BEHAVIOURAL CORRELATES OF SPEECH PROCESSING IN NORMAL SPEAKERS UNDER DELAYED AUDITORY FEEDBACK

BANUMATHY (N)

Register No. 02SH0005

A Dissertation submitted in part fulfillment for the final year

M.Sc, (Speech and Hearing)

University of Mysore, Mysore

All India Institute of Speech and Hearing

Naimisham Campus, Manasagangotri

Mysore - 570006.

MAY- 2004

CERTIFICATE

This is to certify that the dissertation entitled **"BEHAVIOURAL CORRELATES OF SPEECH PROCESSING IN NORMAL SPEAKERS UNDER DELAYED AUDITORY FEEDBACK"** is the bonafide work in part fulfillment for the degree of Master of Science (Speech and Hearing) of the student with Register No. 02SH0005.

Director

Prof. M. Jayaram
All India Institute of
Speech and Hearing
Mysore - 570006.

Mysore
May 2004

CERTIFICATE

This is to certify that the dissertation entitled **"BEHAVIOURAL CORRELATES OF SPEECH PROCESSING IN NORMAL SPEAKERS UNDER DELAYED AUDITORY FEEDBACK"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other university for the award of any Diploma or Degree.

Guide

Dr. R. Manjula
Reader and HOD
Department of Speech Pathology
All India Institute of
Speech and Hearing
Mysore - 570006.

Mysore
May 2004

DECLARATION

I hereby declare that this dissertation entitled **"BEHAVIOURAL CORRELATES OF SPEECH PROCESSING IN NORMAL SPEAKERS UNDER DELAYED AUDITORY FEEDBACK"** is the result of my own study under the guidance of Dr. R. Manjula, Head of the Department, Department of Speech Pathology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in any other university for the award of any Diploma or Degree.

Mysore
May 2004

Register No. 02SH0005

Dedicated to

My

" Beloved Parents (my first teachers)
and loving (mathy) sisters"
&
My teachers (my second parents)
Especially my dearest Guide
Manjula ma'am,

For "U" had been my breath & strength to override all the barriers & in each and every small step that I attempt in my MOVE. . .

Its "U" who have taught me that 'every resource is with me & with in me'...

... Thank You my Lord for showering your blessings on me in their forms.

ACKNOWLEDGEMENTS

I express my sincere gratitude to my guide & my teacher, ***"(Dr. R. Manjula",*** *for the valuable guidance, rich corrections and endless help.* ***"One looks back with appreciation to the brilliant teachers, but with gratitude to those who touched one's human feelings"-*** *ma'am, I'am lost with out words to rightly express my exhaustive feelings for "ALL" that you have imparted in me, knowledge, confidence & to rightly plan, program and execute each & every act of mine especially in terms of research. ..It's your care & guidance that made me GROW academically at AIISH. . .*

I extend my thanks to the director, (Dr. M. Jayaram, AIISH Mysore, for permitting me to carry out the present study.

I would like to express my heartful thanks to Shyamala ma am for permitting me use the research room and use necessary instruments for my data collection.

I express my thanks to (Dr. Asha Yathiraj, HOD, Dept. of Audiology for permitting me use the video camera, Mrs. Revathi, for taking pains in issuing it whenever needed and Mr. Seetharam for teaching me the efficient handling of the camera.

My wholehearted thanks to all my subjects, unless for you guys' patience during the experiment, my dissertation wouldn't have taken it's final shape... thank u guys & gals.

"Good life is guided by knowledge & inspired by love"

My dearest Amma & Appa, what do I have to say. . .for what I'am today, I owe all to "YOU". It's the confidence, motivation, courage, strength that u have given me and the love & faith u have on me, has helped me thrive the troubled waters that I was in.- U R THE BEST ROLE MODEL for us (5) - You mean the world to me... acknowledging you with the word thank would be unappreciative ...

My dear Indhakka, Charakka, Vasakka & Madakka, I'am the richest on world gifted by HIM with 4 wonderful gems, as my "sisters" - this word has its' own power & value which no one else will understand. ...U 4 had always been by source of motivation right from imprinting 90% pass criterion from LKG till my completion of PG. ...I know I cannot part with this criteria even in my future... ***"Blood is thicker than water"- U****nless for u 6, I wouldn't have been here today.*

My dear cutiepies, Sneha, Kamali (pretty little ladies), Kamalesh kutta & Sarvesh kutta (the samrties), you are the cute little gifts that He's blessed me with.

My dear Ishuma & Murugesh anna (dear friends rather than relatives), Thank a lot for u'r boosting words at REAL hard times in place of an own brother. ...I wish our bond goes stronger

during passing times & I pray to God for the sustainance of my bond with my dear ones (I mean IT) atleast from now on...

(Dearest Puri anna (figure of inspiration) & Karthi anna-1 couldn't have asked Him for more caring caring brothers on earth.. .Thank for always being there for me,..

"God gave us relatives; Thank God, we can choose our friends"

Dearest Shivu, my dear brotherly friend, now I know why God didn't give me one for my own right from my childhood as he was waiting to send such a caring, laving, affectionate ... brother to me after 17 yrs of my birth. ..Our bond will strengthen in its own way...Thank for always being there for me bearing the troubles I give u in different forms...

Jinn, My dear luttu, the kind of friendship we share cannot be expressed on black and white As the distance b/w us grows, stronger GROWS, the bond b/w us..

(Dearest Varghese cheta,"debate is masculine, conversation is feminine"-had a nice time conversing with you & listening to the debates as well... did u get it pulavare - more than a friend, u mean to me a lot.

"Choose to listen rather than to talk. Silence increases u'r value" *- I appreciate u, JK for u'r wonderful listening skills (especially with ref. to ME)...I'am struck with words when I think of thanking you for "ALL" the "HELP rendered by you at times of need... THANXXX.*

Dearest Kiru & Anitha, there are no words left in me to express my feelings that I have for you.. "He has showered his blessings in the form of u 2 to help me climb the ladder of hard times & to share "ALL" my feelings ... Thanx for always being there for me in sharing all my good & hard times...

Dearest Kalai, a sisterly friend, thank u so much for always being there without saying no, whenever I needed u.. .will miss u lotz.

"Coming together is beginning, staying together is progress & working together is success"

Sneha, thanx for sharing a wonderful relation, more than a friend whom I can always count on & for letting me carry a whole lot of sweet memories in my heart which I would cherish forever.

RK & Vijay, ... thanks a lot for making even the silliest event memorable.

"(Books and friends should be few, but good"

Anitha, Regu, Then & Shivani, I'am carrying with me REAL sweet memories of each & every moment that I spent with u guys... esp'lly the window talks & terrace chats...

Sindhu (had always wondered your tolerable ears & mouth bearing u & u'r phone), Shereen (had always wondered if I can ignore the morning sun & be on bed till late in the day atleast once), Momsy (had wondered for u'r organized thoughts inspite of the disorganized *surrounding) & Viji, (for u'r speech rate as the jet speed rate) -Thank u for sharing wonderful moments.*

***"It's a good fishing in troubled waters"** - my dear classmates, I thank u guys so much simply 'coz u've helped me learn how to LIVE & LEAD A LIFE on any part of the earth ... 'Think all you speak but speak not all you think'... THANX once again.*

"Count your life by smiles, not tears; Count your life by friends, not years"

Dear Prakash, heartfelt thanx for your encouraging words right form the BEGINNING & for all the valuable suggestions that cleared (still not actually) up my dilemmas..Thanx j^c^or lending a helping hand always.

Dear Savitha, the moments we shared are always afresh in me... Thank you for what u'r to me.

Dear Ranga, Gopi, Jayashree (THANX), Radha, & Sudhakar, thanx for making the life at AIISH memorable.

"Old wood, best to burn; old wine to drink & old friends to trust"

*Thanx to all my friends, Rammi (u've a spl. place in my heart forever), Prabha, Mahesh, Jamuna, Suma, Joseph, Shankar, Vijay - I value u guys sooo much ... miss u all too. My Thanx is due to my behind the screen friends, **Thiru, Dheepa, Sree** (thanxxxx), Jose, Jithu & Sathish.*

Suma, Thanks for u'r valuable help at all moments knowing my needs, even before I do express them. Thanx to all my juniors & seniors for the encouraging words.

My extended thanx to the Library & Library Staff (esp'lly (Raju) Mr. Jagdeesh for giving a final touch and Mr. Shivappa for giving my WORK its' final shape.

"A ***good beginning makes a good ending"** - Finally I thank the Almighty for giving me the courage, confidence, strength & will power in each & every attempt of mine, not only in this work of mine, but to thrive all the times from the beginning till today at AIISH.. I gave the minds to God & hands to WORK.*

***"Instruction ends in the school but education ends only with life",** "Things do not change, we change", "The more busy we are, the more leisure we have", "The place to be happy is here, the time to be happy is now, & the way to be happy is to make other so", "Unknown I came, Known (to some extent) I go"- these are a few golden words I learnt at AIISH. . . Thank u AIISH.*

***Pen is mightier than sword"** - Do hands talk on minds behalf...*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF GRAPHS

INTRODUCTION

Speech is a goal directed and afferent guided motor skill. The neural mechanisms which are used to produce speech and the speech motor control, are achieved through neuronal activities that initiate and regulate muscle contraction for speech production. The speech motor control can be defined as the "motor afferent mechanisms that direct and regulate speech movements" (Netsell, 1982). Such a definition envisages that speech is a fine motor skill, which includes the following features. It is an activity which 1) is performed with accuracy and speed, 2) uses knowledge of results 3) is improved by practice 4) demonstrates motor flexibility in achieving goals and 5) regulates all of those to automatic control where consciousness is freed from the details of action plans (Wolff, 1979). Speech is the result of intricate, complex movement patterns, which require planning, coordination and timed execution. Hence a speaker generally uses a highly flexible motor program with motor equivalence, while achieving maximum precision (clarity) in production.

The theoretical basis for understanding the processes underlying normal speech production is provided by various models (Van der Merwe, 1997; Crary, 1993; Rosenbek, Kent & LaPointe, 1984). The sensorimotor control for speech is hypothesized as a process which involves several phases or hierarchical levels of neural organization (Jakobson & Gooddale, 1991). These phases are generally identified as planning, programming and execution. These are evidently sequential processes (Brooks, 1986; Gracco & Abbs, 1987).

Speech production begins with an idea. To communicate this idea, the speaker organizes into a linguistic code containing meaning and form. The form of the message must then be shaped into units of speech production, which in turn must be organized according to their own rules of appropriate combination (phonology). Because speech is a "physical phenomenon", these organized speech units must be transformed or coded into a motor program, which subsequently, is used to execute movements of the vocal tract that result in production of organized speech units. In this framework, speech begins as a mental concept that becomes linguistically organized, is transformed into a motor behavior, and is executed as a movement. Activity at any step along the process will influence the next step and possibly the preceding step.

Nerve impulses required for above events are generated in the motor sections of the brain and transmitted along the efferent pathways to the muscles and structures of the speech system. Variables that influence movement pattern include muscle strength, muscle tone, timing and synchronization of movement patterns of muscles and structures of respiration, larynx, pharynx, soft palate, tongue tip, lips and mandible. Also, sensory afference which is required for parameter selection is needed during or after movement as FEEDBACK, which plays an important role in the fluent speech production of an individual.

Feedback systems in spoken communication facilitates continual interaction between the speech and hearing mechanisms. That is, we speak the way we hear. When auditory feedback of normal speakers is altered, speech control suffers and this is well documented by various studies (Venkatagiri, 1980; Nataraja, Ramesh & Pandita, 1982; Ramesh, 1983). If for example, a delay is introduced between when a sound is spoken and when it is heard (DAF), speech rate decreases and speech errors occur. They include repetitions, prolongations, hesitations, pauses, increase in loudness and pitch with abnormal prosody and distorted articulation. Apart from disfliiencies and changes in voice parameters, difference in rate of speech was reported by Ramesh (1983). The explanation of these effects as cited in the literature suggests that speakers normally monitor their auditory feedback in order to check that the speech which is being produced is correct. Thus, when auditory feedback is artificially altered / interfered with, speech control suffers. In contrast to poor control in normal speakers under DAF, speech control in stutterers improves when feedback is altered. In line with explanations originally proposed for normals, the stutterers were thought to have an auditory feedback-monitoring problem in their speech which is rectified by altering feedback.

Many models of stuttering and speech produced under DAF conditions are based on some theories of linguistic rhythm. It is suggested that DAF causes the speaker to predict the time of occurrence of a future syllable in his own speech production, which is at variance with the time at which the speaker has planned to produce the same syllable. So the attempted correction of this asynchrony is considered to be the cause of disfluent speech production under DAF conditions.

Need for the Study:

Investigators in the past have attempted to provide information on "how" rather than "why" stutterers and non-stutterers differ with respect to different stages of speech production. The various models proposed to explain this factor, have in common highlighted an intrinsic (premature) feedback that disrupts the speech output at different levels. However, there is no clear consensus as to the level at which there is a breakdown. Also, there is no information in literature about the use of a behavioural approach to study the disfluencies of speech in normals under the influence of DAF and relating the disfluencies to the different levels of speech production process. Hence, the present study attempts to explore this factor in normals using a behavioral approach to analyze the level and type of disruption in speech production evident under the influence of DAF.

Review of literature suggests that when auditory feedback of normal speakers is altered, speech control suffers and this is well documented by various studies (Nataraja et al, 1982; Venkatagiri, 1980; Ramesh, 1983). It is reported that temporal control of the movements of different structures determines fluency. The classic central-peripheral issue that has guided much of the research in motor theory has given way to the more reasonable perspective that movement reflects an interaction of peripheral influences and central motor processes and hence behaviours are sensory motor in nature.

Several attempts have been made to determine the organization of speech motor control, i.e., to identify the appropriate level of articulatory organization. But lack of invariant individual articulatory actions and the relatively consistent ensemble articulatory actions suggest that the nervous system does not explicitly control the actions of a single muscle or articulator (Gracco & Abbs, 1986). Rather, speech motor actions are originated at a level that reflects the interaction of a number of muscles and / or articulators engaged in the same functional task.

Studies and different models have often hypothesized that the sensorimotor control for speech is a process, which involves several phases or hierarchical levels of neural organization (Jakobson & Goodale, 1991). These phases are generally identified as planning, programming and execution. Akin to such observations, the different processes, which contribute to an internal phenomenon, might be inferred through the use of a behavioral approach like Delayed Auditory Feedback (DAF). It is hypothesized that when DAF is induced in normal speakers, it is reported to cause speech errors such as repetitions, prolongations, hesitations, pauses, increase in loudness and pitch with abnormal prosody and distorted articulation. These disruptions suggest that speakers normally monitor their speech via auditory channel in order to check that the speech which is being produced is correct. The study will provide insights into the nature of different disruptions in normal speaker's speech under DAF in relation to deficits at different speech processing levels/ phases.

Tasks of varying cognitive - linguistic complexity were selected in the study to evaluate the effect of complexity of the stimulus on different stages of processing under the influence of different levels of DAF. Many studies have shown that complexity of the task affects speech differently in normals (Venkatagiri, 1980), in different clinical population as in stutterers and apraxics (Wingate, 1976; Postma, Kolk and Povel, 1990; Crary, 1993; Van der Merwe, 1997). Tasks varying in cognitive-linguistic complexity, will have an effect on the kind of formulation i.e., planning, muscle forces for different commands and their execution. This in turn will have an effect on the speech produced by an individual under DAF.

Aims of the study

- To investigate the disfluencies of normal speakers under the influence of DAF while performing tasks with different cognitive-linguistic complexity.
- To delineate the behavioural correlates of different levels of speech processing in normal speakers under the influence of DAF.

Method

30 normal adult speakers (15 males and 15 females) in the age range of 17-25 years were selected for the study and they were subjected to tasks of varying cognitive-linguistic complexity, first being, narration of a story and answering questions related to the story and second being the 'reverse spelling'. These tasks were preformed by the subjects under three different experimental conditions, viz, normal auditory feedback, DAF at 180 ms and DAF at 280 ms. The speech of the speakers under the three experimental conditions with two different tasks was analyzed for:

a) the overall disfluency of the subjects across the three different conditions,

b) Specific type of disfluencies (repetitions / prolongations/ inaudible pauses / audible pauses) across the three conditions,

c) performance on time taken for uttering words of different syllabic lengths across the three conditions,

d) rate of correct syllables (number of correct syllables per 100 words) recalled across the three conditions and across the words of different syllabic lengths,

e) other speech errors.

Immediately after exposure to the experimental conditions, the subjects were provided with a questionnaire (self-report) and the views about their quality of speech under the three feedback conditions were analyzed. The results from the perceptual analysis by the investigator and from the self-report were then correlated and discussed.

Implications of the study:

A preliminary attempt is made to delineate the behavioral correlates of different levels of speech processing in normal speakers under the influence of DAF. Many studies in the past have focused on different types of disfluencies that are characteristic of DAF induced speech disruption and have suggested remarkable similarities between DAF induced speech disruption and stuttering. But most of the studies have made no effort to introspect on the cause of disruption.

The study facilitates understanding of DAF - induced speech disruptions at different levels of speech processing and this will in turn provide valuable insights into the nature and etiology of stuttering.

Limitations of the study:

- Study needs to be replicated with more number of subjects.
- Due to time constraints the analysis was restricted in its extent. A more extensive error analysis / performance analysis might have yielded more information on the precise nature and level of speech breakdown.

REVIEW OF LITERATURE

Speech is an externalized expression of language. Speech production is more than an utterance of a simple string of sounds. It is the finest faculty in human being, which is controlled by specific areas in the human brain. For communication to be effective, the speech of an individual should be fluent. However, fluent speech need not necessarily be a perfect speech. During the speech act, all speakers pause, hesitate, repeat and prolong utterances in a variety of ways, but all these are perceived as being within the limits of normal communication. Under stress, most speakers exhibit disfluencies while using unfamiliar vocabulary or when they are made to speak in unfamiliar speaking situations. These disfluencies are not abnormal nor are they categorized as characteristics of stuttering. However, once a speaker crosses the critical boundary (which is not a predetermined entity and which is arbitrary in nature), listeners perceive them as abnormal disfluencies and they are evaluated differently by the listeners (Culatta & Goldberg, 1995).

Starkweather (1987) suggested that many of the variables that determine fluency includes pauses, rhythm, intonation, stress and rate. All these are determined by when and how fast we move our speech structures. The classic central-peripheral issue that has guided much of the research in motor theory for speech production has given way to the more reasonable perspective that movement reflects an interaction of peripheral influences and central motor processes and hence speech behavior is sensory motor in nature. Because of its well-learned and ethologically significant nature, speech is considered as an ideal behavior for the investigation of sensorimotor control mechanisms.

NEURAL SUBSTRATES AND SPEECH MOTOR CONTROL

In order to discuss the sensori-motor mechanisms that may underlie speech production, it is first necessary to determine the most plausible conceptualization of a system being controlled. During speech, different vocal tract actions are sequenced to produce groups of linguistically relevant sounds. Several attempts have been made to determine the specific organization of speech motor control, i.e., to identify the appropriate level of articulatory organization. The lack of invariant individual articulatory actions and the relatively consistent ensemble articulatory actions suggest that the nervous system does not explicitly control the actions of a single muscle or articulator (Gracco & Abbs, 1986). Rather, speech motor actions are originated at a level that reflects the interaction of a number of muscles and / or articulators engaged in the same functional task.

It has been suggested that there are multiple functional processes underlying the generation and sequencing of speech movements. These processes include phonological (vocal tract) specifications, sensori motor integration, and sequencing of sound producing elements. At present, any attempt to speculate on where or how such patterns are stored would be premature. However, it is possible to consider the sensori motor integration of these hypothetical patterns as well as to generally speculate on the contributions of various distributed neuroanatomical systems that are known to be involved in speech production (Kent, 1983; Gracco & Abbs, 1987).

Any motor behavior starts with a goal or idea, which is organized into a plan, coded into a specific motor program, and executed. Indeed, more areas of the brain are devoted to control muscles of tongue, lips and other speech articulators than to muscle groups needed for walking upright. The finer act of speech is only possible because a rich network of neural substrates controls the speech structures. However the efficient execution of oral speech requires:

a) Smooth sequencing and coordination of processes related to the organization of concepts
b) Planning and formulation, programming of coordinated motor functions including respiration, phonation, resonance, articulation & prosody
c) Performance of motor tasks necessary to produce speech sounds and combine them into words
d) Feedback for successful completion of many of the tasks.

This series of events originates in the brain where a movement plan is conceived, formulated and programmed. Nerve impulses required for such events to occur are generated in the motor sections of the brain and transmitted along the efferent pathways to the muscles and structures of the speech system (Hood, 1998).

The theoretical basis for understanding the processes underlying normal speech production is provided by various models (Rosenbek, Kent & La Pointe, 1984; Crary, 1993; Van der merwe, 1997). The sensori motor control for speech is hypothesized as a process, which involves several phases or hierarchical levels of neural organization (Jakobson & Goodale, 1991). These phases are generally identified as planning, programming and execution. These are evidently sequential processes (Brooks, 1986; Gracco & Abbs, 1987). In this framework, speech begins as a mental concept that becomes linguistically organized, is transformed into a motor behavior, and is executed as a movement. Activity at any step along the process will influence the next step and possibly the preceding step.

An important consideration concerning the sensory motor control of speech is the influence of various sensory modalities. Information extracted from the different sensory modalities forms the basis for communication, linguistic or sensory motor adjustments resulting in global as well as local effects on speech outputs. The three sensory channels that have the potential to modify speech motor output each in overlapping but unique ways are visual, auditory and somatic. In general, visual and somatic information doesn't appear to play a significant or consistent role in the direct regulation of speech motor output, when compared to the auditory channel. The potential effects of auditory input on motor control processes are greater, i.e., when the auditory input is eliminated temporarily, or distorted, then it might play a role in the ongoing modulations of speech motor output (Barlow & Abbs, 1978; Zimmerman, Brown, Kelso, Hurtig, & Forrest, 1988). Hence it follows that the sensory afference needed for parameter selection, is also needed during or after movement as FEEDBACK, which plays an important role in the fluent speech production of an individual. Through the feedback systems in spoken communication, there is continuous interaction between speech and hearing mechanisms. Hence when the auditory feedback of normal speakers is altered, the speech control suffers and speech errors occur.

INFLUENCE OF AUDITORY FEEDBACK

When the auditory feedback of a speaker is disrupted, speech errors such as repetitions, prolongations, hesitations, pauses, increase in loudness and pitch with abnormal prosody and distorted articulation occurs, which suggests that speakers normally monitor their auditory feedback in order to check that the speech which is being produced is correct. This has been proved from experiments, wherein auditory feedback of normal speakers was disrupted using stimuli such as masking noise, delayed auditory feedback and others.

DELAYED AUDITORY FEEDBACK

One type of disruption in auditory feedback is the delayed auditory feedback (DAF). Through DAF, speech in normal hearing individuals can be altered at different rates or delay intervals. The critical level to cause disfluent speech as reported in literature through DAF is around 200 m. secs (Venkatagiri, 1980; Nataraja, Ramesh & Pandita, 1982). When a person reads a passage and listens to his / her own speech through earphones and when there is a delay in the feedback speech of about 200 ms typical changes in speech occurs which includes a slow rate of speech, an increase in intensity and disruptions of usual rhythm of their speech (Hood, 1998).

In contrast to poor control in normal speakers under DAF, speech control in stutterers improves when feedback is altered. Ramesh (1983) reported additional disfluencies such as changes in voice parameters and difference in rate of speech. The occurrence of these effects suggests that speakers normally monitor their auditory feedback in order to check that the speech is correct. In line with explanations originally proposed for normals, the stutterers were thought to have an auditory feedback-monitoring problem in their speech, which is rectified by altering feedback. This is well documented by various investigators (Wingate, 1976; Dell, 1980; Venkatagiri, 1980; Postma, Kolk & Povel, 1991)

EFFECT OF DAF ON NORMAL SPEECH

Venkatagiri (1980) reported from his study on normal speakers, that of all the different forms of disruptions of speech known to occur under DAF, part word repetitions (PWR) are the most direct and persistent. Different effects at different delay intervals, were also reported as follows:

1) Optimum delay interval of 200 m. secs:

Maximum disruptions of articulatory performance occurred at the delay interval of 200 ms Phoneme additions (of which, 70 % consisted of repetitions) were the most common type of error. Thus, it was concluded that the delay interval that interferes most with speech performance also causes a large number of phonemic (part word) repetitions.

2) At non-optimum delay interval:

At delay intervals above and below the optimum delay interval of 200 ms the errors were preponderantly phoneme substitutions and omissions with only a few phoneme additions. Hence it was concluded that non-optimum delay intervals did not produce significant part word repetitions although they were capable of producing a relatively large number of other types of disfluencies. The dysrythmic phonation category included prolongation, distortion and omission of sounds giving the overall impression of imprecise articulation of phonemes. Although prolongation of sound was one of the characteristics that led to the judgement of dysrythmic phonation, such prolongations were almost always accompanied by one or more of the following: (a) Imprecise articulation giving the impression of undershooting of articulatory targets, (b) a notable increase / decrease in pitch and (c) improper stressing. However, there were no broken words. Dysrythmic phonation and part word repetition together accounted for nearly 71% of all disfluencies produced in the study. Therefore, it appeared that DAF primarily interferes with the production of speech elements no larger than a syllable. It was further observed that adaptation and the degree of consistency in the occurrence of disfluencies in the initial syllables of polysyllabic words in non stutterers was similar to that of stutterers. That is, stuttering and speech disruption under DAF were remarkably similar in terms of type and locus of occurrence of disfluencies and the pattern of responding over time. Further probe and clarification on the role of auditory feedback dysfunction in stutterers was suggested.

Nataraja et. al., (1982) observed that disruption of speech in terms repetitions, prolongations, hesitations and pauses under DAF were seen in both males & females. An increase in loudness and pitch with abnormal prosody was also observed. Further, articulation of subjects was affected, which in turn contributed towards poor intelligibility of speech. The results of this study supported the findings of Lee (1950), Fairbanks & Guttman (1958), Black (1951), Fairbanks (1955) and Venkatagiri (1980), which showed that DAF caused an increase in intensity, fundamental frequency, and duration of speech and disfluencies.

Many models of speech production and stuttering (Rosenbek, Kent & Lapointe, 1984; Crary, 1993; Vander Merwe, 1997) and the model of DAF suggests that disfluent speech is caused by a delay in the expected time of perception of the syllable with respect to the time at which the speaker has already planned to produce the same syllable. When there is asynchrony between the expected time of perception and planned time of production, then speech errors such as prolongation of syllables and a reduction in tempo occurs which are reported characteristics of speech produced under DAF conditions (Black, 1951 and Spilka, 1954). So the attempted correction of this asynchrony is considered to be the source of disfluent speech production under DAF conditions. In stutterers, these asynchronies are cancelled out and hence a fluent speech under DAF is seen.

It was reported that the elemental disfluencies present in stuttering, were predominant features of induced speech disruption. Frequent disfluencies on polysyllabic words, repetitions of initial syllables of words in part word repetitions were common to both groups. Thus stuttering and DAF induced speech disruption are remarkably similar in terms of the types and locus of occurrence of disfluencies and the pattern of responding over time. Wingate (1976) conceptualized that the production of speech involves a series of steps or "levels", beginning with an 'idea' and culminating in the formation of an acoustic signal. A malfunctioning at a particular 'level' irrespective of the causal factors involved may result in a specific form of disruption. From this point of view, Venkatagiri (1980) suggested that DAF and stuttering disrupt speech at approximately the same "level" along the speech production though the cause of disruption may or may not be similar. Wingate (1976) further observed that there are differences in the dysfluencies exhibited by stutterers and non-stutterers under DAF and he has also shown that almost all the conditions that temporarily ameliorate stuttering involve a slower rate of speech and significant changes in "Vocal Expression". Thus the 'tactics' used by nonstutterers under DAF to maintain fluency are the same as those that promote fluency in stutterers. He thus opined that it is highly probable that a breakdown at a particular level along the speech production process, irrespective of the causal factors involved, requires similar corrective measures.

EVIDENCE FROM STUDIES IN DISORDERED POPULATION

Postma, Kolk and Povel (1990) and Kolk (1991) from their study on nonstutterers and stutterers, assumed that the selection of phonological segments is disturbed due to a slowing down in the activation of phonological segments. The retrieval of a word form can be envisioned as the spreading of activation in a network of nodes representing various units of phonological structure. Activation spreads from the word meaning representation (lemma) to the segment nodes (Dell, 1980). Normally, at a certain moment during phonological encoding, the segment that is most highly activated will be selected for inclusion in the articulatory plan. However if activation builds up slowly, the activational competition between segmental representations may not be settled when selection takes place, i.e., several segments have roughly equal activations. As a result, wrong selections may occur more often than normal, which leads to errors in the articulatory plan.

In stutterers, errors are detected through internal monitoring, that is before they are uttered. The detection of an error leads to the interruption of speech output and to one or several attempts to reverse and reorganize the articulatory plan, which produces overt repetitions. Alternatively, the speaker may "hold" the speech output until the articulatory plan is appropriately fixed, which produces prolongations. Repetition of syllable onsets are interpreted as attempts to start speaking before the articulatory plan (i.e. the product of phonological encoding) has been completely specified (Wijnen and Boers, 1994). Prolongations and silent speech durations are reported to be appropriate measures of speech planning, viz., phonological encoding (Postma, Kolk and Povel, 1990). In the study by Postma, Kolk and Povel (1990), it was also observed that planning was more affected than programming and execution, as more of prolongations and inaudible pauses were noticed. Repetitions were characterized as more of execution errors and it was lesser in all the subjects who were exposed to DAF. Repetitions were also reported to be a part of planning error. Mc Clean (1996) hypothesized that stuttering dysfluencies are caused by a perturbation of phonological encoding, i.e., the construction of a fully specified articulatory program on the basis of word form information stored in the mental lexicon. Wijnen and Boers (1994) indicate that in stutterers, encoding of non-initial parts of syllables is delayed. The primary symptoms (repetitions or prolongation of syllable initial segment) are assumed to result from attempts at executing a syllable prior to the incorporation of correct vowel information in the articulatory plan.

Lozano & Dreyer (1978) tried DAF on dyspraxic patients. They did not find any change in dyspraxic speech production at word level with DAF. It seemed reasonable for them to conclude that the observed breakdown of voluntary control in dyspraxia of speech is based on a system other than that of auditory monitoring. The breakdown could occur in initiating motor function, kinesthetic or proprioceptive feedback, or combinations of those elements that are integrated for complete programmed motor performance. Many models which explain the speech characteristics of apraxics (Roy, 1978; Crary, 1993; Vander Merwe, 1997) assume that the speech errors in this group are due to disruptions in either the planning, programming or execution domains.

It is interesting to note that Byrd and Cooper (1989) noted some similarities in apraxia of speech and stuttering. The similarities in the symptoms have been related to central neurologic deficits, which appear to underlie both disorders (Rosenbek, 1980). Central neurological processing deficits have also been suggested as a possible etiological factor in stuttering (Rosenbek, 1980; Andrews, Craig, Feyer, Hoddinott, Howie & Neilson, 1983). Byrd and Cooper's study showed that the performance of stuttering group and developmental apraxia of speech (DAS) group were similar on seven of the eight subtests in Screening test for developmental apraxia of speech. The fact of similarity between two groups can be interpreted as supporting those who view the two disorders as having common features. That is, stutterers are assumed to have particular difficulties in speech programming, which make their speech plans vulnerable to error intrusions. Also, by means of internal monitoring, that is, monitoring of the speech plan itself, stutterers try to detect and correct these errors before they appear in the overt output (Kolk, 1991). Kolk, 1991 hypothesizes that the speech programming difficulties are concerned with disturbances in phonological encoding. Consequently, the errors that need correction would be phonemic and phonetic distortions bearing a strong resemblance to well-known speech error or slip-of the tongue categories like phoneme reversals, deletions or substitutions. In a similar vein, the covert self-repairs would lie in a continuum with overt self-repairs of speech errors. Naturally this approach is cited as not limited to habitual stutterers, but might apply to disfluency in normal speakers as well (Postma, Kolk, & Povel, 1991). These observations of stutterers speech is similar to that of apraxics in whom characteristics like groping behaviors, hesitations, perseverations are said to be the result of deficient planning and or execution (Crary, 1993)

In summary, from the studies on stutterers and apraxic's speech output and the models of normal speech production & DAF as explained above, we can hypothesize that the level at which speech errors occur in these three groups, that is, normal speakers under DAF, stutterers and apraxics may be the same. The study is undertaken to verify this aspect in the speech of normal speakers who exhibit disfluencies under disruption of their auditory feedback. DAF has been used in the present study as a behavioural measure to investigate the 'exact level of speech processing' at which there is a disruption and to identify and deliberate on the reasons for disfluencies in normal speakers under DAF.

METHOD

Auditory feedback plays a critical role in speech production. Delayed auditory feedback disrupts the speech fluency in normal speakers. The disfluency thus caused, when analyzed provides useful insight into how and what are the factors that seem to control speech production. The study attempts to investigate this issue. The study aimed to:

1) investigate the disfluencies of normal speakers under the influence of DAF, and analyze their performance on tasks with different cognitive-linguistic complexity.
2) observe and understand the behavioural correlates of different levels of speech processing viz, planning, programming and execution in normal speakers under the influence of DAF.

***Subjects**:*

30 normal adult speakers (15 males and 15 females), who were screened for speech, language and hearing impairment and history of dysfluent speech, served as subjects for the study. These subjects were kept blind to the purpose of the study.

***Instrumentation**:*

"Facilitator", a portable therapy instrument was used. It was set to DAF module and time delays of 180 ms and 280 ms were introduced when the subjects performed selected speech tasks. A tape recorder was used to audio-record the speech samples of the subjects during the performance of the tasks under the influence of DAF.

Tasks.

Two tasks which varied in cognitive - linguistic complexity were selected. The reason for the selection of these tasks was based on the hypothesis that they could reflect on the different levels of speech processes. That is, the variation in the cognitive linguistic load of the material could affect the levels of speech processes differently.

The 2 tasks were:

1) *Recalling, narration and answering questions:*

This task required recalling and narrating a story and answering to questions asked related to the story. This task was selected because the subjects required to think and formulate the sentences consciously in order to recall and narrate the story. In addition to this, it also facilitated observation of differences if any in the performance of subjects during the subtasks of a) narrating the story and b) answering to questions related to the story.

2) *Reverse spelling:*

This task involved words of varying syllable lengths (which varied from bisyllables to five syllables). The task was selected based on the hypothesis that processing for recall of syllables in a word in the reverse order would be different and complex.

Experimental conditions:

Stage I*:* subjects performed the selected tasks in three feedback conditions:

- Normal auditory feedback
- Delayed Auditory Feedback(DAF) at 180 ms delay interval, and
- Delayed Auditory Feedback(DAF) at 280 ms delay interval

These delay intervals were selected as literature quotes that 200 ms is the critical level for occurrence of disfluencies (Black, 1951, Venkatagiri, 1980; Nataraja et al, 1982). All the 30 subjects were subjected to three different experimental conditions in the above mentioned order for each of the tasks i.e., they were first subjected to normal auditory feedback condition followed by DAF at 180msec and finally by DAF at 280msec. Though this order of conditions remained the same the tasks were presented randomly across each of the subjects.

***Stage II**:*

The experiment also included a questionnaire (enclosed in Appendix A). This questionnaire consisted of two sections, section A and B. The questions were categorized based on the feature it intended to probe in the speech processing, i.e., planning, programming and execution. For example, since planning phase involves appropriate selection and sequencing of sounds and words, questions related to these features were asked. Examples for such a categorization are given in Appendix B. In the programming phase, since activation of muscular commands are involved, questions related to movement of jaw, lips and other articulators were involved. Since execution phase is more characterized as a peripheral involvement, questions related to the actual act of speech such as loud or soft speech, abnormal respiratory pattern etc. were included.

This questionnaire was administered to the each of the 30 subjects immediately after the completion of experimental tasks. They were asked to express their views regarding quality of their speech under the experimental situations. The instruction was given as follows:

"Please read the questionnaire and answer to the questions in sections A & B. Describe your experiences under the experimental situations in brief for the question in section A and indicate as yes/no for the questions in section B ".

***Material**:*

A) For task 1 i.e., story narration and answering questions related to stories), three stories which were equally difficult were selected. However, each subject could choose anyone from among the three stories (the titles of these stories were written on three separate cards), which was presented in random for narration as well as answering to questions. For each story the experimenter prepared a set of 5 questions. They were written on cards and presented to subjects in a random order one by one during the subtask performance of answering to questions. The test materials for the above tasks were developed differently for three different conditions i.e., three stories were selected so that the subject selects one story among the three for each of the three conditions, i.e., normal auditory feedback, DAF at 180 ms and DAF at 280 ms.

B) For task 2 i.e., reverse spelling, three cards, each consisting of four word lists for bi-syllabic, tri-syllabic, four-syllabic and five-syllabic words were prepared with each list consisting of five words.

C) For task 3, a questionnaire was prepared consisting of two sections: sections A & B. Section A consisted of open ended questionnaire where the subjects were asked to describe their experiences during the delayed feedback conditions in brief. Section B consisted of 24 Yes / No questions. In the latter, the questions were designed such that it probed into the details to delineate the breakdown in the behavioural correlates of speech processing abilities, viz planning, programming and execution.

Data collection and recording of speech samples:

The materials for the two tasks in study were randomly presented across subjects to rule out the order effect. The tasks were performed by the subjects under the three experimental conditions.

With respect to each of the tasks, the subjects were instructed in the following manner:

Task 1: *Story narration and answering to questions:* the three stories selected were given to the client for reading, approximately 15 minutes prior to the commencement of the experiment. The instruction was given as follows: *"Please narrate the story that you have chosen and answer the five questions related to the story that is presented in the card".*

Task 2*: Reverse spelling:* The subjects were provided with bi-syllabic, tri-syllabic, four syllabic and five syllabic words (with five words in each set). The subjects were instructed as follows: *"Please read out the word given in the card. The card will be taken away after you read the word in the card once and then you will have to reverse spell the word with out looking at the card ".* The instructions mentioned here was the same across subjects for all the three experimental conditions mentioned above.

The speech samples under all the three experimental conditions for each of the above tasks were audio recorded using a tape recorder.

Immediately after the exposure to experimental conditions, all the subjects were asked to answer a questionnaire, consisting of two sections, A and B. Section A consisted of open ended questionnaire where the subjects were asked to describe their experiences during the delayed feedback conditions in brief. Section B consisted of 24 Yes / No questions.

***Analysis**:*

Analysis was carried out in three stages:

1. Perceptual analysis:

Perceptual analysis was carried out by the experimenter for identification and tabulation of various disfluencies in the speech of the subjects, during the performance of various speech tasks under normal auditory feedback and two different delay intervals. This section was analysed as follows:

***Task 1**:* This included two subtasks, i.e., narration and answering to questions. Here, the total number of words uttered by each of the subjects in a particular task and the total number of disfluencies exhibited by them was calculated. Then, rate of disfluency, that is, the number of disfluencies per 100 words, was calculated. This was computed as: total number of disfluencies divided by the total number of words uttered multiplied by 100. The raw data on rate of disfluency was then subjected to statistical analysis using 'paired T- test' to find if there was a significant difference in the rate of disfluency across the three experimental conditions (NAF, DAF at 180 ms and DAF at 280 ms). Rate of disfluency was also compared statistically using 'paired T-test' between the two subtasks to check if there was a significant difference between the two.

Perceptual analysis of speech was also carried out to identify and tabulate the frequency of occurrence on the different types of disfluencies in specific such as prolongations, repetitions, inaudible and audible pauses in each of the subtasks in task 1. The data was analyzed for total number of occurrences and the difference in occurrence of different disfluencies. The data was statistically analyzed using 'One-way ANOVA' to find if there was a significant difference across the three experimental conditions and to identify the disfluency that occurred most frequently.

***Task 2**:* Task 2 was reverse spelling. Here the experimenter measured the total time taken for the complete utterance of each word in the word list (five words in each syllabic groups). The raw scores were recorded in 'seconds' and the results were tabulated.

The number of correctly uttered syllables in each of the syllable structure (bi-syllabic to five syllabic) was also calculated. The rate of correctly uttered syllables was calculated by dividing the number of correctly uttered syllables by the total number of syllables in the word (under each of the four syllable conditions viz, bi-syllable, tri-syllable, four-syllable and five-syllable) and multiplied by 100.

The raw data for total time duration and rate of correctly uttered syllables were statistically tested using 'One-way ANOVA' to find:

- The difference in performance across the three experimental conditions.
- The difference in performance across words with four different syllable structure,

- The difference in performance in the rate of correctly uttered syllables across the three experimental conditions.

Task 3:

2. Section A - Self evaluation of the listening experience by the subjects (from section A of the questionnaire). Here the views of the subjects about the quality of their speech under the experimental situations were analyzed. The results were extracted by listing out the common features that were reported by the subjects in a hierarchical order.

3. Section B - Yes / No responses to questionnaire:

This section consisted of questions that were designed to probe into and delineate the level of breakdown in behavioural correlates of speech processing abilities, viz planning, programming and execution. The number of subjects reporting specific types of disfluencies such as prolongation, repetition, inaudible pauses, audible pauses, abnormal rhythm, intonation, stress or in general prosody for each of the three experimental conditions were tabulated. This was converted to a percentage score by dividing the number of subjects reporting specific type of disfluency by the total number of subjects multiplied by 100.

The results were discussed and inferences were drawn. This is presented in the next chapter.

RESULTS AND DISCUSSION

The aims of the study were:

a) to investigate the disfluencies of normal speakers under the influence of different levels of DAF while performing tasks with different cognitive-linguistic complexity and

b) to delineate the behavioural correlates of different levels of speech processing in normal speakers under the influence of DAF.

Thirty normal adult speakers (15 males and 15 females) in the age range of 17-25 years were selected for the study. These subjects were kept blind to the purpose of the study.

Two tasks of different cognitive - linguistic complexity were selected and these tasks included:

a) story narration and answering questions related to the story and

b) reverse spelling.

The three experimental conditions included:

a) Normal auditory feedback without any delay

b) DAF at 180 ms, and

c) DAF at 280 ms.

The tasks were presented in random order to all subjects to rule out any order effect. The subjects were asked to speak under the three experimental conditions and their speech samples were audio recorded. After the experimental conditions, the subjects' recorded speech samples were analyzed and the results are discussed under the following sections:

1) Perceptual analysis of speech disfluencies

2) Analysis of responses obtained under Self report from subjects

a) self evaluation of listening experience from section A of the questionnaire

b) self evaluation of listening experience from section B of the questionnaire.

The results are tabulated and discussed under each of these sections:

1) Perceptual analysis of speech disfluencies:

Perceptual analysis of disfluencies in the speech samples of the subjects during the performance of two different speech tasks in the three experimental conditions was carried out only by the investigator. The results in this section are presented task wise and discussed separately.

I) ***Task I:*** This consisted of two subtasks i.e., story narration and answering to questions. The speech samples of the subjects recorded for these two tasks, under the three experimental conditions were analyzed for the following parameters:

A. Overall disfluency rate

B. Types of disfluencies in specific such as repetition, prolongation, inaudible pauses and audible pauses.

A) The overall disfluency rate: the number of disfluencies per 100 words for both the tasks of narration and answering to questions was calculated for individual subjects. The raw scores obtained were then subjected to statistical analysis using 'Paired T-test'. This was done to examine if there is a significant difference in the overall mean disfluency rate across the three experimental conditions, i.e., normal auditory feedback. DAF at 180 ms and DAF at 280 ms. The mean disfluency rates were tabulated as shown in Table 1a.

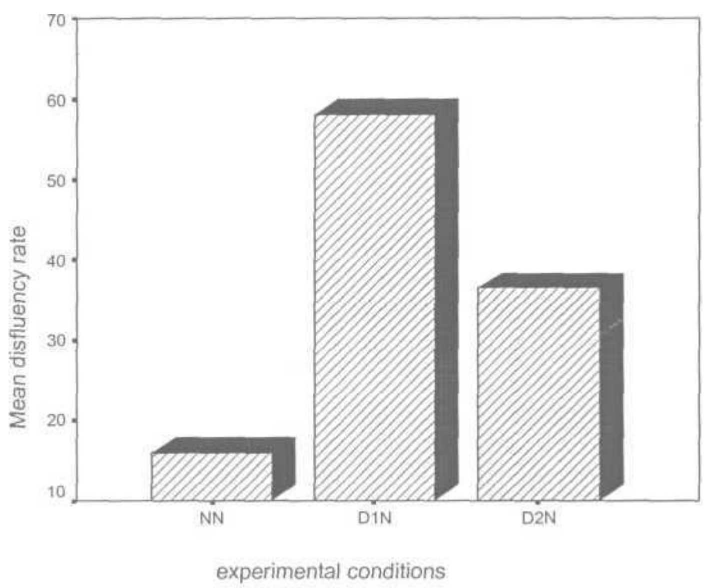
Table 1a: *Mean disfluency rates across the three experimental conditions in the narration task*

Experimental conditions	N	Narration		Mean difference	t values	df	sig
		Mean	SD				
NAF(NN)	30	16.03	9.5	-42.1	-4.643	29	.000*
DAF at 180ms (DIN)	30	58.1	48.6	-20.5	-8.814	29	.000*
DAF at 280ms (D2N)	30	36.5	9.7	21.5	2.462	29	.020*

'*' = significant difference at .05 level.

The results are graphically shown in Graph 1:

Graph 1: *Mean disfluency rates across the three experimental conditions in the narration task*



NN→ NAF; D1N→ DAF (180 ms); D2N→ DAF (280 ms) {for narration task}

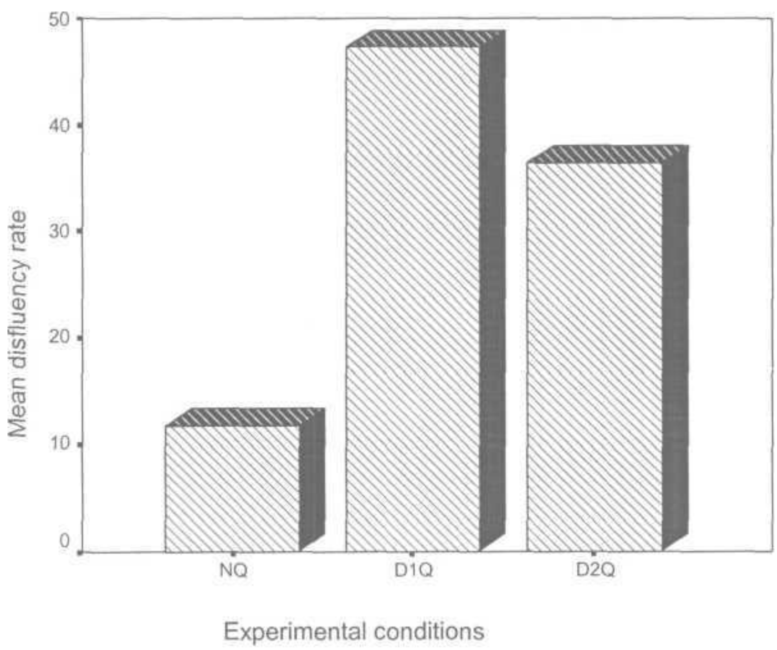
Table lb: *Mean disfluency rates across the three experimental conditions in the task of answering to questions*

Experimental conditions	N	Answering to questions		Mean difference	t values	df	sig
		Mean	SD				
NAF (NQ)	30	**11.7**	**7.72**	-35.5333	-8.278	29	.000*
DAF at **180 ms (D1Q)**	30	**47.3**	**20.8**	-24.6667	-7.466	29	.000*
DAF at **280 ms (D2Q)**	30	**36.4**	**16.4**	10.8667	2.355	29	.026*

'*' = significant difference at .05 level.

The results are graphically shown in Graph 2:

Graph 2: *Mean disfluency rates across the three experimental conditions in the task of answering to questions*



NQ→ NAF; D1Q→ DAF (180 ms); D2Q→ DAF (280 ms) {for answering to questions}

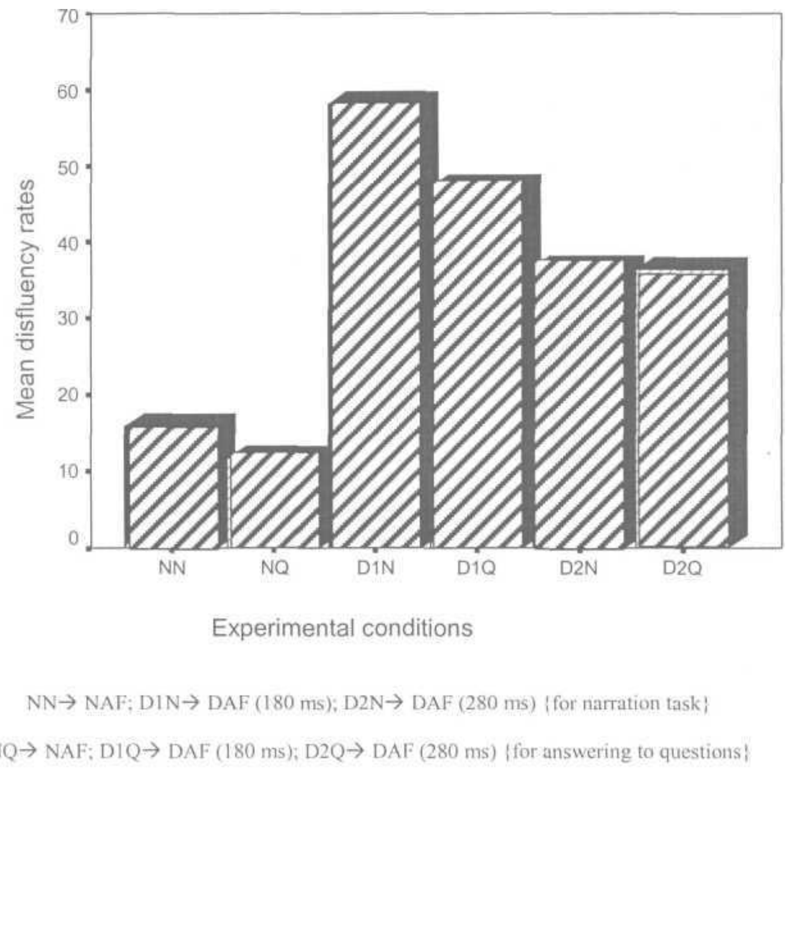
Table lc: *Mean differences between the tasks of narration and answering to questions*

Experimental conditions	N	Paired differences		t values	df	sig
		Mean	SD			
NAF (N-NN)-NAF (A-NQ)	30	4.26	10.67	2.190	29	.037*
DAF (N-DIN)-DAF (A-D1Q)	30	10.83	39.45	1.504	29	.143
DAF (N-D2N)-DAF (A-D2Q)	30	.13	15.81	.046	29	.963

'*'= significant difference at .05 level. (N) à Narration; (A) à Answering to questions.

The results are graphically shown in Graph 3:

Graph 3: *Mean differences between the tasks of narration and answering to questions*



NN→ NAF; D1N→ DAF (180 ms); D2N→ DAF (280 ms) {for narration task}

NQ→ NAF; D1Q→ DAF (180 ms); D2Q→ DAF (280 ms) {for answering to questions}

It is evident from the results in Table 1 a and Graph 1 that there is a significant difference at .05 level between the three experimental conditions for narration task. From the mean values, we can infer that the overall disfluency rate (number of disfluencies per 100 words) at 180 ms delay interval is highest followed by the disfluency rate at 280 ms and finally by the disfluency rate at normal auditory feedback. This pattern of error occurrence seems to be similar for the task of answering to questions also, which is evident from the results in Table lb and Graph 2. This shows that normal speakers exhibit disfluency more at the delay interval 180 ms than at 280 ms. Under normal auditory feedback, subjects showed least disfluency rate when compared to that at delay intervals 180 ms and 280 ms respectively. This supports the findings of Venkatagiri (1980), on normal speakers, wherein maximum disruptions of articulatory performance was reported to occur at the optimum delay interval of 200 ms than at delay intervals above and below the optimum delay interval of 200 ms. Fairbanks (1955) has reported that delays in feedback longer or shorter than the critical 0.2 sec disrupt a normal speaker's speech output less than at the critical level.

When the disfluency rate was compared between the two subtasks, the results (as shown in Table lc and Graph 3) showed that, there is a significant difference in the disfluency rate between the narration task and task of answering to questions under normal auditory feedback. There is no significant difference between the two subtasks under either of the delay intervals in question. This shows that normal speakers' exhibit more difficulty in recalling and narrating than when answering to questions under normal auditory feedback condition. This can be reasoned on the basis that more complex thought processes are involved for recall and narration rather than for answering to questions. The reduced rate of disfluency during answering to questions related to the story can also be attributed to the facilitating effect that was enjoyed by the subjects through the visual presentation of the questions. This could have helped the subjects in planning better for the expression, as most of the words to be expressed were graphically presented on cards. Probably they gained more time which helped them to process the correct answer for the questions.

When the disfluency rate of males and females were compared statistically using univariate analysis, i.e., 'One-way ANOVA' to check for any significant variations between the groups, it was found that there is no significant difference between the two groups in terms of the disfluency rate. This finding is contradicting to the findings by Wingate (1976) who reported of men having greater disfiuencies than women and Fukawa, Yoshioka, Ozawa & Yoshida (1988) who reported of men being more susceptible to DAF than women in the non-stuttering group. The results showed similar trend for the normal speakers group comparable to that for stutterers in Fukawa's study. The similarity seen in the performance of both the sexes in this study suggests that there could be some processing phases that are similar in the two groups.

B) Perceptual analysis of specific disfiuencies:

The speech samples were perceptually analyzed for various types of disfiuencies such as repetitions, prolongations, inaudible pauses and audible pauses across the three experimental conditions. The raw scores were subjected to statistical analysis using 'One way-ANOVA'. The results are tabulated in Table 2a and 2b. This was done separately for the two subtasks (Narration and Answering to questions).

Table 2a: *Mean and standard deviation (SD) of different disfluencies across the three experimental conditions in narration task*

Experimental conditions	N	Types of disfluencies	Mean	SD	F - ratio	P value
NAF (NDF)	30	-Repetition	5.33 +#	5.42	5.373	.002*
	30	-Prolongation	7.00 +	4.57		
	30	-Inaudible pauses	2.56 #	2.58		
	30	-Audible pause	4.13 +#	4.62		
DAF(180ms)	30	Repetition	10.40 +	7.74	52.724	.000*
-D1DF	30	-Prolongation	47.53 #	27.76		
	30	-Inaudible pauses	8.00 +	5.96		
	30	-Audible pause	5.70 +	5.45		
DAF (280ms)	30	Repetition	10.06 +	7.03	46.623	.000*
-D2DF	30	-Prolongation	43.03 #	26.68		
	30	-Inaudible pauses	7.43 +	5.89		
	30	-Audible pauses	5.16 +	4.89		

'*'= significant difference at .05 level. df's – 3, 116; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level). The mean significant differences are denoted by, "+", "#" and +#. The mean values that are denoted by different symbols are significantly different from each other. Those denoted by same symbols are not significantly different. This holds good for all the mean values in the following tasks also.

The results are graphically shown in Graph 4:

Graph 4: *Mean disfluencies across the three experimental conditions in narration task*

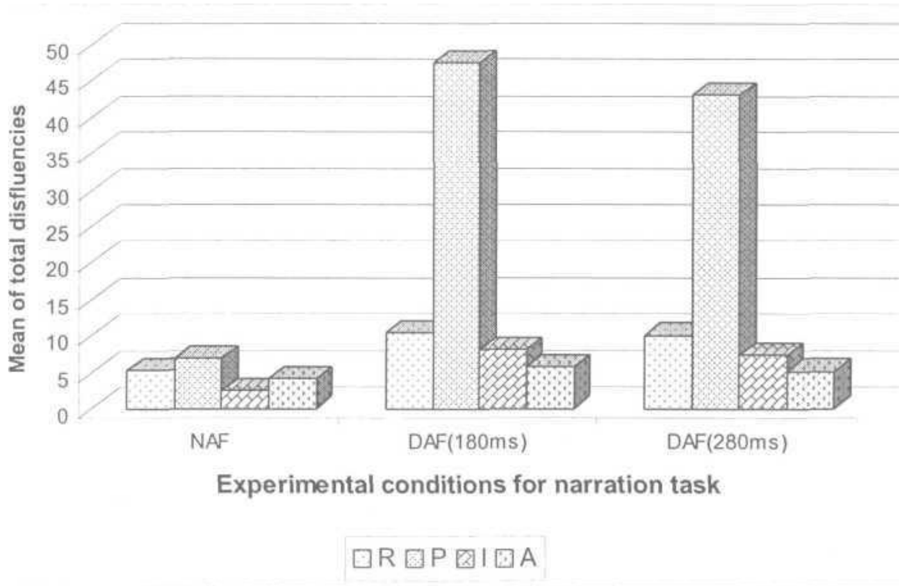


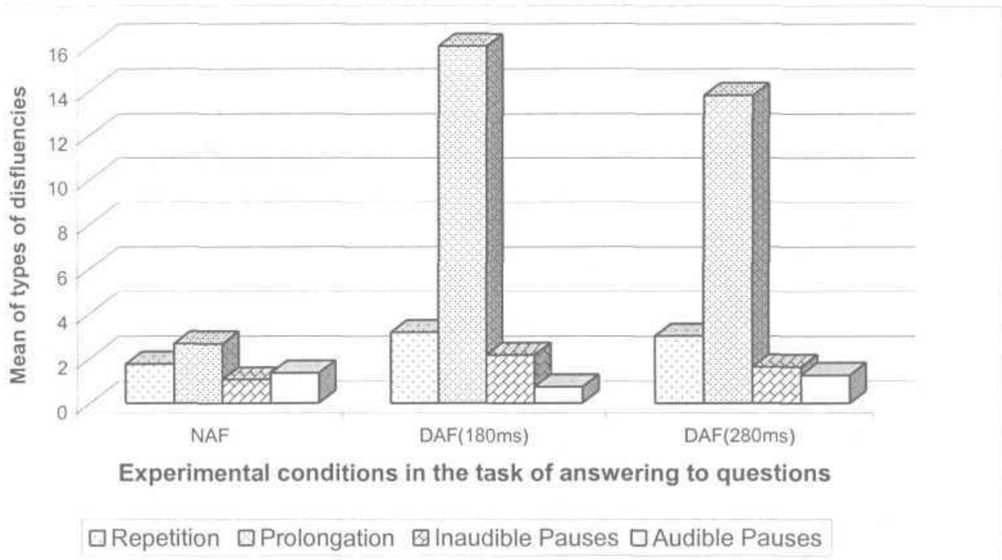
Table 2b: Mean and standard deviation (SD) of different disfluencies across the three experimental conditions in the task of answering to questions.

Experimental conditions	N	Types of disfluencies	Mean	SD	F - ratio	P value
NAF (NDFQ)	30	-Repetition	1.76+#	1.83	4.511	.005*
	30	-Prolongation	2.66 +	2.23		
	30	-Inaudible pauses	1.06 +	1.83		
	30	-Audible pause	1.36+#	2.23		
DAF (180ms) -D1DFQ	30	-Repetition	3.16 +	1.69	38.801	.000*
	30	-Prolongation	16.00 #	1.87		
	30	-Inaudible pauses	2.16 +	3.16		
	30	-Audible pause	.73 +	1.20		
DAF (280ms) - D2DFQ	30	Repetition	3.00 +	2.65	47.643	.000*
	30	-Prolongation	13.80 #	8.80		
	30	-Inaudible pauses	1.63 +	1.58		
	30	-Audible pause	1.26 +	1.59		

'*' = significant difference at .05 level. df's – 3, 116; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 5:

Graph 5: *Mean disfluencies across the three experimental conditions in the task of answering to questions.*



From table 2a, 2b and from Graph 4 & 5, it can be inferred that there is a significant difference across the four types of disfluencies exhibited by the subjects between the three experimental feedback conditions. The overall disfluency is significantly greater in feedback condition with 180msec delay interval followed by 280msec delay interval and it is least under normal auditory feedback condition. This correlates with the results obtained in the earlier section where the overall disfluency rate was greater under the 180msec delay interval followed by that with 280msec delay interval and it was least with normal auditory feedback condition. When type of disfluencies were compared with in each of the feedback conditions, it is observed that:

- In NAF condition, prolongations are significantly greater than inaudible pauses.

- With DAP at 180 ms delay, prolongations were again significantly greater from other three parameters, i.e., repetitions, inaudible and audible pauses.
- With DAF at 280 ms, again prolongation errors were significantly greater from other three parameters.

The results obtained were similar for both the subtasks as shown in tables 4a and 4b respectively.

Each of the four types of disfiuencies in the three conditions were further compared and the results are shown in Tables (table 2c and 2d).

Table 2c: *Mean and standard deviation (SD) of specific disfiuencies across different experimental feedback conditions in narration task.*

Types of disfiuencies	**N**	**Experimental conditions**	**Mean**	**SD**	**F - ratio**	**P value**
Repetition (rep)	30	NAF	5.46 +	5.34	4.957	.009*
	30	DAF (180ms)	10.40 #	7.74		
	30	DAF (280ms)	10.06 +	7.03		
Prolongation (prol)	30	NAF	6.86 +	4.72	29.717	.000*
	30	DAF (180ms)	47.53 #	27.76		
	30	DAF (280ms)	43.03 #	26.68		
Inaudible pauses (iap)	30	NAF	2.56 +	2.58	10.429	.000*
	30	DAF (180ms)	8.00 #	5.96		
	30	DAF (280ms)	7.43 #	5.89		
Audible pauses (ap)	30	NAF	4.13	4.62	.760	.471
	30	DAF (180ms)	5.70	5.45		
	30	DAF (280ms)	5.16	4.89		

'*' = significant difference at .05 level. df's – 2, 87 ; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 6:

Graph 6: *Mean of specific disfiuencies across different experimental feedback conditions in narration task.*

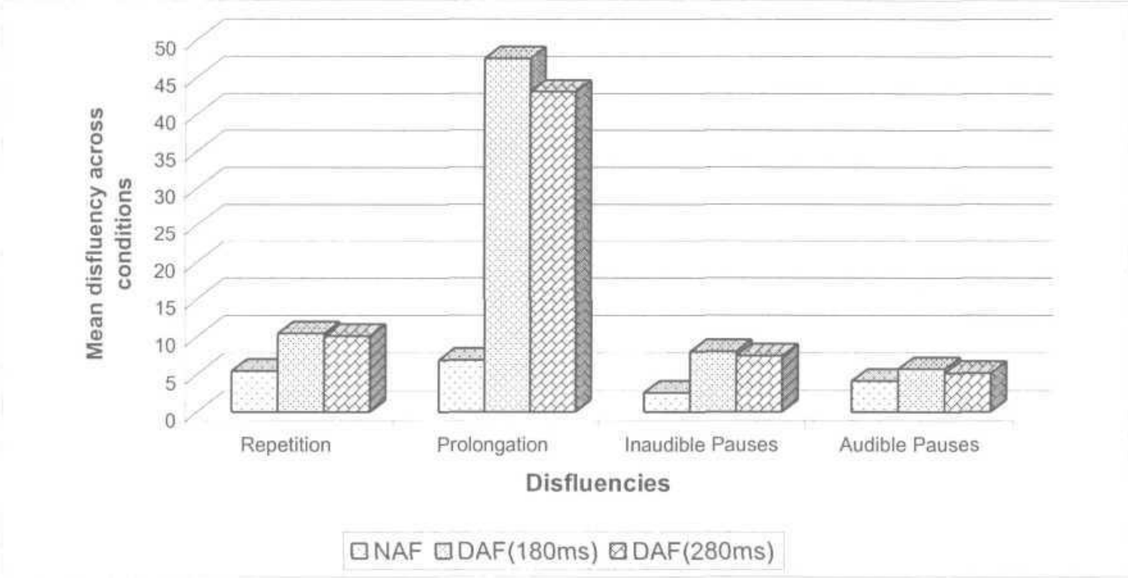


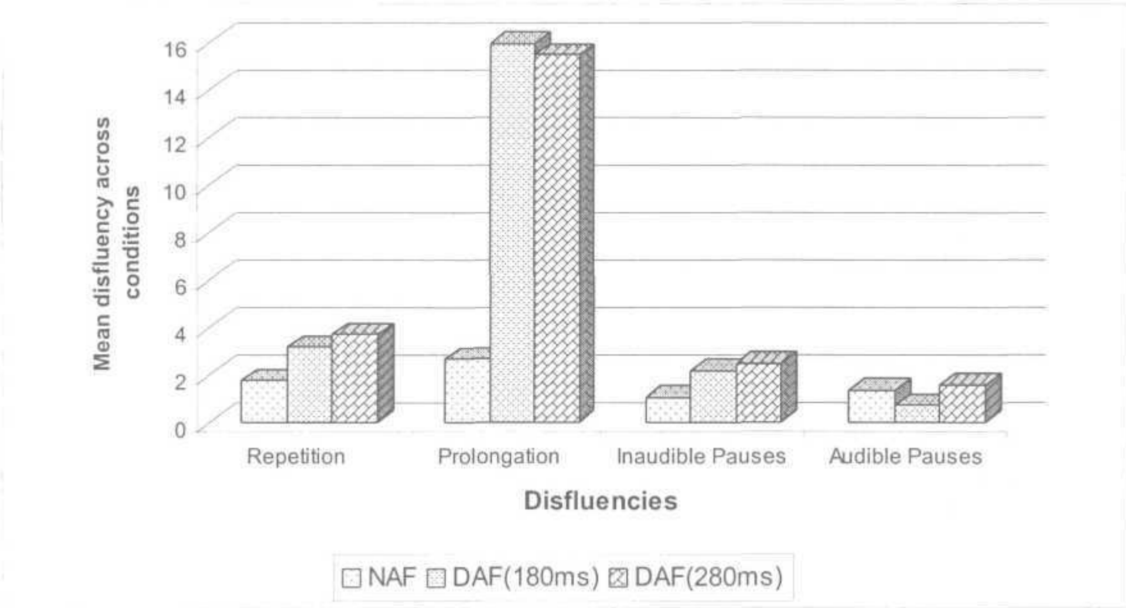
Table 2d: *Mean and standard deviation (SD) of specific disfiuencies across different experimental feedback conditions in the task of answering to questions.*

Types of disfiuencies	N	Experimental conditions	Mean	SD	F - ratio	P value
Repetition	30	NAF	1.76 +	1.83	3.389	.038*
	30	DAF (180ms)	3.16+#	2.85		
	30	DAF (280ms)	3.70 #	3.86		
Prolongation	30	NAF	2.66 +	2.23	21.459	.000*
	30	DAF (180ms)	16.00 #	11.59		
	30	DAF (280ms)	15.53 #	10.03		
Inaudible pauses	30	NAF	1.06	1.28	2.828	.065
	30	DAF (180ms)	2.16	3.16		
	30	DAF (280ms)	2.46	2.37		
Audible pauses	30	NAF	1.36	1.69	1.842	.165
	30	DAF (180ms)	.73	1.20		
	30	DAF (280ms)	1.56	2.22		

'* ' = significant difference at .05 level. df's – 3, 116 ; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 7:

Graph 7: *Mean of specific disfluencies across different experimental feedback conditions in the task of answering to questions.*



The results in Tables 2c, 2d and the Graphs 6 & 7 show that there is a significant difference between the parameters, repetition, prolongation and inaudible pauses whereas audible pauses are not significantly different from other parameters. When each of the disfluency types were analyzed individually across the three conditions, the following results were obtained which is denoted in the table by the symbols, '+'and '#. The values with same notation shows no significant difference and those represented with different notations are significantly different from each other. It can be summarized as:

- In narration task, repetitions in NAF are significantly different from those at delay intervals 180 ms and 280 ms respectively. For the task of answering to questions, repetitions with NAF are significantly different from that at 280 ms delay interval but are not significantly different from that at 180 ms delay interval.

- Prolongation errors in NAF are significantly different from those at delay intervals 180 ms and 280 ms respectively for both the subtasks.
- Inaudible pauses in NAF are significantly different from those at delay intervals 180 ms and 280 ms respectively in case of narration task but they are not significantly different between the three conditions in the task of answering to questions
- Audible pauses are also not significantly different between the three feedback conditions in both the subtasks.

Overall, it is seen that prolongation errors are greater in delayed feedback conditions i.e., at 180 ms and 280 ms delay intervals than at NAF condition. It is notable that, though there is significant difference in the overall disfluency rate across the three experimental conditions, there is no significant difference between the two delayed feedback (180msec and 280msec) conditions when specific disfluencies were analyzed. While measuring the rate of disfluency, the total number of words uttered by the individual is taken into consideration. Since the total number of words uttered itself is significantly different across three feedback conditions, this would have brought about the significant difference in the overall rate of disfluency. Whereas, while measuring the specific disfluencies, the numbers of occurrences of disruptions were counted i.e., the raw scores for each of the subjects were calculated and tabulated. When these raw scores were statistically analyzed, it is seen that there is no significant difference between the two delay conditions. However, prolongation errors are significantly different from the rest of the parameters. Also, the present study shows that prolongations, repetitions and inaudible pauses are highest in delayed feedback conditions than in normal auditory feedback condition. Prolongation errors are followed by repetitions, which in turn is followed by inaudible pauses. There is no significant difference in audible pauses across the three conditions.

These findings may be viewed in the backdrop of observations made by studies on similar facts: Postma, Kolk and Povel (1990), explained the covert repair hypothesis in stutterers and stated that it is applicable to disfluencies exhibited by normal speakers. They reported that the primary symptoms like repetitions and prolongations are results from attempts at executing a syllable prior to the incorporation of correct vowel information in the articulatory plan. They further argued that when there is a disco-ordination resulting from neurophysiological instability, it leads to oscillations and tonic behaviours and these oscillations would produce repetitions and tonicity would result in prolongations. Hence they assume that the selection of phonological segments is disturbed, due to a slowing down in the activation of phonological segments. However, if the activation for a particular segment in the articulatory plan builds up slowly, the activational competition between segmental representations may not have been settled when selection takes place, i.e., several segments have roughly equal activations. As a result, mis-selections may occur more often than normal, which leads to errors in the articulatory plan. These errors if detected through internal monitoring, that is before they are uttered, leads to disrupted speech output and when one makes several attempts to reverse and re-output the articulatory plan, it results in overt *repetitions.* Alternatively, the speaker may "hold" the speech output until the articulatory plan is appropriately fixed, which produces *prolongations.* Hence, prolongations and repetitions are interpreted as attempts to start speaking before the articulatory plan. Prolongations and silent speech durations (inaudible pauses) are a measure of speech planning times (i.e., the product of phonological encoding). The above postulations are reported to hold good for both stuttering and normal disfluencies according to Kolk (1991).

Venkatagiri (1980) found that the most common category of disfluency, not surprisingly was dysrhythmic phonations. It is well known that subjects tend to prolong speech sounds under DAF (Black, 1951; Spilka, 1954). Although the prolongation of sound was one of the characteristics that led to the judgement of dysrhythmic phonations, such prolongations were almost always accompanied by one or more of the following: imprecise articulation giving the impression of undershooting of articulatory targets, a noticeable increase / decrease in pitch, and improper stressing. Given the fact that there is no difficulty in initiation of a sound in prolongation error, but it is the continuity of the sound that is affected, one may relate this feature to failure in either planning or programming. The fact that there is less tonic involvement in the nature of prolongation error and such an error has been due to failure in the programming process (Peters & Hulstijn, 1987), it may be reasoned that prolongation errors reflect an error in both planning and programming processes. Hence, not many correlatory observations are available to explain the processing level of prolongations.

In contrast to the findings by Venkatigiri (1980) who states that there is predominate occurrence of part word repetitions at an optimum delay interval of 200 ms, the findings of present study shows that prolongations are predominant over repetitions at 180 ms delay and also it was the highest in all the feedback conditions. This goes to show that higher level speech processes play a very important role even during normal auditory feedback condition and at a delay interval above the optimal level.

Stuttering is hypothesized to be caused by a perturbation in phonological encoding i.e., the construction of the fully specified articulatory program on the basis of word form information stored in the mental lexicon (Boers & Wijnen, 1994). Conture, Schwartz, & Brewer (1985) reported from his study that sound prolongations and repetitions are due to inappropriate abductory and or adductory laryngeal behaviour which is contributed by the complex interaction among the laryngeal, articulatory and respiratory systems. It is suggested that longer laryngeal reaction times exhibited by the stutterers reflect learned anticipatory fears of phonatory initiation and maladaptive muscular sets (Reich, till & Goldsmith, 1981), which could again be characterized as programming deficit. Audible pauses that are seen as a feature of DAF induced speech disruption are non-linguistic behaviour shown by the subject under DAF as well as under NAF. These audible pauses are also evident in stutterers' speech as a compensatory strategy. Though it may not be possible to categorize the audible pauses under any of the three parameters in study, it could be hypothesized that the strategies used to overcome disfluency is also same among stutterers and non-stutterers, i.e., the tactics used by non-stutterers under DAF to maintain fluency are the same as those that promote fluency in stutterers. However, we must be careful while interpreting these data with in a speech motor framework simply because the same factors that impede efficient planning and programming of the muscle commands before the onset of speech may also obstruct the planning and programming of later units during the execution.

In explaining these different types of disfluencies based on above mentioned different viewpoints and the model of DAF, it could be summarized that the preferred type of disfluency is caused by a delay in the expected time of perception of the syllable with respect to the time at which the speaker has already planned to produce the same syllable. When there is asynchrony between the expected time of perception and planned time of production, then speech errors such as prolongation of syllables and a reduction in tempo occurs (Black, 1951; Spilka, 1954). So the attempted correction of this asynchrony is considered to be the source of disfluent speech under DAF conditions. In stutterers, these asynchronies are cancelled out and hence a fluent speech under DAF is seen.

Wingate (1976) conceptualized that the production of speech involves a series of steps or "levels", beginning with an 'idea' and culminating in the formation of an acoustic signal. Any malfunction at a particular 'level' irrespective of the causal factors involved may result in a specific form of disruption. From this viewpoint, Venkatagiri (1980) suggested that DAF and stuttering disrupt speech at approximately the same "level" along the speech production though the cause of disruption may or may not be similar.

In summary, it may be possible to indirectly implicate that the higher level processes, i.e., planning and programming are more affected in the speech processing of normal speakers under DAF, which could be similar to / resemble the type of processing in stutterers.

II) ***Task 2:*** 'Reverse spelling'. This was analyzed with reference to two parameters. They are:

a) Time taken for the complete and correct utterance of words varying in syllabic lengths, (bi-syllable to five-syllable). The total time taken for the utterance of five words in each of the syllabic lists was calculated and tabulated. The data was then subjected to statistical analysis using 'One way-ANOVA to find if there is any significant difference in the time taken for uttering words of varying syllable lengths across the three experimental conditions. The results obtained are as shown in the following Tables 3a & 3b and the Graphs 8 & 9.

Table 3a: *Mean and standard deviation (SD) of time taken for uttering words of different syllabic lengths across the three conditions*

Experimental conditions	N	Syllabic lengths	Mean	SD	F - ratio	P value
NAF	18	Bi-syllable	29.94 +	4.78	50.682	.000*
	18	Tri-syllable	30.44 +	9.01		
	18	Four-syllable	50.61 #	11.07		
	18	Five-syllable	67.44 ^	15.29		
DAF (180 ms)-Dl	18	Bi-syllable	29.50 +	7.24	30.742	.000*
	18	Tri-syllable	50.72 #	14.54		
	18	Four-syllable	64.72 #	17.99		
	18	Five-syllable	83.22 ^	24.83		
DAF (280 ms) - D2	18	Bi-syllable	36.72 +	7.20	31.429	.000*
	18	Tri-syllable	43.94 +	10.06		
	18	Four-syllable	58.33 #	13.66		
	18	Five-syllable	75.50^	18.22		

'*' = significant difference at .05 level. df's – 3, 68 ; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 8:

Graph 8: *Mean time taken (in seconds) for uttering words of different syllabic lengths across the three conditions*

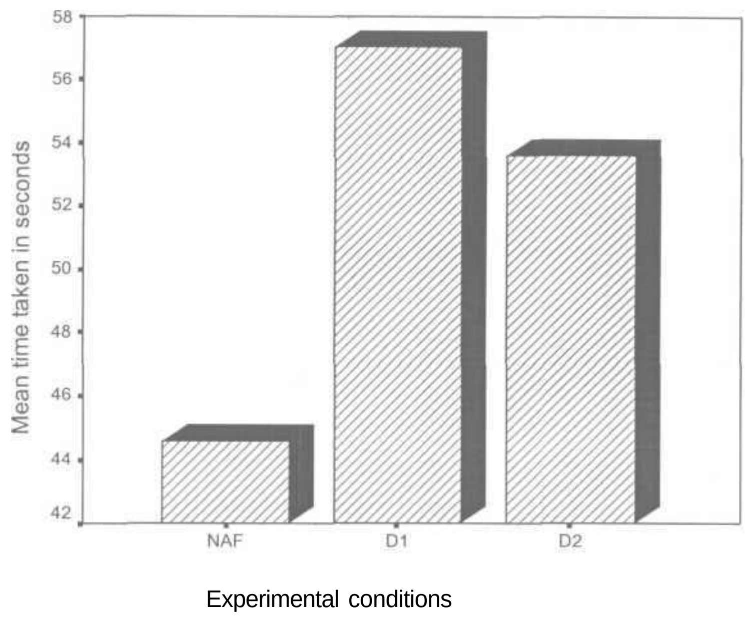


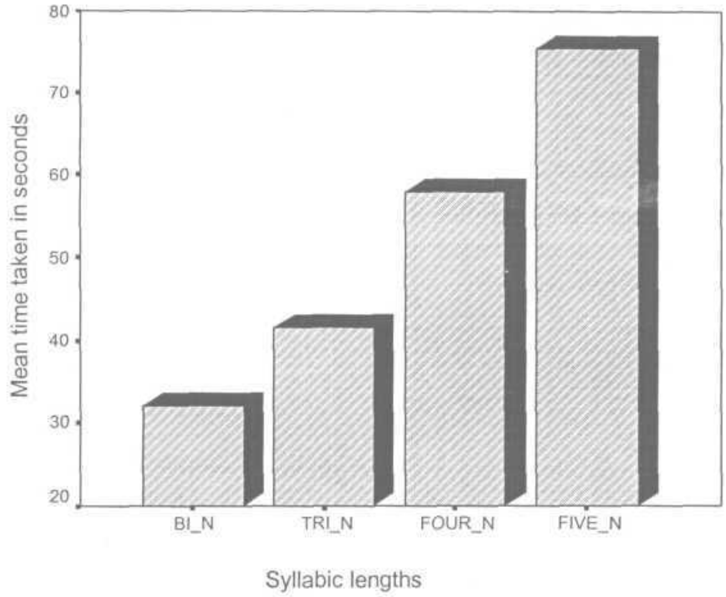
Table 3b: *Mean and standard deviation of time taken for specific syllabic lengths across the three conditions*

Syllabic lengths	N	Experimental conditions	Mean	SD	F - ratio	P value
Bi-syllable	18	NAF	29.94 +	4.78	6.946	.002*
	18	DAF(180ms)	29.50 +	7.24		
	18	DAF (280ms)	36.72 #	7.20		
Tri-syllable	18	NAF	30.44 +	9.01	14.599	.000*
	18	DAF (180ms)	50.72 #	14.54		
	18	DAF (280ms)	43.94 #	10.06		
Four-syllable	18	NAF	50.61 +	11.07	4.258	.019*
	18	DAF (180ms)	64.72 #	17.99		
	18	DAF (280ms)	58.33 +#	13.66		
Five-syllable	18	NAF	67.44	15.29	2.842	.068
	18	DAF (180ms)	83.22	24.83		
	18	DAF (280ms)	75.50	18.22		

'*' = significant difference at .05 level. df's – 2, 51; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 9:

Graph 9: *Mean time taken (in seconds) for specific syllabic lengths across the three conditions*



From the results that are tabulated in Table 3a and the Graph 8, it is seen that the total time taken is significantly different between the three experimental conditions for all the syllabic lengths, that is, in NAF and delayed feedback conditions. The time taken for the utterance of five syllabic words is greater and significantly different from other three syllable conditions, In the delayed feedback at 180 ms, the time taken for four syllable words is again significantly different from other three syllable conditions, whereas in NAF and DAF of 280 ms, it is significantly different from the time taken for bi-syllables but not from tri-syllables. There is also no significant difference between the time taken for bisyllables and tri syllables.

To summarize, the time taken by the subjects for uttering the five syllable words is greater when compared to other syllable conditions and this is more evidently seen in delayed auditory feedback of 180 ms followed by DAF at 280 ms and then by the NAF. As the complexity increases with increase in syllable lengths, it is seen that subjects exhibit difficulty in processing the adjacent sounds in a particular word. This again can be attributed to the delay level pf 180 ms which seem to be the crucial level for speech disruption under DAF. Similar findings were reported by Venkatagiri (1980), Black (1951), Fairbanks (1955).

From the results in Table 3b, Graph 9 and from the analysis of specific syllable lengths in each of the three feedback conditions, it is evident that the time taken for bi-syllable is greater in DAF at 280 ms whereas the time taken for tri-syllables and four syllables is significantly greater with DAF at 180 ms, then followed by that with DAF at 280 ms and NAF. The values with same notation shows no significant difference and those represented with different notations are significantly different from each other. There is no significant difference between the time taken for tri-syllables and four syllables across the three feedback conditions. There is no significant difference in the time taken for five syllables across the three conditions though it is significantly higher when compared to other syllable conditions. This shows that beyond four syllables, the subjects' performance is the same that is, they take longer time for reverse spelling the words, whereas, with smaller syllable lengths (bi-syllables and tri-syllables), the processing seems to be faster in reverse spelling. According to Stuart et al (2002), if the peripheral feedback system(s) of fluent speakers are responsible for the disruptive effects of DAF on normal speech production at long auditory feedback delays, then the time taken for processing words of different syllable lengths should not differ in the optimal and non-optimal delay conditions. Since the present study shows that the there is a difference in the time taken for uttering words of shorter and longer syllable lengths, it can be hypothesized that the processing pattern could be different further involving higher level processes and not just a disruption at a peripheral level.

b) The rate of correct syllables recalled by the subjects was calculated in each of the four syllable length conditions across three different experimental conditions and subjected to 'One way-ANOVA'. The following results were obtained. The significant differences in values are denoted in the table by notations,'+' and '#'. The values with same notation shows no significant difference and those represented with different notations are significantly different from each other.

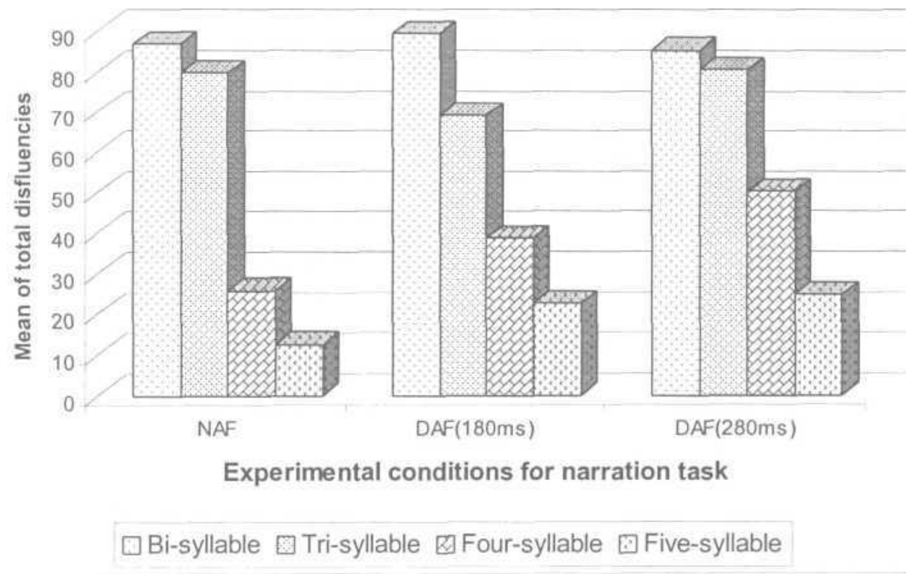
Table 4a: *Mean and standard deviation (SD) of correct syllables recalled across the three conditions.*

Experimental conditions	N	Syllabic lengths	Mean	SD	F - ratio	P value
NAF	30	Bi-syllable	86.66+	14.2	117.575	.000*
	30	Tri-syllable	79.66+	19.7		
	30	Four-syllable	25.66#	22.8		
	30	Five-syllable	12.66#	17.7		
DAF (180ms)	30	Bi-syllable	89.33+	11.4	42.242	.000*
	30	Tri-syllable	69.33#	24.03		
	30	Four-syllable	38.66^	30.1		
	30	Five-syllable	22.66^	27.6		
DAF (280ms)	30	Bi-syllable	85.33+	12.7	44.972	.000*
	30	Tri-syllable	80.66+	17.7		
	30	Four-syllable	50.33#	29.5		
	30	Five-syllable	24.66^	28.1		

'*' = significant difference at .05 level; df's – 3, 116; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 10:

Graph 10: *Mean rate of correct syllables recalled across the three conditions.*



From the results in Table 4a and Graph 10, it is seen that the rate of correct syllables recalled (i.e., the number of correct syllables recalled per 100 syllables) is significantly different at .05 level between the three feedback conditions. It is significantly greater in the delay interval of 280 ms than at NAF and DAF at 180 ms. The greater number of correct syllables recalled in DAF at 280 ms condition could be attributed to the longer processing time that is available through a greater delay in the 280 ms condition. This is followed by the performance at DAF of 180msec. Because the time provided by the delay of 180 ms for processing is lesser than that provided by a 280 ms delay but greater than that of the immediate feedback condition (where subjects function with normal auditory feedback condition). Hence it can be reasoned that under NAF, since the subjects got an immediate feedback of their utterances and since that was not in synchrony with planned time of production in the task of reverse spelling, they may have tended to make more errors in the recall of syllables in the reverse order. If it was only a peripheral feedback that disrupted the speech output as reported in literature (Stuart et al, 2002), then there should not have been any difference seen in the recall of syllables in the two delay conditions. Also, there should have been a poorer performance in the delayed feedback conditions and a better performance with normal auditory feedback. But the present study showed vice versa results, which may be an evidence of deficit in higher level processing rather than a peripheral deficit.

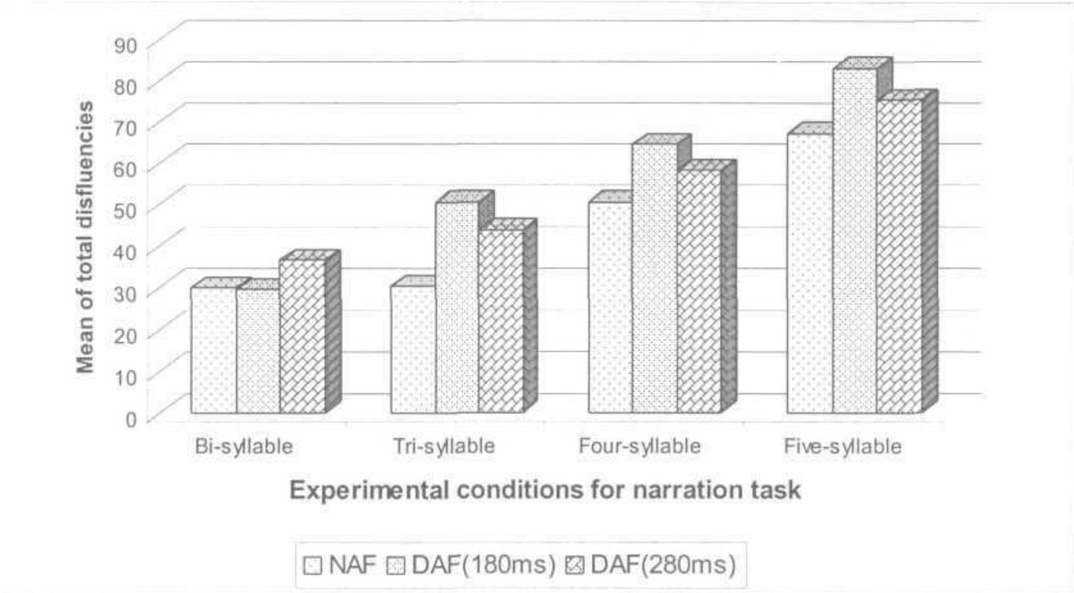
Table 4b: *Mean and standard deviation of rate of correct syllables recalled for specific syllabic lengths across the three conditions*

Syllabic lengths	N	Experimental conditions	Mean	SD	F - ratio	P value
Bi-syllable	30	NAF	29.9	4.7	6.946	.002*
	30	DAF (180ms)	29.5	7.24		
	30	DAF (280ms)	36.7	7.2		
Tri-syllable	30	NAF	30.4 +	9.0	14.599	.000*
	30	DAF (180ms)	50.7 +	14.5		
	30	DAF (280ms)	43.9 #	10.0		
Four-syllable	30	NAF	50.6 +	11.0	4.258	.019*
	30	DA1F (180ms)	64.7+#	17.9		
	30	DAF (280ms)	58.3 #	13.6		
Five-syllable	30	NAF	67.4	15.2	2.842	.068
	30	DAF (180ms)	83.2	24.8		
	30	DAF (280ms)	75.5	18.2		

'*' = significant difference at .05 level. df's – 2, 87 ; Multiple comparison tests by Scheffe's post hoc test (limit fixed at .05 level).

The results are graphically shown in Graph 11:

Graph 11: *Mean rate of correct syllables recalled for specific syllabic lengths across the three conditions*



From the results that are tabulated in Table 4b and Graph 11, it shows that there is a significant difference in overall performance between the three syllable conditions i.e., bisyllables, tri syllables and four syllables across the three conditions. But when specific syllable condition is evaluated with in the three conditions, it is seen that there is no significant difference in performance in recalling bi-syllable words across the three feedback conditions, where as there is a significant difference in recalling of trisyllables and four syllable words between the three feedback conditions. That is, the tri syllabic words are recalled better under DAF of 280 ms when compared to DAF of 180 ms and NAF. Four syllabic words are also recalled better under DAF of 280msec than under NAF, whereas performance under DAF of 180 ms is not significantly different from either of the other two feedback conditions. Also there is no significant difference in recalling of five syllabic words across the three conditions.

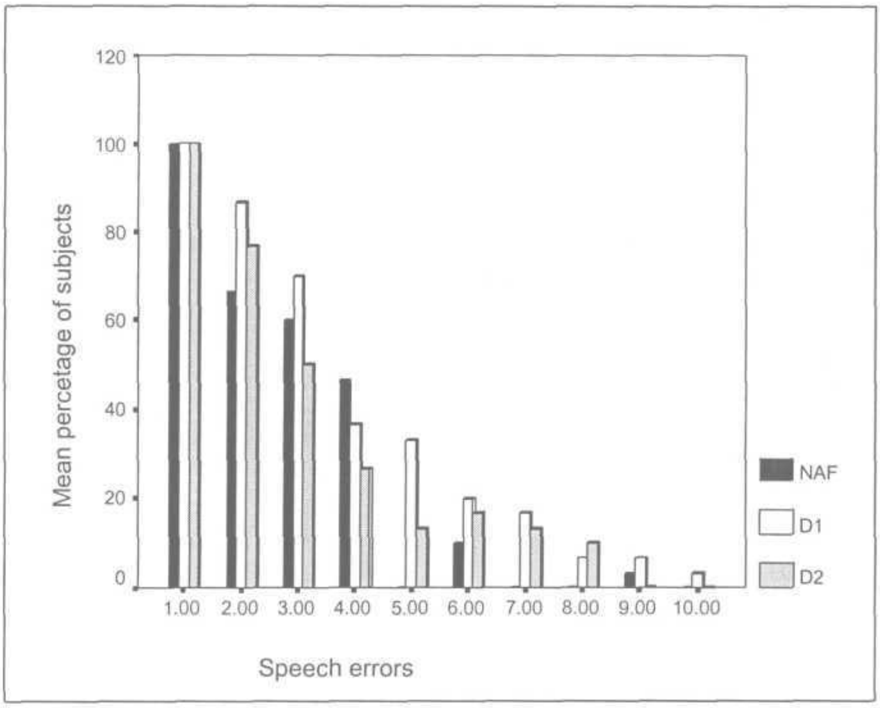
The above findings suggest that beyond four syllables and lesser than three syllables (with reference to bi-syllables), the performance of normal speakers in the delayed feedback conditions is same as that under NAF. Hence, when the complexity in terms of syllable length increases, the performance or recalling of correct sounds (in the reverse order) in a word deteriorates till a certain level (till words of four syllable length) and the performance achieves an asymptote beyond that level.

Finally, when analyzing the speech samples of the subjects during the task of reverse spelling, there were some additional errors that was noticed by the investigator and the frequency of such errors reported by the number of subjects under each of the three feedback conditions were calculated and tabulated, the results of which are graphically displayed in Graph 12:

Table 5: *Mean percentage subjects reporting different types of speech errors*

Speech errors	NAF	DAF-180msec	DAF - 280msec
1.00	100.00	100.00	100.00
2.00	66.60	76.60	80.00
3.00	60.00	60.00	43.30
4.00	46.60	36.60	26.60
5.00	.00	33.00	13.30
6.00	10.00	20.00	16.60
7.00	.00	16.60	13.30
8.00	.00	6.60	10.00
9.00	3.30	6.60	.00
10.00	.00	3.30	.00

Graph 12: *mean percentage subjects reporting different types of speech errors*



The different numbers representing clusters of bars in the x-axis are: 1-syllabic omission; 2- consonant omission; 3- vowel omission; 4- phoneme reversals; 5- syllable reversal; 6- vowel substitution; 7- vowel addition; 8- consonant substitution; 9-consonant addition; 10- syllable repetition.

These errors are graphically displayed in the hierarchy of occurrence in the speech samples of the subjects. The y-axis shows the percentage of subjects who have exhibited these errors under the three experimental conditions. From the Graph 12, it is evident that:

- 100% of the subjects had syllable omission in their speech under all three feedback conditions.
- Consonant omissions, vowel omission, syllable reversal, vowel substitution, vowel addition, consonant substitution, consonant addition and syllable repetition seems to be greater under DAF of 180 ms than under the other two feedback conditions.

This shows that speech disruption seems to occur maximally at 180 ms delay interval than at 280 ms delay interval and normal feedback condition.

- Phoneme reversals are found to be minimum under DAF of 280 ms compared to that at 180 ms, where as it is maximum in normal feedback condition. This finding suggests that, greater the processing time provided for the subjects through the induced delay, lesser the number of errors.

When above findings from tasks of varying cognitive - linguistic complexity are put together, greater correlation is seen between some of the features:

- When tasks involved recall and narration, to think and answer the questions, it is found that the overall disfluency rate is higher in the delayed feedback conditions (greater at 180 ms than at 280 ms) than in the normal auditory feedback condition. Also among the different types of disfluencies, prolongations are always greater when compared to other types such as repetitions, inaudible and audible pauses.
- In the task of reverse spelling, the time taken for correctly spelling the words in the reverse order is greater in the polysyllabic condition (four syllable and five syllable words) than with reduced (bi-syllable and tri-syllable words) syllabic lengths. Also, the rate of correct syllables recalled is greater in the maximal delay condition than in the optimal (180 ms) delay condition and normal auditory feedback condition. That is, it is found that with greater processing time provided in the form of induced delays, lesser the occurrence of speech disruptions.

The above findings from the perceptual analysis by the investigator, correlated with the literature findings (Venkatagiri, 1980; Nataraja, Ramesh & Pandita, 1982; Postma, Kolk & Povel, 1990), as quoted from the various studies in the discussion of this section. But there results of the present study also contradicted the findings that were seen in literature (Fukawa et al, 1988; Stuart et al, 2002). They are:

- In the present study it was found that there is no difference in the performance between males and females. This contradicted the results in literature where they have found a difference between the sexes, wherein males are reported to show more disruptions than females. But the findings in the present study correlates with that of stuttering population where they have reported of no differences between the sexes. This could be taken as an evidence for similar loci of deficit in the stutterers speech and DAF induced speech in non stutterers.
- In literature there are no studies which report of the processing time taken by the subjects under DAF with increasing utterance lengths. Present study is a preliminary attempt which focused on the processing time taken by normal speakers for increasing length of utterances. This provides an in depth view of the involvement of three phases in question i.e., planning, programming and execution and contradicts the findings that support a peripheral cause for speech disruptions under DAF.

In summary the findings of the present study proves that the disruption in the speech output of normal speakers under DAF may be attributed to the deficit at a higher level processing i.e., involving planning and programming phases and may not be due to a disturbance at a peripheral level as suggested in the literature.

2) Self evaluation of the listening experience from section A of the questionnaire:

Here the views of the subjects about the quality of their speech under the experimental situations were analyzed. Majority of the subjects, both males and females, reported the following under delayed feedback conditions:

- Speech was disfluent under DAF
- They prolonged the utterances while speaking
- They paused (mostly inaudible pauses) between words.
- They experienced difficulty in thinking
- They experienced difficulty in selecting appropriate words to complete sentences
- They experienced difficulty in conveying the idea formulated
- Their rate of speech was slow.

Few reported of:

- Repetitions and blocks in hierarchy
- Slurred speech quality
- Speech resembling that of "Drunkard speech" etc.
- Monotonous speech with out inflections.
- Loud speech.

They had reported of absence of any such features in the normal auditory feedback condition. The above findings (reported as features of delayed feedback conditions) show that the subjects experience disruptions in their thought processes in terms of selection of appropriate words, prolongation of utterances, pauses etc. This could be attributed to the disruption in the overt monitoring of the speech by these subjects. Since the subjects' thought processes were disrupted, probably they were deprived of formulating a complete plan (deficit in planning) of their thoughts by selecting appropriate words. Hence they would have attempted to prolong the utterances and pause between utterances which would have increased the processing time and in turn facilitated selection of the forth coming syllables for the words. Also, the activation of nerve fibers in sending commands to the oral musculature could have slowed down (evidence of deficit in programming) because of which the articulators would have experienced sluggishness in their movements. This sluggishness would have resulted in the slurred and slow rate of speech that has been reported by the subjects. The slurring of speech could have also resulted because of deprivation of the afferent feedback, which normally is present in case of covert monitoring through normal auditory feedback.

It is also possible that there was an asynchrony between the time of perception and the time at which they had planned to produce the same utterances. They have generally opined that their thought processes were affected and they were not able to convey their ideas, as planned. Hence these disruptions as explained above could have been either due to deficit in the planning and / or programming phases rather than a peripheral deficit. The above findings in self-evaluation show that they had more of planning and programming speech disruptions compared to execution. Hood (1998) observed slower rate of speech, an increase in intensity and disruption of the usual rhythm of speech as typical changes in speech productions under conditions of DAF. Similar effects were also seen in their results. Also, it is possible that the deficit in planning and programming phases would have had an extended effect on the execution, which could have accounted for the loud speech that is reported by these subjects.

3) Responses to questions in section B:

The questions (as given in the questionnaire in the Appendix A) were so framed that the answers could be categorized under levels of processing disabilities, i.e., planning, programming and execution. Different models of speech production in normals and of stuttering have cited that three phases are the dominant phases of sensorimotor processing for normal speech production. It is of interest then to probe into their role in the occurrence of speech disruptions in normal speakers under DAF. Hence, these questions were framed on the basis of features that are reported in literature as characteristic of each of the three categories. Examples of the questions categorized under the three phases are given in Appendix B. The subjects' responses were also categorized accordingly, that is, if the subjects had said 'yes' to a question in the specific category, it was scored as '1' and if it was answered as 'no', it was given a score of '0'. Thus the raw scores for each of these subjects were calculated for each of the three categories in question. The total responses of the subjects for each of these categories were computed and tabulated. These raw scores were then converted to a percentage score. The percentage scores were subjected to statistical analysis using 'Paired T-test' and the results are given in Table 6.

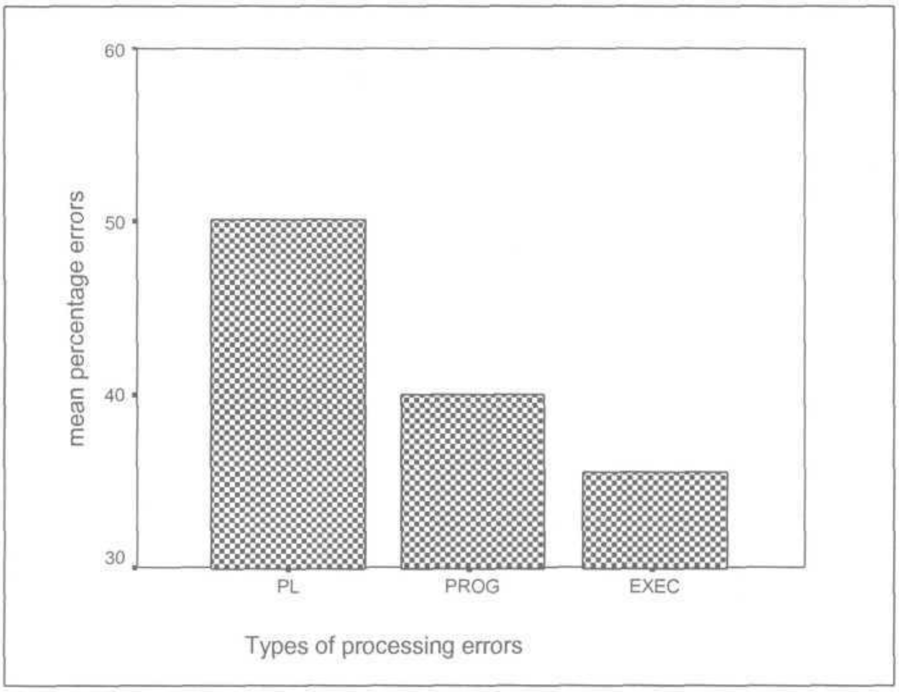
Table 6: *Mean percentage errors for the three phases in section B*

Groups	N	Mean	SD	t value	df	Sig.
Planning (PL)	30	50.00	20.17	2.135	29	.041*
Programming (PROG)	30	39.16	20.43	3.974	29	.000*
Execution (EXEC)	30	34.97	18.23	.898	29	.377

'*' = significant difference at .05 level.

The above data is also represented in Graph 13:

Graph 13: *Mean percentage errors for the three phases in section B*



PL – planning ; PROG – programming; EXEC – execution

From the results as shown in Table 6 and Graph 13, it is evident that,

- there is a significant difference in the mean percentage responses for planning compared to the parameters of programming and execution.
- the difference is not significant between programming and execution.

It is evident from the evaluation of the subjects' responses to the questions in part-B of the questionnaire that, planning is more impaired compared to programming and execution. This result was for the responses given by the subjects from their experience for all the tasks in the delayed feedback conditions.

When section B of the questionnaire was analyzed, the types of speech disruptions reported as positive by the subjects in their speech were tabulated and it is shown in the Table 7 in a descending order of percentage occurrence.

Table7: *Scoring in terms of percentage of subjects reporting different speech characteristics under DAF*

Speech characteristics	**Scores** (%)
Prolongation and Initiation	96.6%
Repetition	83.3%
Disturbed Rhythm pattern	80%
Slurred speech and improper stress	63.3%
Improper pronunciation	60%
Monotonous speech	50%

Table 7 shows the hierarchy of occurrence of speech disruptions as reported by the subjects. Prolongation and initiation errors are reported by 96.6% of the subjects, followed by repetition errors reported by 83.3%. If the activation for a particular segment in the articulatory plan builds up slowly, the activational competition between segmental representations may not have been settled when selection takes place, i.e., several segments have roughly equal activations (Postma, Kolk & Povel, 1990). As a result, mis-selections may occur more often than normal, which leads to errors in the articulatory plan. These errors if detected through internal monitoring, that is before they are uttered, leads to disrupted speech output and when one makes several attempts to reverse and re-output the articulatory plan, it produces overt *repetitions.* Alternatively the speaker may "hold" the speech output until the articulatory plan is appropriately fixed, which produces *prolongations.* They further argued that when there is a disco-ordination resulting from neurophysiological instability, it leads to oscillations and tonic behaviours and these oscillations would produce repetitions and tonicity would result in prolongations. Hence they assume that the selection of phonological segments is disturbed, due to a slowing down in the activation of phonological segments. Since prolongation and initiation errors are defined as planning errors in the literature and repetitions are pictured as may be due to planning or programming deficit (Venkatagiri, 1980; Postma, Kolk, & Povel, 1991), it is evident that higher level processes i.e., planning and programming are affected than the lower level processing i.e., execution. Also, stutterers are said to have longer speech initiation times in various tasks (Starkweather, 1987), which is similar to that seen in normal speakers under DAF in the present study.

Other features such as slow rate of speech, which resembled that of a 'drunkard' speech, under the influence of DAF, could be due the sluggishness that's experienced in the articulatory movements. Sluggishness in the different articulatory movements could be due to delayed activation or firing of nerve fibers in sending the commands to the muscles of tongue, jaw and lips. In literature, when the non-speech movements were analyzed in stutterers' while speaking fluently, it was found that they exhibited lengthened jaw opening and closing displacements. This deviating motor pattern was supposed to reflect motor compensations necessary to achieve fluent speech. Hence the results as an evidence for assumption that, stutterers and non-stutterers used the same control strategies to come out with fluent speech (Jancke, Bauer, Kaiser & Kalveram, 1997; Starkweather, Franklin & Smigo, 1984).

When the findings from the two experimental phases are summarized as follows:

- Findings of both phases showed that through tasks of varying cognitive-linguistic complexity, an understanding can be drawn as to level of speech processing that is involved in DAF induced speech disruptions.
- Findings from both phases showed that the deficit at higher level processes (planning and / or programming) could probably be the cause of speech disruptions in normal speakers under the influence of DAF.
- Using a behavioural approach such as that used in the present study (Delayed Auditory Feedback), we can infer about the level of deficit that is responsible for the occurrence of speech disruptions under DAF.

SUMMARY AND CONCLUSIONS

Spoken language is a form of communication through which human beings convey information. A speaker uses a highly flexible speech motor program with motor equivalence, while simultaneously achieving maximum precision (clarity) in production. Various theories explain the process of speech motor control through three basic steps, namely planning, programming and execution (Rosenbek, Kent & LaPointe, 1984; Roy, 1978; Van der Merwe, 1997). Successful processing of neurolinguistic codes in these three stages are considered to be responsible in fluent speech production of an individual. An unimpaired sensory afference in the form of FEEDBACK is also required for maintainance of speech fluency. It is reported in the literature (Venkatagiri, 1980; Nataraja, Ramesh & Pandita, 1982) that when speech of normal speakers is disrupted under DAF, errors occur in speech production. But these disruptions are not well explained as to their cause of occurrence with specific reference to breakdown in speech processing chain such as the stage of planning, programming and / or execution. The disruptions in speech positively suggest that normal speakers monitor their auditory feedback in order to check and actively monitor if the speech which is being produced is correct. The study aimed to provide insights into the nature of speech disruptions in normal speaker's speech under the influence of DAF and attempted to relate the speech errors (peripheral factor) to different speech processing levels/ phases (central factor).

The study attempted to investigate the disfluencies of normal speakers under the influence of DAF while performing tasks with different cognitive-linguistic complexity and also to delineate the behavioural correlates of different levels of speech processing in normal speakers under the influence of different levels of DAF. The reason for the selection of these tasks was based on the hypothesis that they would reflect on the different levels of speech processes. That is, variation in the cognitive linguistic load of the material could affect the level of speech processes differently.

30 normal adult speakers (15 males and 15 females) in the age range of 17-25 years were selected for the study and they were subjected to tasks of varying cognitive-linguistic complexity under three different experimental conditions, viz, normal auditory feedback, DAF at 180 ms and DAF at 280 ms. The tasks included: 1) Story narration and answering questions related to the story, and 2) Reverse spelling. The experimental conditions had two stages: a) In stage 1 the subjects' performed the above two tasks under three experimental conditions. The speech samples of the subjects' during the above tasks under three experimental conditions were audio recorded, b) Stage 2 included a questionnaire (self-report) which consisted of two sections A & B respectively. Section A consisted of open-ended questionnaire where the subjects were asked to describe their experiences during the delayed feedback conditions in brief. Section B consisted of 24 Yes / No questions. In the latter, the questions were designed such that it probed into details to delineate the breakdown in the behavioural correlates of speech processing abilities, viz planning, programming and execution.

Analysis was carried out in three stages:

1) Perceptual analysis of the recorded samples by the investigator

2) Analysis of responses to self report of the listening experience by the subjects (from section A of the questionnaire).
3) Analysis of Yes / No responses to questionnaire (from section B)

The perceptual analysis of the recorded speech samples were analyzed for:

- the overall disfluency rate of the subjects across the three different conditions,
- predominance of specific type of disfluency (repetitions / prolongations/ inaudible pauses/ audible pauses) across the three conditions,
- differences in time taken for uttering words of different syllabic lengths across the three conditions,
- differences in rate of correct syllables (number of correct syllables per 100 words) recalled in the three conditions and across the words of different syllabic lengths.
- speech errors other than the specified disfluencies.

The responses under self report were analyzed as follows:

- Section A: views of the subjects about the quality of their speech under the experimental situations were analyzed. The results were extracted by listing out the common features that were reported by the subjects in a hierarchical order.
- Section B: The number of subjects reporting specific types of disfluencies such as prolongation, repetition, inaudible pauses, audible pauses, abnormal rhythm, intonation, stress or prosody under each of the three experimental conditions

was tabulated. This was converted to a percentage score by dividing the number of subjects by the total number of subjects multiplied by 100.

The results were discussed and inferences were drawn using suitable statistical procedures. The salient findings are summarized with respect to each of the three tasks as follows:

A) Task 1:

1. Overall performance under different feedback conditions:

Overall disfluency rate was greater in the delayed feedback conditions than in the normal auditory feedback condition.

Speech disfluencies were greater in DAF of 180 ms compared to DAF of 280 ms. This pattern of error occurrence was similar for both the subtasks of narration and answering to questions.

There was a significant difference in the disfluency rate between the task of narration and task of answering to questions under normal auditory feedback. There was no significant difference between the two subtasks under either of the delay intervals.

The above findings are reasoned on the basis that more complex thought processes are involved for recall and narration rather than for answering to questions.

2. Error types:

Prolongations, repetitions and inaudible pauses were highest in delayed feedback conditions (180 ms and 280 ms delay intervals) than in normal auditory feedback condition.

Prolongation errors were significantly greater compared to other three types i.e., repetitions, inaudible and audible pauses.

The above findings are reasoned as follows:

Symptoms like repetitions and prolongations could be due to attempts at executing a syllable prior to the incorporation of correct vowel information in the articulatory plan. If the activation for a particular segment in the articulatory plan builds up slowly, the activational competition between segmental representations would not have settled and yet selection takes place, i.e., several segments get equally activated at a time. As a result, mis-selections may occur more often than normal, which leads to errors in the articulatory plan. These errors if detected through internal monitoring, that is before they are uttered, leads to disrupted speech output and when one makes several attempts to reverse and reproduce the articulatory plan, it may result in overt *repetitions.* Alternatively, the speaker may "hold" the speech output until the articulatory plan is appropriately fixed, which leads to production of *prolongations* (Postma, Kolk and Povel, 1990). Given the fact that there is no difficulty in initiation of a sound in prolongation error, but it is the continuity of the sound that is affected, one may relate this feature to failure in either planning or programming (Venkatagiri, 1980; Peters & Hulstijn, 1987)

B) Task 2: Reverse spelling

1. *Syllabic lengths and three feedback conditions:*

The time taken for the utterance of five syllabic words was greater and significantly different from other three syllable conditions. This was more evident in delayed auditory feedback of 180 ms followed by DAF at 280 ms and then by the NAF.

Subjects took longer time to reverse spell words with four syllables and greater, whereas, subjects were faster in reverse spelling words with reduced syllable lengths (bi-syllables and tri-syllables).

With increased delay (DAF of 280 ms), the rate of correct syllables recalled was significantly greater than that in the NAF and DAF of 180 ms. This could be attributed to the longer processing time that is available through a greater delay in the 280 ms condition.

When the complexity in terms of syllable length increases, the performance or recall of correct sounds (in the reverse order) in a word deteriorated till four syllable words and thereafter further deterioration was not observed although the syllable length increased.

2. Error types (in Tasks 1 & 2):

Consonant omission, vowel omission, syllable reversal, vowel substitution, vowel addition, consonant substitution, consonant addition, Phoneme reversals and syllable repetitions were greater under DAF of 180 ms than under the other two feedback conditions.

C) Task 3: Results from analysis of self-report are summarized as follows:

From the results of section A of self-report, it was found that subjects reported of experiencing disruptions like prolongation of utterances, pauses and disruptions in their thought processes while selecting

- Using a behavioural approach with tasks of varying cognitive-linguistic complexity such as that used in the present study (Delayed auditory feedback), we can delineate to some extent the level of deficit in the higher level processes, which is responsible for the occurrence of speech disruptions under DAF.

Recommendations:

The study may be replicated with more number of tasks with varying cognitive-linguistic complexity

The study may be replicated with different levels of DAF, different age group of normal subjects and in speech motor disorders such as apraxia of speech.

In order to understand the covert operation of the higher level processes, it is recommended that an in-depth analysis / performance types be carried out. This was not possible in the present study due to time constraints.

appropriate words. Slurring and slow rate of speech was also reported by the subjects

Since the subjects' thought processes were reportedly disrupted, this could have probably deprived the ability to formulate a complete plan (deficit in planning) of their thoughts in the form of selecting appropriate words. Indirectly, it may be inferred that activation of nerve fibers in sending commands to the oral musculature could have been slowed down (evidence of deficit in programming) because of which the subjects experienced that their articulators were sluggish while producing movements related to speech.

From the analysis of results in section B in the questionnaire, it was found that prolongation and initiation errors were reported by 96.6% of the subjects, followed by repetition errors which were reported by 83.3%. There was a significant difference in the mean percentage responses for planning compared to the parameters of programming and execution.

There was no significant difference between programming and execution when the responses given by the subjects to the questionnaire were compared.

Conclusions:

In view of the above results, following conclusions can be drawn:

- Results suggest that deficit at a higher level processing (planning and / or programming) could probably be the cause of disruptions in speech in normal speakers under the influence of DAF, rather than a peripheral deficit.

BIBLIOGRAPHY

Andrews, G., Craig, A., Feyer, A., Hoddinott. S., Howie, P., & Neilson, M., (1983). Stuttering: A review of research findings and theories circa, 1982. *Journal of Speech and Hearing Disorders, 48,* 226-246.

Barlow, S.M. & Abbs, H.M. (1978). *Some evidence of auditory feedback contributions to ongoing speech motor control,* Paper presented at the ASHA convention, San Francisco, CA.

Black, J. (1951). "The effect of sidetone delay upon vocal rate and intensity". *Journal of Speech and Hearing Disorders, 16,* 50-56.

Brooks, B. (1986). *The neural basis of motor control.* New York: Oxford University Press.

Byrd, K., & Cooper, E.B., (1989). Apraxic speech errors in Stuttering, developmentally apraxic, and normal speaking children, *Journal of Fluency Disorders, 14,* 215-229.

Conture, E.G., Schwartz, H.D., & Brewer, D. (1985). A further study of laryngeal behaviour during stuttering, *Journal of Speech and Hearing Research, 28,* 233-240.

Crary, M.A. (1993). *Developmental motor speech disorders*, Whurr Publishers, California.

Culatta, R., & Goldberg, S. (1995). *Stuttering therapy: An integrated approach to theory and practice.* Boston: Allyn & Bacon.

Dell, G.S. (1980). *Phonological and lexical encoding: an analysis of naturally occurring and experimentally elicited speech errors.* Phd.diss, University of Toronto

Fairbanks, G. (1955). Selective vocal effects of DAF. *Journal of Speech and Hearing Disorders, 20,* 333-346.

Fairbanks, G., & Guttman, N. (1958). "Effects of DAF upon articulation". *Journal of Speech and Hearing Research, 1,* 12-22.

Fukawa, T., Yoshioka, H., Ozawa, E. & Yoshida, S. (1988). Difference of susceptibility to DAF between stutterers and non-stutterers. *Journal of Speech and Hearing Research, 31,* 471-490.

Gracco, V.L., & Abbs, J.H. (1986). Variant and invariant characteristics of speech movements. In M.R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders, (pp 1-25).* New York: Thieme Medical Publishers, Inc.

Gracco, V.L, & Abbs, J.H. (1987). Programming and Execution processes of speech movement control: Potential neural correlates. In M.R. McNeil (Ed.), *Clinical management of sensorimotor speech disorders,* (pp 1-25). New York: Thieme Medical Publishers, Inc.

Hood, L.J., (1998). An overview of neural function and feedback control in human communication. *Journal of Communication Disorders, 12,* 461-470.

Jakobson, L.S., & Goodale, M.A. (1991). Factors affecting higher-order movement planning: a kinesthetic analysis of human comprehension. *Exceptional Brain Research, 86,* 199-208.

Jancke, L., Bauer, A., Kaiser, P., & Kalveram, K.I. (1997). Timing and stiffness in speech motor control of stuttering and non-stuttering adults. *Journal of Fluency Disorders, 22*, 309-321.

Kelso, J.A.S., Tuller, B. & Harris, K.S. (1983). A "Dynamic pattern" perspective on the control and coordination of movement. In P.F. MacNeilage (Ed.), *The production of speech.* Springer-Verlag, New York.

Kent, R.D. (1983). In K. Byrd & E.B. Cooper (1989). Apraxic speech errors in Stuttering, developmentally apraxic, and normal speaking children, *Journal of Fluency Disorders, 14*, 215-229.

Kent, R.D., & Rosenbek, J.C., (1983). Acoustic patterns of apraxia of speech. *Journal of Speech and Hearing Disorders, 26*, 231-49.

Kolk, H (1991). Is stuttering a symptom of adaptation or of impairment? In H.F.M. Peters, W. Hulstijn, and C.W. Starkweather (Eds), *Speech motor control and stuttering.* Elsevier / Excerpta Medica, Amsterdam.

Lee, B.S. (1950). Effects of delayed speech feedback. *The Journal of the Acoustical Society of America, 22*, 824-826.

Lozano, R.A., & Dreyer, D.S. (1978). Some effects of DAF on Dyspraxic speech, *Journal of Communication Disorders, 9*, 407-416.

Mc Clean, M.D. (1996). Lip muscle reflexes during speech movement preparation in stutterers. *Journal of Fluency Disorders, 21*, 49-60.

Nataraja, N.P., Ramesh. M.V. & Pandita, R.K., (1982). Disfluencies in normals under DAF. *Journal of All India Institute of Speech and Hearing, 3*, 41-45.

Netsell, R. (1982). Speech motor control and selected neurologic disorders. In S, Grillner, B, Lindblom, J, Lubker, and A, Persson (Eds.) *Speech motor control.* Oxford: Pergamon Press.

Peters, H.F.M., & Hulstijn, W. (1987). Programming and initiation of speech utterances in stuttering. In H.F.M. Peters & W. Hulstijn (Eds.), *speech motor dynamics in stuttering.* Wien Springer Valag.

Postma, A., Kolk. H., & Povel, D.J. (1990). Speech planning and execution in stutterers. *Journal of Fluency disorders, 15,* 49-59.

Postma, A., Kolk. H., & Povel, D.J. (1991). Disfluencies as resulting from correct self-repairs applied to internal speech errors. In H.F.M. Peters, W. Hulstijn, and C.W.Starkweather (Eds), *Speech motor control and stuttering.* Elsevier / Excerpt Medica, Amsterdam.

Ramesh, M.V. (1983). The spectrographic analysis of stutterers speech under DAF. *Journal of All India Institute of Speech and Hearing, 14,* 127-134.

Reich, A., Till, J., & Goldsmith, H. (1981). Laryngeal and manual reaction times of stuttering and non-stuttering adults, *Journal of Speech and Hearing Research, 24,* 192-196.

Rosenbek, J.C. (1980). Cited in K, Byrd & E.B. Cooper (1989). Apraxic speech errors in Stuttering, developmentally apraxic, and normal speaking children, *Journal of Fluency Disorders, 14,* 215-229.

Rosenbek, J.C., Kent, R.D., & LaPointe, L.L. (1984). Cited in P.K., Hall, L.S., Jordan and D.A., Robin (1993). *Developmental Apraxia of Speech,* (pp 49-66). Texas: PRO - ED, Inc.

Roy, E.A. (1978). Apraxia: A new book at an old syndrome. *Journal of Human Movement studies, 4,* 191-210.

Spilka, B. (1954). Some vocal effects of reading passages and time delays in speech feedback. *Journal of Speech and Hearing Disorders, 19,* 33-37.

Starkweather, C.W. (1987). *Fluency and stuttering.* Englewood Cliffs, Prentice-Hall, New Jersey.

Starkweather, C.W., Franklin, S., & Smigo, T.M. (1984). *Vocal and finger reaction time in stutterers and non-stutterers: differences and correlations,* 27, 193-196.

Stuart, A., Kalinowski, J., Rastatter, M.P., & Lynch, K. (2002). Effect of delayed auditory feedback on normal speakers at two speech rates. *The Journal of the Acoustical Society of America, 111 (5),* 2237-2241.

Van der Merwe, A. (1997). A theoretical framework for the characterization of pathological speech sensorimotor control. In M.R., McNeil (Ed.), *Clinical management of sensorimotor speech disorders,* (pp 1-25). New York: Thieme Medical Publishers, Inc.

Venkatagiri, H.S., (1980). Relevance of DAF induced speech disruption to the understanding of stuttering. *Journal of Fluency Disorders, 5,* 87-98.

Venkatagiri, H.S., (1980). The core disruption under DAF: evidence from adaptation study. *Journal of Communication Disorders, 10,* 365-371.

Wijnen, F., & Boers, I. (1994). Phonological priming effects in stutterers. *Journal of Fluency Disorders, 19,* 1-20

Wingate, M.E. (1976). *Stuttering: Theory and Treatment.* Irvington, New York.

Wolff, P. (1979). Cited in R, Netsell. (1986). *A neurobiologic view of speech production and the dysarthrias, (pp: 33-52).* SanDeigo: College-Hill Press, Inc.

Zimmerman, G.N., Brown, C.K., Kelso, J.A.S., Hurtig, R. & Forrest, K. (1988). The association between acoustic and articulatory events in a DAF Paradigm. *Journal of Phonetics, 16,* 437-451.

APPENDIX A

Section A

Describe what you felt when you were trying to express verbally when you were performing the tasks.

Section B

Answer the following questions as yes/no:

1. Did you have problem in selecting appropriate sounds to form meaningful words?

2. Did you feel that your thoughts were blocked and you could not recollect any word at all?

3. Did you feel that your oral performance on various tasks of this experiment was inadequate and you were unable to perform as you had actually planned to perform?

4. Did you have difficulty in arranging words in proper order to form a sentence?

5. Did you find it difficult to arrange the sounds with in words to form a particular word?

6. Did you feel any inadequacy in the movements of the jaw while speaking?

7. Did you feel any inadequacy in the movements of the lips while speaking?

8. Did you feel that your tongue movements were restricted

9. Did you feel that your tongue movements were overactive?

10. Did you feel any tension in your neck muscles while speaking?

11. Did you feel that you spoke louder / softer than you would have performed in a normal situation?

12. Did you feel that you could not breathe easily while performing the tasks?

13. Did you feel that there was too much of stress and strain on larynx?

14. Did you find any difference any difference in your voice quality?

15. Were there instances when you felt that you could not initiate voicing while speaking?

16. Did you perceive your voice as nasal?

17. Did you feel that you were prolonging the sounds at some instances while speaking?

18. Were you repeating the same sound / word again and again during various tasks?

19. While imitating a sentence, did you experience a block or after imitating, did you abruptly stop speaking in between the sentences?

20. Did you find any difference in your pronunciation of sounds while performing the various tasks?

21. Did you feel that your speech was getting slurred or distorted like a "drunkard's speech"?

22. Did you find yourself speaking monotonously that is, like a robot's speech without any variations or inflections in your speech?

23. Did you feel that you were stressing or emphasizing on each and every word while speaking?

24. Did you feel that you spoke with an abnormal rhythm pattern while speaking?

APPENDIX B

For the purpose of analysis, the responses to questions I section B of Appendix A were categorized into three sections. The responses presumed to reflect on any one of the levels of speech processing, that is, planning, programming and execution. Some examples of such categorization are given below:

Planning:

1) Did you find it difficult to arrange the sounds with in words to form a particular word?
2) Did you have problem in selecting appropriate sounds to form meaningful words?
3) Did you feel that your thoughts were blocked and you could not recollect any word at all?

Since selection and sequencing are considered as due to deficit in the linguistic - symbolic planning stage, they were categorized under this section.

Programming:

1) Did you feel any inadequacy in the movements of the jaw while speaking?
2) Did you feel any inadequacy in the movements of the lips while speaking?
3) Did you feel that your tongue movements were restricted?

Since programming is the stage where muscular commands are given to different articulators, the above questions were categorized under this section.

Execution:

1) Did you feel that you spoke louder / softer than you would have performed in a normal situation?
2) Did you feel that you could not breathe easily while performing the tasks?
3) Did you perceive your voice as nasal?

Since loud / nasal speech and abnormal breathing are characterized as more due to deficit in execution level, they were categorized under this section.