-4	0	-3	-2

cont/......

SUBJECT	RNC	RC	LC	LNC	R.AVERAGE	L.AVERAGE	%ERROR
SF1	0	8	5	0	4	2.5	3
SF2	0	5	2	0	2.5	1	2
SF3	0	8	5	0	4	2.5	3
SF5	0	2	8	0	1	4	3
SF4	0	0	0	0	0	0	0
SF6	-4	-2	5	0	-3	2.5	0
SF7	0	0	0	0	0	0	0
SF8	2	8	8	2	5	5	5
SF9	0	0	0	0	0	0	0
SF10	0	10	5	0	5	2.5	4
SF11	0	5	0	0	2.5	0	1
SF12	0	0	0	0	0	0	0
SF13	0	0	2	-4	0	-1	-1
SF14	0	2	0	0	1	0	1
SF15	0	0	0	0	0	0	0

APPENDIX Q

COMPETING SENTENCES TEST : RAW DATA

	R %	L %
NSM1	100	90
NSM2	100	90
NSM3	100	100
NSM4	100	100
NSM5	100	90
NSM6	90	90
NSM7	100	100
NSM8	100	90
NSM9	100	100
NSM10	90	90
NSM11	90	80
NSM12	80	90
NSM13	100	100
NSM14	90	100
NSM15	100	100

	R %	L %
NSF1	100	100
NSF2	100	100
NSF3	100	90
NSF4	90	90
NSF5	90	80
NSF6	100	100
NSF7	100	100
NSF8	100	100
NSF9	100	100
NSF10	100	100
NSF11	100	100
NSF12	100	90
NSF13	90	80
NSF14	100	100
NSM15	80	80

cont/...

MALE STUTTERERS	RIGHT EAR PERCENT CORRECT	LEFT EAR PERCENT CORRECT
SM1	80	70
SM2	70	80
SM3	100	90
SM4	90	80
SM5	100	100
SM6	80	70
SM7	100	90
SM8	100	90
SM9	100	100
SM10	100	90
SM11	90	90
SM12	80	90
SM13	90	100
SM14	80	80
SM15	100	90

FEMALE STUTTERERS	RIGHT EAR PERCENT CORRECT	LEFT EAR PERCENT CORRECT
SF1	90	90
SF2	80	100
SF3	80	80
SF4	100	90
SF5	100	100
SF6	80	70
SF7	100	100
SF8	90	100
SF9	100	100
SF10	90	90
SF11	80	90
SF12	100	100
SF13	80	90
SF14	90	90
SF15	90	90

APPENDIX R

SSI

AUDITEC

1. Small boat with a picture has become

2. Built the government with the force almos

3. Go change your car color is red

4. Forward march said the boy had a

5. March around without a care in your

6. That neighbor who said business is better

7. Battle cry and be better than ever

8. Down by the time is real enough

9. Agree with him only to find out

10. Women view men with green paper shou

APPENDIX S

SSI-ICM : RAW SCORES

SUBJECT	EAR	TEST COND.: MCR'S			
		-20dBMCR	-10dBMCR	0dBMCR	+10dBMCR
NSM1 NSM1	R L	50 50	80 70	100 90	100 100
NSM2 NSM2	R L	60 60	90 80	100 100	100 100
NSM3 NSM3	R L	40 40	80 80	100 90	100 100
NSM4 NSM4	R L	70 80	90 90	100 90	100 100
NSM5 NSM5	R L	60 70	90 90	90 100	100 100
NSM6 NSM6	R L	50 40	70 70	100 100	100 100
NSM7 NSM7	R L	60 50	90 70	90 100	100 100
NSM8 NSM8	R L	70 60	90 80	100 100	100 100
NSM9 NSM9	R L	50 50	90 80	90 100	100 100
NSM10 NSM10	R L	70 70	100 100	100 100	100 100
NSM11 NSM11	R L	60 50	70 80	90 90	90 100
NSM12 NSM12	R L	50 50	80 70	90 80	90 100
NSM13 NSM13	R L	50 50	80 90	90 100	100 100
NSM14 NSM14	R L	60 50	80 70	90 90	100 100
NSM15 NSM15	R L	60 70	90 90	100 100	100 100

cont/...

SUBJECT	EAR	TEST COND.: MCR'S			
		-20dBMCR	-10dBMCR	0dBMCR	+10dBMCR
NSF1 NSF1	R L	50 50	80 80	90 100	100 100
NSF2 NSF2	R L	60 60	80 80	100 90	100 100
NSF3 NSF3	R L	60 60	90 90	100 100	100 100
NSF4 NSF4	R L	60 50	80 90	90 100	100 100
NSF5 NSF5	R L	40 40	70 70	90 90	100 100
NSF6 NSF6	R L	50 50	70 80	80 90	100 100
NSF7 NSF7	R L	70 70	90 100	100 100	100 100
NSF8 NSF8	R L	50 50	70 70	100 100	100 100
NSF9 NSF9	R L	50 60	70 70	90 90	100 100
NSF10 NSF10	R L	70 60	100 80	100 90	100 100
NSF11 NSF11	R L	60 50	90 80	100 100	100 100
NSF12 NSF12	R L	60 50	70 70	90 90	100 100
NSF13 NSF13	R L	50 50	80 70	90 80	100 100
NSF14 NSF14	R L	70 60	100 100	100 100	100 100
NSF15 NSF15	R L	70 60	90 80	100 100	100 100

cont/...

SUBJECT	EAR	TEST COND.: MCR'S			
		-20dBMCR	-10dBMCR	0dBMCR	+10dBMCR
SM1	R	60	80	90	100
SM1	L	50	70	100	100
SM2	R	40	80	100	100
SM2	L	60	90	100	100
SM3	R	50	70	100	100
SM3	L	50	70	100	100
SM4	R	40	70	100	100
SM4	L	40	70	100	100
SM5	R	30	60	100	100
SM5	L	20	60	100	100
SM6	R	50	80	90	100
SM6	L	50	80	100	100
SM7	R	50	80	100	100
SM7	L	50	70	100	100
SM8	R	70	90	100	100
SM8	L	70	90	100	100
SM9	R	20	50	90	100
SM9	L	20	70	100	100
SM10	R	60	80	90	100
SM10	L	80	90	90	100
SM11	R	30	60	80	100
SM11	L	40	80	90	100
SM12	R	60	80	100	100
SM12	L	60	70	100	100
SM13	R	60	70	100	100
SM13	L	60	80	90	100
SM14	R	40	70	90	100
SM14	L	50	90	90	100
SM15	R	60	80	90	100
SM15	L	60	70	100	100

cont/...

SUBJECT	EAR	TEST COND.: MCR'S			
		-20dBMCR	-10dBMCR	0dBMCR	+10dBMCR
SF1	R	20	60	90	100
SF1	L	30	60	100	100
SF2	R	60	80	100	100
SF2	L	60	80	100	100
SF3	R	50	70	100	100
SF3	L	70	90	100	100
SF4	R	60	80	100	100
SF4	L	50	80	100	100
SF5	R	40	60	90	100
SF5	L	50	60	80	100
SF6	R	30	60	90	100
SF6	L	30	70	90	100
SF7	R	60	80	90	100
SF7	L	50	70	90	100
SF8	R	40	70	90	90
SF8	L	60	90	100	100
SF9	R	60	70	100	100
SF9	L	60	80	100	100
SF10	R	20	40	90	100
SF10	L	30	50	90	100
SF11	R	60	80	100	100
SF11	L	60	80	100	100
SF12	R	70	90	100	100
SF12	L	60	80	100	100
SF13	R	50	70	100	100
SF13	L	40	80	100	100
SF14	R	60	90	100	100
SF14	L	60	100	100	100
SF15	R	60	80	100	100
SF15	L	50	80	100	100

4.12.3 ARLT - Sample Printouts

GSI 33

Middle-Ear Analyzer

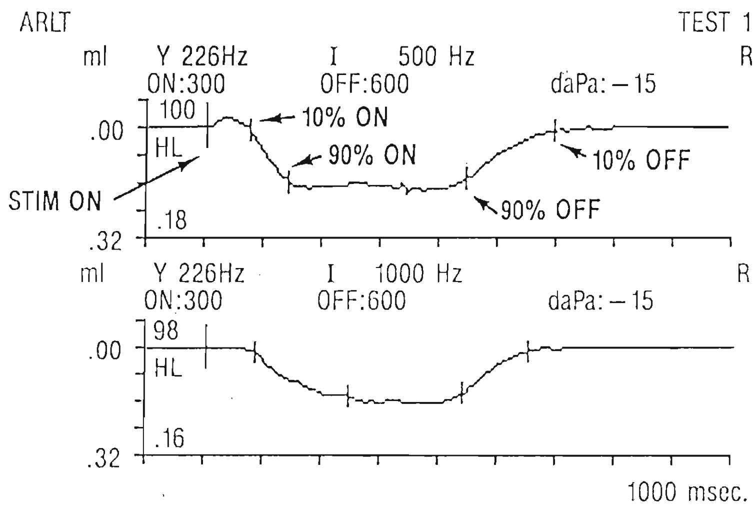
NAME: ______________________

I.D. #: ______________________

ADDRESS: ______________________

OPERATOR: ______________________

DATE: ____________ EARTIP: ____________



	10% / 90%	10% / 90%
ON:	74 / 140	86 / 240
OFF:	280 / 136	236 / 126
# AVG:	2	2

APPENDIX U

RAW SCORES ARLT TEST

SF1	R	500	ON	10	I	68
				10	C	102
		1000	ON	10	I	80
				10	C	82
		2000	ON	10	I	88
				10	C	76
	L	500	ON	10	I	74
				10	C	108
		1000	ON	10	I	72
				10	C	96
		2000	ON	10	I	82
				10	C	74
SF2	R	500	ON	10	I	122
				10	C	122
		1000	ON	10	I	164
				10	C	198
		2000	ON	10	I	128
				10	C	136
	L	500	ON	10	I	118
				10	C	124
		1000	ON	10	I	184
				10	C	170
		2000	ON	10	I	148
				10	C	152
SF3	R	500	ON	10	I	84
				10	C	126
		1000	ON	10	I	98
				10	C	118
		2000	ON	10	I	130
				10	C	138
	L	500	ON	10	I	84
				10	C	126
		1000	ON	10	I	94
				10	C	111
		2000	ON	10	I	120
				10	C	134
SF4	R	500	ON	10	I	130
				10	C	138
		1000	ON	10	I	136
				10	C	142
		2000	ON	10	I	142
				10	C	136
	L	500	ON	10	I	138
				10	C	134
		1000	ON	10	I	132
				10	C	140
		2000	ON	10	I	146
				10	C	140

cont/...

SF5	R	500	ON	10	I	108
				10	C	104
		1000	ON	10	I	122
				10	C	114
		2000	ON	10	I	116
				10	C	120
	L	500	ON	10	I	96
				10	C	100
		1000	ON	10	I	98
				10	C	102
		2000	ON	10	I	128
				10	C	146
SF6	R	500	ON	10	I	138
				10	C	118
		1000	ON	10	I	130
				10	C	120
		2000	ON	10	I	168
				10	C	176
	L	500	ON	10	I	130
				10	C	128
		1000	ON	10	I	136
				10	C	138
		2000	ON	10	I	174
				10	C	182
SF7	R	500	ON	10	I	88
				10	C	82
		1000	ON	10	I	108
				10	C	130
		2000	ON	10	I	152
				10	C	182
	L	500	ON	10	I	72
				10	C	78
		1000	ON	10	I	116
				10	C	128
		2000	ON	10	I	182
				10	C	168
SF8	R	500	ON	10	I	174
				10	C	162
		1000	ON	10	I	154
				10	C	146
		2000	ON	10	I	180
				10	C	192
	L	500	ON	10	I	170
				10	C	164
		1000	ON	10	I	144
				10	C	160
		2000	ON	10	I	188
				10	C	192

cont/...

SF9	R	500	ON	10	I	90
				10	C	84
		1000	ON	10	I	80
				10	C	82
		2000	ON	10	I	112
				10	C	98
	L	500	ON	10	I	92
				10	C	98
		1000	ON	10	I	104
				10	C	92
		2000	ON	10	I	112
				10	C	108
SF10	R	500	ON	10	I	94
				10	C	106
		1000	ON	10	I	124
				10	C	132
		2000	ON	10	I	194
				10	C	164
	L	500	ON	10	I	98
				10	C	114
		1000	ON	10	I	114
				10	C	138
		2000	ON	10	I	168
				10	C	172
SF11	R	500	ON	10	I	112
				10	C	114
		1000	ON	10	I	124
				10	C	120
		2000	ON	10	I	144
				10	C	152
	L	500	ON	10	I	108
				10	C	106
		1000	ON	10	I	126
				10	C	122
		2000	ON	10	I	152
				10	C	140
SF11	R	500	ON	10	I	84
				10	C	82
		1000	ON	10	I	84
				10	C	106
		2000	ON	10	I	132
				10	C	130
	L	500	ON	10	I	94
				10	C	98
		1000	ON	10	I	96
				10	C	96
		2000	ON	10	I	138
				10	C	140

cont/...

SF13	R	500	ON	10	I	128
				10	C	140
		1000	ON	10	I	132
				10	C	72
		2000	ON	10	I	188
				10	C	182
	L	500	ON	10	I	118
				10	C	138
		1000	ON	10	I	136
				10	C	174
		2000	ON	10	I	196
				10	C	200
SF14	R	500	ON	10	I	92
				10	C	100
		1000	ON	10	I	154
				10	C	108
		2000	ON	10	I	142
				10	C	130
	L	500	ON	10	I	92
				10	C	98
		1000	ON	10	I	92
				10	C	100
		2000	ON	10	I	148
				10	C	146
SF15	R	500	ON	10	I	128
				10	C	132
		1000	ON	10	I	110
				10	C	112
		2000	ON	10	I	148
				10	C	152
	L	500	ON	10	I	122
				10	C	134
		1000	ON	10	I	114
				10	C	118
		2000	ON	10	I	152
				10	C	156

cont/...

SM1	R	500	ON	10	I	112
				10	C	96
		1000	ON	10	I	148
				10	C	102
		2000	ON	10	I	122
				10	C	112
	L	500	ON	10	I	96
				10	C	86
		1000	ON	10	I	108
				10	C	102
		2000	ON	10	I	108
				10	C	100
SM2	R	500	ON	10	I	108
				10	C	102
		1000	ON	10	I	114
				10	C	108
		2000	ON	10	I	136
				10	C	142
	L	500	ON	10	I	120
				10	C	108
		1000	ON	10	I	128
				10	C	110
		2000	ON	10	I	154
				10	C	148
SM3	R	500	ON	10	I	122
				10	C	134
		1000	ON	10	I	96
				10	C	106
		2000	ON	10	I	126
				10	C	126
	L	500	ON	10	I	122
				10	C	134
		1000	ON	10	I	106
				10	C	104
		2000	ON	10	I	126
				10	C	128
SM4	R	500	ON	10	I	72
				10	C	110
		1000	ON	10	I	74
				10	C	72
		2000	ON	10	I	106
				10	C	100
	L	500	ON	10	I	102
				10	C	98
		1000	ON	10	I	108
				10	C	124
		2000	ON	10	I	106
				10	C	100

cont/...

SM5	R	500	ON	10	I	10
				10	C	24
		1000	ON	10	I	12
				10	C	10
		2000	ON	10	I	14
				10	C	18
	L	500	ON	10	I	24
				10	C	20
		1000	ON	10	I	10
				10	C	12
		2000	ON	10	I	36
				10	C	38
SM6	R	500	ON	10	I	138
				10	C	142
		1000	ON	10	I	154
				10	C	160
		2000	ON	10	I	174
				10	C	182
	L	500	ON	10	I	142
				10	C	148
		1000	ON	10	I	158
				10	C	162
		2000	ON	10	I	178
				10	C	184
SM7	R	500	ON	10	I	102
				10	C	106
		1000	ON	10	I	116
				10	C	120
		2000	ON	10	I	138
				10	C	142
	L	500	ON	10	I	112
				10	C	108
		1000	ON	10	I	106
				10	C	108
		2000	ON	10	I	148
				10	C	140
SM8	R	500	ON	10	I	108
				10	C	132
		1000	ON	10	I	134
				10	C	146
		2000	ON	10	I	166
				10	C	172
	L	500	ON	10	I	116
				10	C	128
		1000	ON	10	I	140
				10	C	152
		2000	ON	10	I	164
				10	C	166

cont/...

SM9	R	500	ON	10	I	74
				10	C	72
		1000	ON	10	I	80
				10	C	71
		2000	ON	10	I	108
				10	C	106
	L	500	ON	10	I	88
				10	C	72
		1000	ON	10	I	88
				10	C	92
		2000	ON	10	I	108
				10	C	108
				10	C	158
SM10	R	500	ON	10	I	132
				10	C	136
		1000	ON	10	I	142
				10	C	136
		2000	ON	10	I	148
				10	C	142
	L	500	ON	10	I	138
				10	C	138
		1000	ON	10	I	133
				10	C	130
		2000	ON	10	I	146
				10	C	148
SM11	R	500	ON	10	I	88
				10	C	82
		1000	ON	10	I	120
				10	C	112
		2000	ON	10	I	136
				10	C	136
	L	500	ON	10	I	84
				10	C	88
		1000	ON	10	I	126
				10	C	104
		2000	ON	10	I	140
				10	C	138
SM12	R	500	ON	10	I	118
				10	C	108
		1000	ON	10	I	118
				10	C	112
		2000	ON	10	I	144
				10	C	142
	L	500	ON	10	I	96
				10	C	96
		1000	ON	10	I	104
				10	C	10
		2000	ON	10	I	144

cont/...

SM13	R	500	ON	10	I	96
				10	C	96
		1000	ON	10	I	98
				10	C	110
		2000	ON	10	I	134
				10	C	134
	L	500	ON	10	I	78
				10	C	80
		1000	ON	10	I	98
				10	C	96
		2000	ON	10	I	106
				10	C	120
SM14	R	500	ON	10	I	106
				10	C	124
		1000	ON	10	I	136
				10	C	124
		2000	ON	10	I	170
				10	C	166
	L	500	ON	10	I	112
				10	C	120
		1000	ON	10	I	136
				10	C	116
		2000	ON	10	I	186
				10	C	164
SM15	R	500	ON	10	I	122
				10	C	138
		1000	ON	10	I	136
				10	C	146
		2000	ON	10	I	162
				10	C	158
	L	500	ON	10	I	128
				10	C	126
		1000	ON	10	I	128
				10	C	138
		2000	ON	10	I	168
				10	C	172
NSM1	R	500	ON	10	I	102
				10	C	104
		1000	ON	10	I	84
				10	C	138
		2000	ON	10	I	108
				10	C	112
	L	500	ON	10	I	96
				10	C	98
		1000	ON	10	I	86
				10	C	110
		2000	ON	10	I	132
				10	C	134

cont/...

NSM2	R	500	ON	10	I	100
				10	C	120
		1000	ON	10	I	104
				10	C	100
		2000	ON	10	I	148
				10	C	152
	L	500	ON	10	I	108
				10	C	110
		1000	ON	10	I	106
				10	C	108
		2000	ON	10	I	152
				10	C	168
NSM3		500	ON	10	I	110
				10	C	106
		1000	ON	10	I	120
				10	C	124
		2000	ON	10	I	156
				10	C	186
	L	500	ON	10	I	116
				10	C	106
		1000	ON	10	I	112
				10	C	114
		2000	ON	10	I	120
				10	C	112
NSM4	R	500	ON	10	I	94
				10	C	108
		1000	ON	10	I	98
				10	C	124
		2000	ON	10	I	134
				10	C	146
	L	500	ON	10	I	100
				10	C	102
		1000	ON	10	I	94
				10	C	106
		2000	ON	10	I	146
				10	C	158
NSM5	R	500	ON	10	I	130
				10	C	114
		2000	ON	10	I	106
				10	C	74
	L	500	ON	10	I	94
				10	C	106
		1000	ON	10	I	116
				10	C	104
		2000	ON	10	I	110
				10	C	84

cont/...

NSM6	R	500	ON	10	I	106
				10	C	132
		1000	ON	10	I	110
				10	C	112
		2000	ON	10	I	116
				10	C	278
	L	500	ON	10	I	102
				10	C	108
		1000	ON	10	I	110
				10	C	128
		2000	ON	10	I	126
				10	C	124
NSM7	R	500	ON	10	I	146
				10	C	132
		1000	ON	10	I	132
				10	C	148
		2000	ON	10	I	144
				10	C	154
	L	500	ON	10	I	122
				10	C	134
		1000	ON	10	I	116
				10	C	106
		2000	ON	10	I	170
				10	C	160
NSM8	R	500	ON	10	I	116
				10	C	120
		1000	ON	10	I	106
				10	C	118
		2000	ON	10	I	128
				10	C	118
	L	500	ON	10	I	92
				10	C	96
		1000	ON	10	I	124
				10	C	104
		2000	ON	10	I	140
				10	C	124
NSM9	R	500	ON	10	I	126
				10	C	128
		1000	ON	10	I	134
				10	C	128
		2000	ON	10	I	146
				10	C	158
	L	500	ON	10	I	98
				10	C	108
		1000	ON	10	I	128
				10	C	144
		2000	ON	10	I	184
				10	C	144

cont/...

NSM10	R	500	ON	10	I	90
				10	C	108
		1000	ON	10	I	106
				10	C	102
		2000	ON	10	I	104
				10	C	100
	L	500	ON	10	I	94
				10	C	112
		1000	ON	10	I	100
				10	C	106
		2000	ON	10	I	114
				10	C	121
NSM11	R	500	ON	10	I	120
				10	C	118
		1000	ON	10	I	118
				10	C	128
		2000	ON	10	I	138
				10	C	148
	L	500	ON	10	I	102
				10	C	110
		1000	ON	10	I	118
				10	C	120
		2000	ON	10	I	128
				10	C	138
NSM12	R	500	ON	10	I	130
				10	C	136
		1000	ON	10	I	106
				10	C	104
		2000	ON	10	I	140
				10	C	122
	L	500	ON	10	I	102
				10	C	96
		1000	ON	10	I	102
				10	C	96
		2000	ON	10	I	126
				10	C	118
NSM13	R	500	ON	10	I	92
				10	C	90
		1000	ON	10	I	100
				10	C	86
		2000	ON	10	I	186
				10	C	172
	L	500	ON	10	I	92
				10	C	90
		1000	ON	10	I	102
				10	C	98
		2000	ON	10	I	178
				10	C	164

cont/...

NSM14	R	500	ON	10	I	102
				10	C	108
		1000	ON	10	I	112
				10	C	128
		2000	ON	10	I	108
				10	C	124
	L	500	ON	10	I	98
				10	C	102
		1000	ON	10	I	100
				10	C	96
		2000	ON	10	I	102
				10	C	108
NSM15	R	500	ON	10	I	114
				10	C	106
		1000	ON	10	I	90
				10	C	80
		2000	ON	10	I	122
				10	C	120
	L	500	ON	10	I	98
				10	C	108
		1000	ON	10	I	96
				10	C	88
		2000	ON	10	I	134
				10	C	146
NSF1	R	500	ON	10	I	76
				10	C	82
		1000	ON	10	I	82
				10	C	92
		2000	ON	10	I	98
				10	C	102
	L	500	ON	10	I	82
				10	C	78
		1000	ON	10	I	88
				10	C	88
		2000	ON	10	I	96
				10	C	102
NSF2	R	500	ON	10	I	102
				10	C	114
		1000	ON	10	I	96
				10	C	90
		2000	ON	10	I	106
				10	C	102
	L	500	ON	10	I	94
				10	C	104
		1000	ON	10	I	104
				10	C	106
		2000	ON	10	I	110
				10	C	86

cont/...

NSF3	R	500	ON	10	I	80
				10	C	86
		1000	ON	10	I	90
				10	C	96
		2000	ON	10	I	112
				10	C	108
	L	500	ON	10	I	88
				10	C	86
		1000	ON	10	I	98
				10	C	94
		2000	ON	10	I	128
				10	C	134
NSF4	R	500	ON	10	I	102
				10	C	98
		1000	ON	10	I	110
				10	C	108
		2000	ON	10	I	124
				10	C	100
	L	500	ON	10	I	108
				10	C	102
		1000	ON	10	I	94
				10	C	108
		2000	ON	10	I	132
				10	C	106
NSF5	R	500	ON	10	I	114
				10	C	120
		1000	ON	10	I	124
				10	C	106
		2000	ON	10	I	126
				10	C	148
	L	500	ON	10	I	120
				10	C	124
		1000	ON	10	I	122
				10	C	104
		2000	ON	10	I	158
				10	C	152
NSF6	R	500	ON	10	I	106
				10	C	102
		1000	ON	10	I	88
				10	C	92
		2000	ON	10	I	98
				10	C	110
	L	500	ON	10	I	106
				10	C	96
		1000	ON	10	I	90
				10	C	88
		2000	ON	10	I	126
				10	C	130

cont/...

NSF7	R	500	ON	10	I	106
				10	C	114
		1000	ON	10	I	106
				10	C	108
		2000	ON	10	I	150
				10	C	146
	L	500	ON	10	I	104
				10	C	114
		1000	ON	10	I	128
				10	C	128
		2000	ON	10	I	138
				10	C	158
NSF8	R	500	ON	10	I	110
				10	C	102
		1000	ON	10	I	106
				10	C	110
		2000	ON	10	I	148
				10	C	160
	L	500	ON	10	I	110
				10	C	100
		1000	ON	10	I	146
				10	C	126
		2000	ON	10	I	148
				10	C	162
NSF9	R	500	ON	10	I	106
				10	C	112
		1000	ON	10	I	120
				10	C	106
		2000	ON	10	I	148
				10	C	156
	L	500	ON	10	I	110
				10	C	120
		1000	ON	10	I	124
				10	C	124
		2000	ON	10	I	176
				10	C	184
NSF10	R	500	ON	10	I	74
				10	C	84
		1000	ON	10	I	92
				10	C	86
		2000	ON	10	I	108
				10	C	100
	L	500	ON	10	I	86
				10	C	82
		1000	ON	10	I	96
				10	C	98
		2000	ON	10	I	108
				10	C	100

cont/...

NSF11	R	500	ON	10	I	98
				10	C	90
		1000	ON	10	I	112
				10	C	108
		2000	ON	10	I	108
				10	C	112
	L	500	ON	10	I	106
				10	C	84
		1000	ON	10	I	102
				10	C	92
		2000	ON	10	I	118
				10	C	108
NSF12	R	500	ON	10	I	106
				10	C	84
		1000	ON	10	I	106
				10	C	92
		2000	ON	10	I	118
				10	C	106
	L	500	ON	10	I	98
				10	C	90
		1000	ON	10	I	112
				10	C	112
		2000	ON	10	I	112
				10	C	108
NSF13	R	500	ON	10	I	88
				10	C	82
		2000	ON	10	I	106
				10	C	108
	L	500	ON	10	I	92
				10	C	96
		1000	ON	10	I	92
				10	C	86
		2000	ON	10	I	116
				10	C	120
NSF14	R	500	ON	10	I	106
				10	C	100
		1000	ON	10	I	126
				10	C	130
		2000	ON	10	I	158
				10	C	164
	L	500	ON	10	I	94
				10	C	92
		1000	ON	10	I	112
				10	C	118
		2000	ON	10	I	100
				10	C	98

cont/...

NSF15	R	500	ON	10	I	98
				10	C	108
		1000	ON	10	I	92
				10	C	96
		2000	ON	10	I	118
				10	C	110
	L	500	ON	10	I	100
				10	C	92
		1000	ON	10	I	96
				10	C	92
		2000	ON	10	I	148
				10	C	152

APPENDIX V

TEST RETEST RELIABILITY

DCV

SUBJECT	R	R	L	L	(R+L)	(R+L)	DC	DC
NSM2	54	56	34	36	88	92	29	33
NSM4	43	44	30	32	73	76	29	25
NSM13	43	45	29	32	72	77	28	29
NSF5	36	35	22	23	58	58	20	18
NSF14	39	43	24	29	63	72	24	20
SM2	24	28	36	42	60	70	20	19
SM14	26	28	39	40	65	68	19	17
SF9	43	46	30	32	73	78	25	22
SF15	49	51	34	35	83	86	30	28

cont/...

SSW - TEST : RETEST

	TE	TE	RNC	RNC	RC	RC	LC	LC	LNC	LNC	REV	REV
NSM2	1	0	0	0	0	0	1	0	0	0	1	0
NSM4	2	1	0	0	1	0	1	1	0	0	0	0
NSM13	0	1	0	0	0	1	0	0	0	0	0	2
NSF5		2	0	0	1	0	2	2	0	0	0	0
NSF14	0	1	0	0	0	1	0	0	0	0	0	0
SM2	6	4	0	0	1	3	2	1	0	0	8	10
SM14	5	5	0	1	3	3	2	1	0	0	1	0
SF9	0	0	0	0	0	0	0	0	0	0	0	0
SF15	0	0	0	0	0	0	0	0	0	0	0	0

cont/...

SSI : RETEST

SUBJECT	-20				-10			
	R	R	L	L	R	R	L	L
NSM2	6	6	5	6	9	9	8	8
NSM4	7	7	8	7	9	8	9	9
NSM13	5	6	5	5	8	8	9	8
NSF5	4	5	4	5	7	6	7	6
NSF14	7	6	6	5	10	9	10	9
SM2	4	3	6	6	8	6	9	9
SM14	4	3	5	6	7	8	9	8
SF9	5	5	5	5	6	6	6	7
SF15	5	5	4	4	7	7	8	7

SUBJECT	0				+10			
	R	R	L	L	R	R	L	L
NSM2	10	10	10	10	10	10	10	10
NSM4	10	10	9	10	10	10	10	10
NSM13	9	10	10	10	10	10	10	10
NSF5	9	10	9	10	10	10	10	10
NSF14	10	10	10	10	10	10	10	10
SM2	10	10	10	10	10	10	10	10
SM14	9	9	9	9	10	10	10	10
SF9	9	10	8	7	10	10	10	10
SF15	9	10	10	10	10	10	10	10

cont/...

CST : TEST RETEST

SUBJECT	R	R	L	L
NSM2	100	100	90	100
NSM4	100	100	100	100
NSM13	100	100	100	100
NSF5	90	90	80	80
NSF14	100	100	100	100
SM2	70	70	80	90
SM14	80	80	80	90
SF9	100	100	100	100
SF15	90	100	90	100

cont/...

ARLT TEST : RETEST

SUBJECT	-500 IPSI				500 CONTRA			
	R	R	L	L	R	R	L	L
NSM2	90	102	92	112	84	98	98	106
NSM4	94	112	100	102	108	118	102	106
NSM13	92	106	92	98	90	108	90	96
NSF5	114	96	120	102	120	98	124	108
NSF14	106	126	94	112	100	100	92	108
SM2	108	106	120	112	102	108	108	106
SM14	106	108	112	112	124	112	120	108
SF9	100	112	108	106	120	110	110	102
SF15	128	120	122	122	132	138	134	138

	1000 IPSI				1000 CONTRA			
SUBJECT	R	R	L	L	R	R	L	L
NSM2	80	88	104	102	82	86	92	108
NSM4	98	112	94	102	124	108	106	106
NSM13	100	102	102	110	86	100	98	106
NSF5	124	100	100	142	106	106	104	120
NSF14	126	152	152	134	130	44	118	132
SM2	114	106	106	124	108	106	110	120
SM14	136	134	134	132	124	120	116	128
SF9	104	96	96	94	100	98	108	94
SF15	110	110	110	120	112	108	118	122

cont/......

SUBJECT	2000 IPSI				2000 CONTRA			
	R	R	L	L	R	R	L	L
NSM2	112	120	112	120	98	108	108	108
NSM4	134	128	146	140	136	120	158	132
NSM13	186	162	178	152	172	174	164	164
NSF5	126	152	158	152	148	156	152	140
NSF14	158	158	150	114	166	164	148	152
SM2	136	154	154	152	142	156	148	148
SM14	170	148	186	178	166	152	164	166
SF9	148	106	152	110	152	108	168	112
SF15	142	154	152	152	152	160	156	148

services, the quality of the public goods and services, and mix of production inputs.