Behavioural Correlates of Speech Processing in Normal Speakers under Delayed Auditory Feedback

Banumathy N. & R. Manjula*

Abstract

Disfluencies of normal speakers under the influence of Delayed Auditory Feedback (DAF) while performing tasks with different cognitive-linguistic complexity were investigated. 15 male and 15 female normal speakers in the age range, 17-25 years were administered with tasks of varying cognitive-linguistic complexity under three different experimental conditions namely, normal auditory feedback, DAF at 180 ms and DAF at 280 ms. Results suggested that deficit at a higher level processing (planning and or programming) could probably be the cause of disruptions in speech of normal speakers under DAF, rather than a peripheral deficit. The study facilitates understanding of DAF induced speech disruptions at different levels of speech processing, in turn providing valuable insights into the nature and etiology of stuttering.

Introduction

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. 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). Successful processing of neurolinguistic codes in these three stages is considered to be responsible in fluent speech production of an individual.

* Professor of Speech Pathology, All India Institute of Speech and Hearing, Mysore, India
e-mail: r_manjula@yahoo.com

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 facilitate 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 (Delayed Auditory Feedback - 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 disfluencies 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. The present 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).

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. In addition, there is dearth of 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.

Consequently, the present study aimed 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. 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 & 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.

Method

Aim of the study:

The study aimed to investigate the disfluencies of normal speakers under DAF while performing tasks with different cognitive-linguistic complexity. This in turn aims to delineate the behavioural correlates of different levels of speech processing in normal speakers under the influence of DAF.

Subjects:

Thirty adult speakers (15 males and 15 females) with normal speech and language skills participated in the study. They were blind to the purpose of the study.

Instrumentation:

- "Facilitator", a portable therapy instrument was used. The DAF module was chosen and time delays were set to 180 ms and 280 ms.
- Tape recorder, 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 selected were:

1. Recalling, narration and answering questions:

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

2. Reverse spelling:

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

Experimental conditions:

Stage1:

Selected tasks were administered 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 condtion followed by DAF at 180 msec and finally by DAF at 280 msec. 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 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) Task 1 (story narration and answering to questions): Three stories that 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 were 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 randomly 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) Task 2 (reverse spelling): Three cards, each consisting of four word lists for bi-syllabic, tri-syllabic, four-syllabic and five-syllabic words were prepared. Each list consisted of five words.

C) Task 3: A questionnaire consisting of two sections: sections A & B, was prepared. 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 same manner. 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 the questionnaire.

Data Analysis:

Analysis was carried out in three stages:

I) 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 analyzed as follows:

1. Task 1:

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/Total number of words uttered x 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 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 carried out to identify and tabulate the frequency of occurrence of 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.

2. Task 2:

Task 2 was reverse spelling. The experimenter measured the total time taken for the complete utterance of each word in the word list (five words in each syllabic group). 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 structures
- The difference in performance in the rate of correctly uttered syllables across the three experimental conditions.

3. Task 3:

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.

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.

Results and Discussion

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
3) Self evaluation of listening experience from section A of the questionnaire
4) Self evaluation of listening experience from section B of the questionnaire.

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.

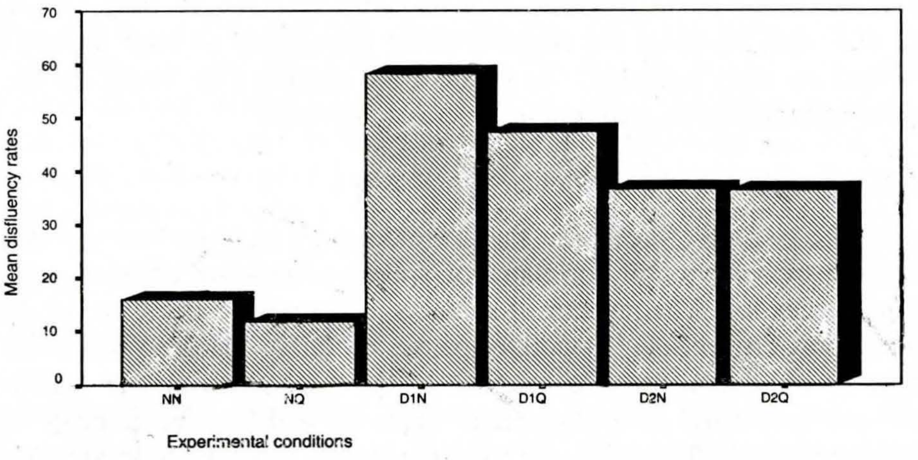
I) Task 1: This consisted of two subtasks i.e., story narration and answering to questions. The speech samples of the subjects recorded for these two tasks, under the three experimental conditions were analyzed for the following parameters:

A) 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 results are graphically shown in Graph 1.

From the mean values in graph 1 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. This shows that normal speakers exhibit disfluency more at the delay interval 180 ms than at 280 ms.

Graph 1: 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}

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 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.

B) Perceptual analysis of specific disfluencies:

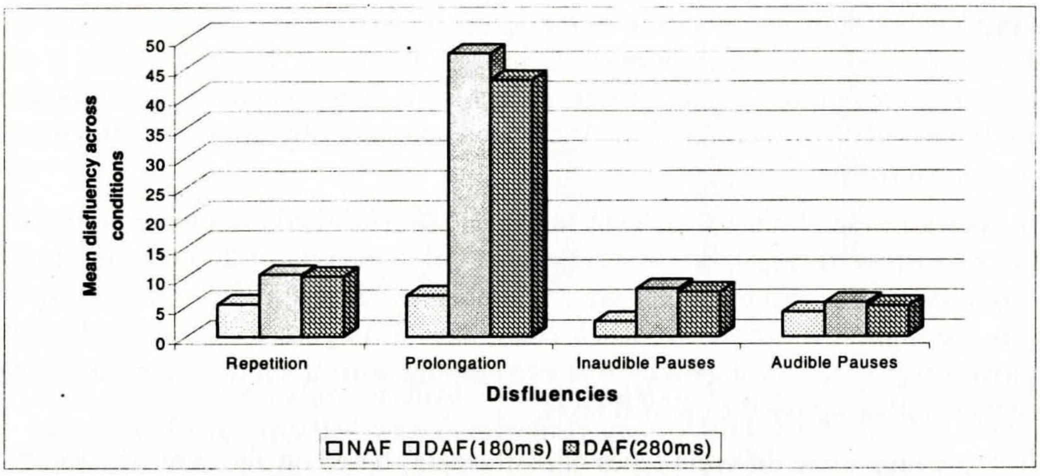
The speech samples were perceptually analyzed for various types of disfluencies such as repetitions, prolongations, inaudible pauses and audible pauses across the three experimental conditions. The raw scores were subjected to statistical analysis using 'One way-ANOVA'. The results show that there is a significant difference between the parameters, repetition, prolongation and inaudible pauses whereas audible pauses are not significantly different from other parameters.

- 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 findings are graphically displayed in Graph 2:

Graph 2: Mean of specific disfluencies across different experimental feedback conditions



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 & 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 discoordination 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 resulting 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 however, 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 fèature 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 predominant 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.

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.

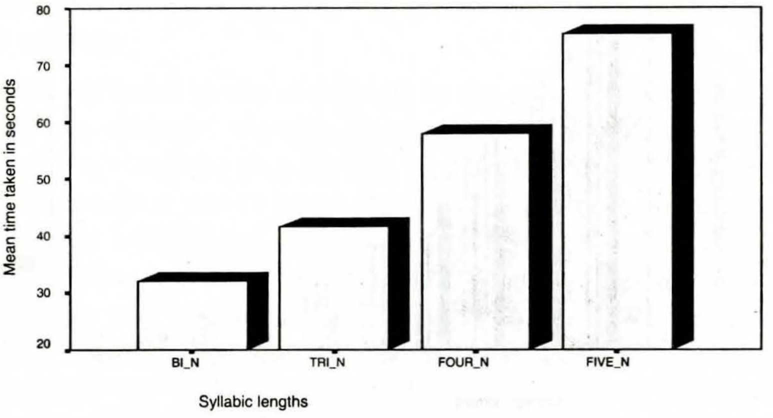
II) ***Task 2:*** 'Reverse spelling'. This was analyzed with reference to two parameters. They are:

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. Using Graph 3, the following findings can be understood:

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.

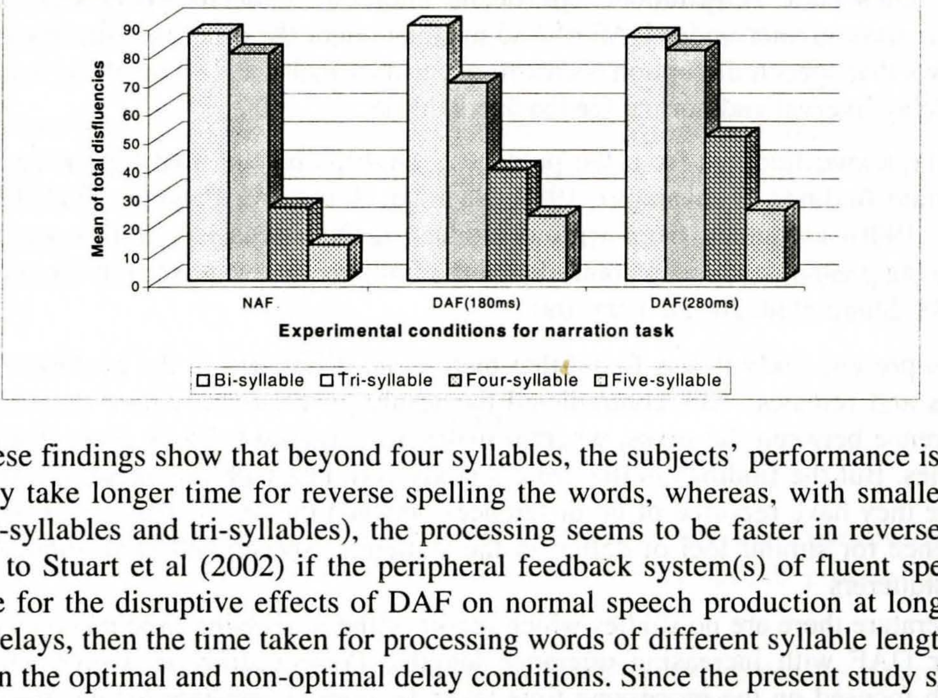
Participants took longer time to reverse spell words with four syllables and greater, whereas, subjects were faster in reverse spelling words with reduced syllable lengths (bi-syllables and tri-syllables).

Graph 3:Mean time taken (in seconds) for specific syllabic lengths across the three conditions



b) Rate of correct syllables recalled: 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.

Graph 4. Mean rate of correct syllables recalled across the three conditions.

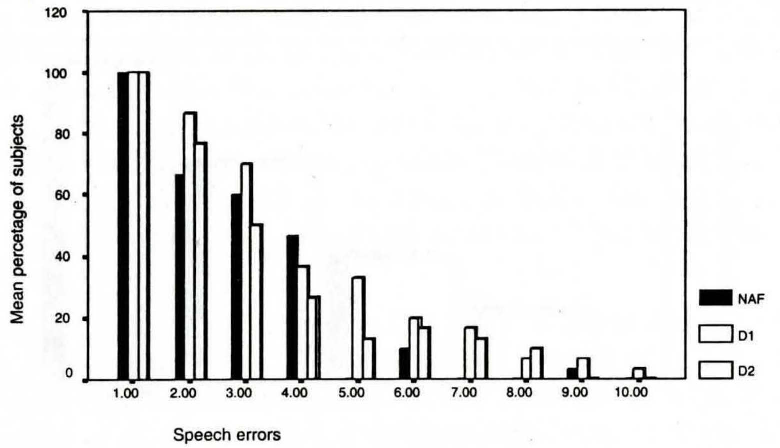


These findings show that beyond four syllables, the subjects' performance is the same that is, they take longer time for reverse spelling the words, whereas, with smaller syllable lengths (bi-syllables and tri-syllables), the processing seems to be faster in reverse spelling. According to Stuart et al (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 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.

Error types (in Tasks 1 & 2):

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 5.

Graph 5: 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.

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

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 various studies in the discussion of this section. But the 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 correlate 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) Task 3: Results from analysis of self-report are summarized as follows:

a) *Responses to questions in section A:*

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

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.

b) Responses to questions in section B:

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. 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.

Conclusions

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

- 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 with tasks of varying cognitive-linguistic complexity such as that used in the present study 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.

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.

References

American Psychological Association. (1994). *Publication manual of the American Psychological Association* (4th ed.). Washington, DC: Author.

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.

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

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

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. (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.

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.

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.

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 & Persson A. (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 & 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.

Rosenbek, J. C., Kent, R. D. & LaPointe, L. L. (1984). In P. K., Hall, L. S., Jordan & Robin, D. A., (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.

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 theoritical 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.

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.