EFFECT OF ALTERED AUDITORY FEEDBACK ON THE SPEECH RHYTHM OF INDIVIDUALS WITH STUTTERING

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CERTIFICATE

This is to certify that this dissertation entitled "**Effect of Altered Auditory Feedback on the Speech Rhythm of Individuals with Stuttering**" is a bona fide work submitted in part fulfilment for the Degree of Master of Science (Speech Language Pathology) of the student (Registration No.: 12SLP029). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any of the University for the Award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "**Effect of Altered Auditory Feedback on the Speech Rhythm of Individuals with Stuttering**" 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.

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DECLARATION

This is to certify that this dissertation entitled "**Effect of Altered Auditory Feedback on the Speech Rhythm of Individuals with Stuttering**" is the result of my own study under the guidance of Dr. Santosh M, Reader in Speech Sciences, Department of Speech - Language Sciences, 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.

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May, 2014.

Dedicated to my

Achan and Amma who stood by me

& motivated me in every possible way,

to pursue my ambitions...

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CHAPTER 1

Introduction

Numerous studies have shown that altered auditory feedback (AAF) induces fluency in individuals who stutter (Armson & Stuart, 1998; Macleod, Hargrave, Kalinowski, Stuart, & Armson, 1994; Howell, El-Yaniv, & Powell, 1987; Kalinowski, Armson, Roland-Mieszkowki, Stuart, & Gracco, 1993; Kalinowski, Stuart, & Armson, 1995; among others). Altered auditory feedback can be (i) hearing your voice through headphones in a distorted form, (ii) masked auditory feedback (MAF), (iii) delayed auditory feedback- hearing the voice through headphones which may be delayed by fraction of a second, (iv) frequency altered feedback - hearing your voice through headphones which is shifted to either lower or higher pitch, (v) speaking in chorus with another person, (vi) shadowing.

The fact that fluency improves in the presence of altered auditory feedback conditions evidently suggests relationship between auditory processing and stuttering. Goldiamond (1965) was the first researcher who reported improvement in fluency when persons with stuttering are placed under delayed auditory feedback (DAF). Following this Curlee and Perkins (1969), and Perkins (1973) formulated a management technique in which the fluency was induced in persons with stuttering by making the participants speak under DAF with a delay of 250 milliseconds. Gradually the delay was reduced in 50 milliseconds until the fluent speech was generalized. Frequency altered feedback and delayed auditory feedback was utilized by Macleod, Kalinowski, Stuart, and Armstrong (1995) to assess the processing abilities in adult with stuttering. Ten stutterers and ten nonstutterers read a passage in the presence and absence of altered feedback, and combination of each (FAF & DAF). Results showed that a reduction in the frequency of dysfluency under the various AAF conditions at both slow and fast rate relative to the NAF condition.

In the DAF condition, the speaker's voice is altered by delaying the signal prior to it reaching the sensing apparatus, ear. Hence, fragment of speech heard by the speaker and the fragment that he had planned to produce at a particular time differ from each other. The justification is that, the disparity is perceived via the ears and a fluent speaker then makes the corrections, which in turn introduces rather than removes errors. The enhanced speech control in speakers who stutter might arise because the atypical feedback is corrected (Howell, 2007). In fluent speakers, DAF slows speech mainly by prolonging vowels. The speech is monotonous and has high amplitude; both effects being easily perceptible on the vowel during DAF speech. In Persons with stuttering, DAF produces a reduction in the incidence of stuttering events.

Like DAF, under frequency altered feedback (FAF) also there is enhancement in fluency of speech even at fast rate of speech (Macleod,1995). When persons with stuttering speak under FAF condition, they feel as if someone is speaking in unison with them as seen in choral reading (Hargrave, Kalinowski, Stuart, Armson, and Jones, 1994). Furthermore, it has been suggested that that the direction and the magnitude of the frequency shift does not have a significant effect on the number of disfluencies (Hargrave et al., 1994; Stuart et al, 1996). Macleod, Kalinowski, Stuart, and Armson (1995) compared NAF, DAF, and FAF conditions in stutters while doing an oral reading task. The results revealed that frequency of stuttering frequency was significantly decreased under all AAF conditions, and found no significant difference between DAF, FAF and DAF/FAF conditions. They also concluded that the DAF and FAF condition by its own enhanced fluency in a better way than DAF and FAF combination condition.

DAF- FAF combinations alters the two different parameters of speech that is, DAF alters the perception of one’s own voice in the temporal domain, while FAF makes changes in pitch perception. This may have a better effect on fluency as they produce more powerful than if either effect was given independently. Lincoln, Packman, and Onslow (2010) investigated the impact of various durations of delayed auditory feedback (DAF), levels of frequency-altered feedback (FAF), and masking auditory feedback (MAF) on percentage of syllables stuttered during conversation. They found a significant difference between the NAF conversation condition and the other 4 combined altered auditory feedbacks (AAF). O’Donnell, Armson, and Kiefte (2008) concluded that there was no obvious pattern between the DAF and FAF parameters selected and stuttering reductions.

To date, surprisingly little is known about the underlying mechanism behind the fluency enhancing effect of AAF. Very few studies have focused on identifying which specific aspects of speech are changed under the manipulated auditory input. Previously reduced rate was considered as the reason for decrease in stuttering (Costello-Ingham, 1993; Goldiamond, 1960). However, Kalinowski, Stuart, Sark, and Armson (1996) found that persons who stutter were fluent under both normal and fast speaking rates with DAF. They concluded that reduction in stuttering is not due to motoric changes in terms of prolonged speech, but due to auditory second speech signal itself. In the recent past, changes in fluency under AAF conditions have been attributed to activation of the mirror neurons (Dayalu & Kalinowski, 2002; Guntupalli, Kalinowski, Saltuklaroglu, &

Nanjundeswaran, 2005). However, Howell, Powell, and Khan (1983) developed a non-feedback account for the effects of DAF based on the work with fluent speakers that showed ameliorations that influence stuttering and termed this as the disruptive rhythm hypothesis (DRH). DRH explains that the speakers who stutter experience difficulty in speech control in normal listening conditions, by trying to execute speech at a fast rate. As rate is slowed under DAF, it allows the speaker more language planning time. The additional language planning time reduces the possibility of stuttering, thus, improving the fluency of persons with stuttering by slowing the speech. Howell and Archer (1984) reported DAF procedures do not disrupt speech as the information is sent through the speech perception system to supply information to the language area. Howell (2007) did an experiment where he examined whether gated speech (on - off) affected the speech control in speakers with stutter, and he concluded that fluency was enhanced when speech was interrupted in this way. In the present study we hypothesize that along with changes in rate of speech, there is indeed change in rhythmic aspects of speech under AAF condition, which is one of the reasons for fluency inducement under AAF condition. In order to test this hypothesis, it is necessary to quantitatively document rhythm under AAF in individuals who stutter.

Speech is perceived as a succession of events in time, and the word rhythm is used to refer to the way these events are disseminated in time. Rhythm occurs from the reiteration of elements which are similarly perceived. These elements in speech are the stressed syllables or syllables. Languages have been classified as ‘‘syllable-timed’’ and as ‘‘stress-timed’’ (Abercrombie, 1967). This typological dichotomy was initially associated to isochronous speech intervals, with the hypothesis that syllables tend to be of the same duration in syllable-timed languages and that stress-delimited feet tend to be of equal duration in stress-timed languages. A third type of rhythm, called, mora-timing, was proposed by Bloch (1942), Han (1962), and Ladefoged (1975). Metrics used for comparing the rhythm of different languages included "interval measures" (Ramus, Nespor, & Mehler, 1999) and "pair wise variability indices" (Grabe & Low, 2002; Low, Grabe, & Nolan, 2000). Rhythm metrics are based on acoustic measures of the duration/ fundamental frequency of consonantal and vocalic intervals in a continuous speech, the variability is accounted and is can be calculated in rate-normalized and raw forms.

Need for the study

Even though it is known that stuttering is a disorder of rhythm, there is no quantitative evidence to validate this factor. If AAF is said to be fluency inducing, subsequently it would have an effect on the speech rhythm as well. Additionally, there is a dearth of studies examining the efficacy of AAF in reading, with no conclusive indication concerning which among the combinations of AAF have the greatest effect on percentage of syllable stuttered and speech rhythm. Therefore, this study is aimed at quantifying the effects of different AAF conditions on speech rhythm.

Aims

The present study aims to investigate the effect of AAF conditions on speech rhythm and frequency of stuttering in adults who stutter.

Objectives

1. To compare frequency of stuttering across different AAF conditions.
2. To compare speech rhythm across different AAF conditions.

CHAPTER 2

Review of Literature

Although stuttering is one of the most widely researched topics in speech-language pathology, it’s cause remains unknown. One possible reason for this could be that the manifestation of stuttering varies across different individuals. Multiple conditions influence stuttering frequency. One such condition is altered auditory feedback. Research since the 1950s has shown that stuttering is markedly reduced under altered auditory feedback (AAF) conditions when compared to non-altered feedback (NAF) condition (Kalinowski Stuart, Sark, & Armson, 1996). Altered auditory feedback can be (i) hearing your voice through headphones in a distorted form, (ii) masked auditory feedback - hearing a synthesized speech in headphones mimic your phonation (MAF), (iii) delayed auditory feedback- hearing the voice through headphones which may be delayed by fraction of a second, (iv) frequency altered feedback-hearing your voice through headphones which is shifted to either lower or higher pitch, (v) speaking in chorus with another person, and (vi) shadowing (Kalinowski et al, 1996). In altered auditory feedback technique the temporal and spectral properties of the speech signal are altered (Kalinowski et al., 1996). Alterations to auditory feedback are particularly important as people who stutter become more fluent when subjected to these alterations (Howell, 2002). This is because the altered feedback is perceived as another person speaking along (Kalinowski et al., 1996). Many reasons of how speech control is improved when speaking under AAF have been there.

Goldiamond (1965) used DAF and operant conditioning procedures in treating stuttering. Amplified DAF was given as an adversive stimulus for stuttering. He obtained conflicting results when DAF was given as a form of punishment for fluency (each word stuttered shuts off DAF for 10 sec). It was observed that two response patterns were competing. First, a slow reading rate and high stuttering rate, and the other as a slow reading rate with little stuttering. According to Goldiamond, slow reading rate with little stuttering were better, i.e., the subject's speech continued to be prolonged with negligible stuttering. He used another set of fluency shaping procedures on stutterers, which were (1) to prolong under DAF, (2) to gradually fade out the delay from 0.25 sec to NAF, and (3) to increase the reading rate through machine programmed materials. The results showed a pattern of fluent oral reading which was well-articulated, rapid, and devoid of stuttering.

Ham and Steer (1967) investigated the effect of different delays of DAF on the total reading time, phonation/time ratio, syllable duration and the frequency of stuttering. Ten stutterers and nonstutterers read the same 111 word passage under randomized conditions of amplified DAF (10, 20, 40, and 80 msec delay) and NAF. Both groups showed a similar peak effects at 10 msec with regard to measures of total reading time, phonation/time ratio, and syllable duration. Longer delay times tended to decrease the duration measures. These investigators also noted that mean vocal intensity did not vary significantly among the delay conditions and NAF but the stutterers were more variable than were nonstutterers on this measure under DAF. In addition, Ham and Steer reported no significant mean difference in frequency of stuttering under NAF and DAF but that greatest variation in stuttering frequency occurred under DAF.

The fact that fluency improves in the presence of altered auditory feedback conditions are proved in various studies and is one of the mechanisms to link auditory processing and stuttering. Numerous studies have shown that altered auditory feedback (AAF) induces fluency in individuals who stutter (Armson & Stuart, 1998; Hargrave, Kalinowski, Stuart, & Armson, 1994; Howell, El-Yaniv, & Powell, 1987; Kalinowski, Armson, Roland-Mieszkowki, Stuart, & Gracco, 1993, Macleod, Kalinowski, Stuart, & Armson, 1995; among others).

Hargrave, Kalinowski, Stuart, Armson, and Jones (1994) studied the effect of the extent and direction of the frequency shift of FAF on frequency of syllable stuttered at both normal and fast rate of speech. Twelve adult males and 2 adult females with stuttering were made to read 300- syllable reading passage under NAF at either a normal or fast rate of speech, and in each of the four FAF conditions in which the frequency was shifted: up by half octave; up by one octave; down by half octave; and down by one octave. Statistically significant main effects of auditory condition and speech rate condition with a no significant interaction of speech rate and auditory condition was seen. Reduction in stuttering was by 50–60% under FAF when compared to NAF. No variation in the frequency of stuttering was noted when the frequency was shifted either up or down by 1/4 or 1/2 octave, which indicated a minimum of 1/4 octave may be the minimum shift required. The individual data presented also demonstrated a heterogeneous response with some, experiencing a maximum stuttering reduction at a downward shift of 1/2 or 1 octave and others required an upward shift of 1/2 or 1 octave. However, group data results revealed that there exists no significant difference in frequency of stuttering between the four FAF conditions. Participants experienced an approximate 80% reduction in frequency of stuttering during FAF when compared to NAF and exhibited more disfluency under the fast speech rate condition relative to the normal speech rate condition.

Ingham, Moglia, Frank, Ingham, and Cordes (1997) conducted a series of single-subject experiments to evaluate the effects of FAF on the speech of four adult males who stutters. Using a shift of plus or minus ± 1 octave, FAF was compared with NAF in spontaneous speech and reading. The audio recorded speech under these conditions was analyzed for stutter-free speech rate, speech naturalness, and stuttered intervals. The effects of extended FAF conditions on spontaneous speech were evaluated for the two subjects who showed a positive response to FAF. No consistencies across subjects in responses to FAF was noted. One subject showed no response,second produced an initial temporary response, third showed a decline in speech quality with minimal stuttering reductions, and fourth displayed considerable and sustained improvements in speech performance.

Stuart, Kalinowski, and Rastatter (1997) investigated the effect of monaural and binaural alterations in auditory feedback on stuttering frequency. Eleven adult persons with stuttering were asked to read aloud under NAF and monaural and binaural conditions of FAF one-quarter octave shift upward, and DAF, 50-ms delay, at a normal speech rate. Relative to the NAF condition, reductions in stuttering frequency of approximately 60%–75% were found with the altered auditory feedback conditions, and a greater reduction in stuttering frequency was observed for binaural compared to monaural altered auditory feedback, further no significant differences in stuttering frequencies for right versus left monaural conditions and DAF versus FAF was found.

Kalinowski, Stuart, Wamsley, and Rastatter (1999) studied stuttering frequency as a function of three monitoring conditions under NAF and frequency-altered feedback (FAF), no monitoring (speaking alone, in the absence of audio and visual recording), audiovisual monitoring (speaking alone with audiovisual recording); and audiovisual monitoring with observers (speaking with audiovisual recording in the presence of two observers). There were seven adult and one adolescent participants who were asked to read aloud six different, 300-syllable Passages. The results of the study revealed that across monitoring conditions, approximately 85% reductions in stuttering frequency occurred during the FAF relative to NAF conditions. Also a significant difference in stuttering frequency across monitoring conditions under each auditory feedback condition was observed.

Natke, GrosserKarl, and Kalveram (2000) studied the effect of frequency shifting on the fundamental frequency and fluency enhancement in persons with stuttering. Ten stuttering and ten nonstuttering persons produced spontaneous speech, while their auditory feedback provided was frequency shifted by half octave downwards, and half octave upwards. In PWS, the downward shift condition led to a significant fluency enhancement of 25%. Although in the upward shift condition, fluency was enhanced by 21%, the significance level was not reached. In non- stuttering individuals, a difference in global fundamental frequency between the NAF condition and the upward shift condition in the opposite direction of the frequency shift indicates a slight compensating response. Persons with stuttering did not show such a change as a group. However, some stuttering change in the global fundamental frequency up to two semitones, but this does not correlate with fluency enhancement.

Added to the effects of DAF/ FAF alone, in inducing fluency in Persons with stuttering, research in the recent past has shown better results in persons with stuttering when they speak under a combination of DAF+FAF. DAF+FAF combination alters the two different parameters of speech, that is, DAF alters the perception of one's own voice in the temporal domain, while FAF makes changes in pitch perception. Macleod, Kalinowski, Stuart, and Armson (1995) studied the effect of combined delayed auditory feedback (DAF) and frequency altered feedback (FAF) which would enhance fluency more than either DAF or FAF alone. Ten adults with stuttering were asked to read eight different passages at normal and fast speech rates under NAF, DAF (50 ms delay), FAF (a one half octave downward shift), and a combination of DAF and FAF [50 ms delay plus a one half octave downward shift]. The results of the study indicated that stuttering frequency was significantly reduced under all altered auditory conditions at high speech rates relative to the NAF condition. There were, however, no significant differences between the altered auditory feedback conditions. Stuttering frequency was significantly higher in the fast rate condition and stuttering frequency was differentially affected under the auditory conditions. The combination condition had a better effect (on fluency as they produced more powerful than if either effect was given independently MacLeod, Kalinowski, Stuart and Armson, 1995).

Lincoln, Packman, Onslow, and Jones (2010) investigated the effect of different durations of delayed auditory feedback (DAF), different levels of frequency-altered feedback (FAF), and masking auditory feedback (MAF) on percentage of syllables stuttered during conversational speech in eleven adults who stutter. The NAF and maximum (MAX) FAF + (MAX) DAF (one octave shift downwards + 100 ms delay) reading conditions were included so that comparison of stuttering scores during conversation and oral reading with and without AAF could be done. The (MAX) AAF settings were chosen for the reading condition because, theoretically, these settings were most likely to result in the largest reductions in stuttering. DAF delays were adjusted between 30 ms and 200 ms with simultaneous adjustment of FAF frequency up a maximum of 0.4 octaves or down a maximum of 1.2 octaves. The results revealed that the conditions with the highest %SS were the control (NAF) conversation and the (MIN) FAF + (MIN) DAF (half octave shift downwards + 55 ms delay) conversation and the largest mean reduction in %SS occurred for (MAX) FAF + (MAX) DAF during reading and for (MIN) FAF + (MAX) DAF (half octave shift downwards + 100 ms delay) in conversation. In brief, the results revealed a significant difference between the NAF and combined AAF Conditions. All of the experimental conditions produced reduced levels of stuttering. The findings of this study confirm that alterations in auditory feedback can play an important role in the amelioration of stuttering.

Several hypotheses have been presented about how DAF and FAF enhance fluency. Older views tend to characterize altered auditory feedback as a means of distracting the speaker who stutters from their concerns about speech production (Barber, 1939, 1940; Bloodstein, 1995, 1999; Jonhson & Rosen, 1937). Others have speculated that altered auditory feedback helps speakers who stutter to circumvent a malfunction or deficit in the auditory system (Stromsta, 1957; Webster & Lubker, 1968). Still others have hypothesized that under DAF and FAF people who stutter modify the movement patterns in the vocal tract musculature, and these modifications are sufficient to allow for the execution or relatively smooth, fluent speech (Perkins, 1979; Wingate, 1969, 1976, 1979). Wingate (1979) argued that stuttering is reduced under the altered feedback condition because speakers who stutter are induced to emphasize phonation and continuity of phonation. This has the effect of altering prosody and, in particular, slows speech rate. Thus, Wingate essentially thought of the fluency enhancing effects of DAF as resulting from extended syllable duration (Wingate, 1979; p. 237). Wingate's (1979) claim that increases in vowel duration underlie the fluency improvements seen in DAF was challenged by Kalinowski et al. (1993), who showed that, a slow speech rate was not required for enhancing fluency either during DAF or during FAF.

Kalinowski Armson, Roland-Mieszkowski, Stuart, and Gracco (1993), investigated the effects of the four different AAF (NAF, MAF, DAF, FAF) conditions on stuttering frequency at two different speech rates, normal and fast rates. The participants read eight passages under these conditions. Results indicated that stuttering frequency was significantly decreased during delayed and frequency altered auditory feedback conditions at both speech rates. These findings disproved Wingate's view that a slowed speech rate is required for inducing fluency under AAF conditions. Based on their results the authors proposed that there may be two inter-reliant factors that are accountable for fluency enhancement: alteration of auditory feedback, and modification of speech production. They also explained the fluency enhancing effects of DAF and FAF as a manifestation of the "double speaker phenomenon". This opinion simply states that stuttering is reduced significantly in any context in which a speaker who stutter talks along with second speech signal (Kalinowski et al., 1996). When persons with stuttering are asked to perform in a choral speaking condition, reduction in stuttering happens and this reduction is attributed to the sensory input, which is the linguistic match to his production.

Sparks, Grant, Millay, Batson, and Hynan (2002) investigated combined effect of fast rate of speech and DAF on the fluency of one adolescent and 3 adults who stutter. The subjects read four passages at both normal and fast reading under both, the DAF (55, 80, and 105 ms) condition and without DAF. For two mildly dysfluent subjects, fluency was the same for both no DAF and DAF conditions at both rates. However, the two severely dysfluent subjects improved in fluency from the no DAF to the DAF conditions. They were found to be dysfluent at both normal and fast oral reading rates without DAF.

Stuart and Kalinowski (2004) compared the perception of speech naturalness between therapy and AAF conditions. Thirty-five young adult listeners rated speech samples of both PWS and persons with no stuttering. Speech samples were recorded (pre therapy and post therapy) from adults with stuttering and adults with mild or severe stuttering who spoke under conditions of NAF, DAF, and FAF. Speech under AAF was rated as significantly more natural sounding than speech under NAF. Speech under FAF was more natural sounding than that produced during DAF for those with mild and severe stuttering. Adults with mild stuttering had more natural sounding speech than that of a severe stutterer speech during AAF. Speech from individuals following therapy was rated significantly less natural sounding than that from individuals during AAF for both mild and severe stuttering. The pre-therapy speech was rated significantly more natural than post therapy speech. Speech of adults with no stuttering were rated as significantly more natural sounding than that produced by adults with stuttering. These findings support the contention that AAF benefits those who stutter through a reduction of stuttering with a gain in perceived speech naturalness. Apart from the above explanations, other possible mechanisms contributing to the improvement in fluency have been proposed by various researchers in the recent past.

Kalinowski et al, 1996 proposed that the speakers who stutter treat DAF and FAF as electronic forms of the double (or second) speaker phenomenon, because the acoustic signals associated with their own voice are received in a way that is different from normal. In essence, they considered FAF as another form of choral (or unison) speech, with additional view of DAF as a form of “shadow speech” in which another speaker’s voice is slightly delayed relative to the speakers’ original speech.

Dayalu and Kalinowski (2002) and Guntupalli, Kalinowski, Saltuklaroglu, and Nanjundeswaran (2005) considered that the altered signal, speech activates the mirror neurons thus reducing stuttering. Neurons which were associated with motor processes fired when they received proper sensory stimulation. Rizzolatti and Craighero (2004) defined a mirror neuron as a neuron that fires both when an animal acts and when the animal observes the same action performed by another; and they seemed to be associated with recognizing and executing actions and this holds good for humans as well (Rizzolatti & Arbib, 1998). The presence of this mirror neuron system, led to the human capability to imitate, later on, to the development of primitive communication, and finally language and speech. Skoyles (1998) observed that imitation is a skill that is performed fluently. The fluent imitation may be seen regardless of linguistic or cognitive level as it is found in communicatively disabled population. The notion of imitation as fluent is significant to the stuttering. The presence of mirror neurons responding to acoustic stimuli that represent a goal directed action may have led to gestural communication progressing from brachio-manual to orofacial gestures.

Neuroimaging techniques have exposed more highly specialized patterns of activation in the auditory cortices to receive speech as opposed to non speech sounds; and has even been shown to be active in the processing of silently lipped speech (Calvert & Campbell, 2003). Imitative forms mark the initial stage of language development which is also a period of fluency, may be considered as an evidence of strong mirror neuron contributions. Any child with an inclination to stutter may begin to exhibit symptoms as expressive language begins to assume longer and more complex forms. If the language development in children never surpassed the imitative stage, stuttering might not appear due to the constant use of mirror system for fluent imitation. Due to the engagement of mirror neuronal systems meeting imitative linguistic needs, stuttering is not manifested in the early infancy hence, it is recommended that the re-engagement of the mirror neuronal systems is the most effective way of presenting fluent speech upon those who stutter. Choral reading is a form of direct imitation.

Choral reading activates mirror neurons and consistently dominates the central involuntary stuttering block, as mirror systems are innate and are present prior to the onset of the pathological condition. In choral reading the engagement of the mirror neuronal systems easily inhibits stuttering and enhances fluency. On the other hand, the inhibition lasts for the duration of the choral speech. Stuttering relapses to its previous level on extinction of the signal. Under choral reading conditions, persons with stuttering are provided with a “gestural mirror” of their own speech that opens the channels for the forward flow of the fluent speech. This facilitates the people with stuttering to be fluent.

This can be applied to the alterations made to the speech; for example DAF at short delays and FAF (Dayalu & Kalinowski, 2002). In contrast, other fluency inducing conditions for persons with stuttering, such as prolonged speech, enhance fluency but do not sound fluent. This suggests that DAF at short delays and FAF unlike other forms of fluency inducing conditions are different because they activate the mirror neuron system that enhances fluency. Studies have shown identical brain image patterns of fluent speakers' from PWS under choral speaking condition. When FAF is presented, fluency in persons with stuttering occurs passively (Saltuklaroglu, Dayalu, & Kalinowski, 2002) and these changes are attributed to the direct effect on the central mirror neuron system. Stuttering may best be reduced by re-engaging mirror neurons via choral speech or its derivatives (AAF) to provide gestural mirrors, which helps overriding the central stuttering block (Kalinowski & Saltuklaroglu, 2003).

Under DAF condition, the disruptions in speech were observed in several dimensions: in the overall speech time, speech rate, fluency and articulation (Fairbanks, 1955; Fairbanks, & Guttman, 1958). The amount of disruption is dependent on the size of the delay between the original speech signal and the corresponding feedback; with its maximum at about 200ms (Black, 1951; Butler, & Galloway, 1955; Fairbanks, 1955). Howell, Powell, and Khan (1983) thus developed a non-feedback account for the effects of DAF based on the work with fluent speakers that showed ameliorations that influence stuttering and termed this as the disruptive rhythm hypothesis (DRH). The effects of DAF arise from an intrusion with the "performance of serially organized behavior (such as speech), produced by a rhythmic event going on at the same time but out of synchrony with the same activity" (Howell, Powell & Khan, 1983). The improvement in the ability of the speakers to control dysfluency during choral reading would be attributed to the facilitating effects of synchronous activity, this could explain FAF condition. The lower amounts of disruption with these synchronous events are obvious as speakers who stutter can shadow at the normal speech rate (Howell, Powell, & El-Yaniv, 1987). In DAF condition a delay in speech by the span of the syllable is given, which is asynchronous and maximally disruptive and this explains why DAF causes difficulties in speech control. DRH explains the difficulty in speech control experienced by PWS in normal listening conditions, by proposing that PWS try executing speech at a faster rate. When rate is slowed under DAF, it allows the speaker more language planning time. The additional language planning time reduces the possibility of stuttering, as has been reported to occur (Ryan& Van Kirk Ryan, 1995) thus, improving the fluency of persons with stuttering by slowing the speech. DAF procedures do not disrupt speech as the information is sent via the speech perception system to supply information to the language area (Howell and Archer, 1984). Howell (2007) did an experiment where he investigated whether speech that was gated on and off (interrupted) affected the speech control of speakers who stutter, and he concluded that fluency was enhanced when speech was interrupted in this way. (Kai Kaspara & Hartmut Rubelinga, 2011) Studied, the role of rhythm and speech content on DAF, using speech units as stimuli; they concluded that rhythm appears to be an important criterion of speech monitoring, and hence a mismatch between spoken words and auditory feedback realized by DAF induces obvious speech problems on rhythmic level regardless of phonemic discrepancy at the same time.

It is necessary to account for the possible explanation of how fluency is induced under different AAF conditions. Hence in the present study, we hypothesize that fluency is induced under the different AAF conditions as a result of the change in rhythm.

Rhythm

Rhythm refers reiteration of elements which are perceived as similar. In speech, these elements are syllables, or stressed syllables. Languages have been classified as ‘‘syllable-timed’’ and as ‘‘stress-timed’’ (Abercrombie, 1967; Pike, 1945). This typological dichotomy was initially associated to isochronous speech intervals, with the hypothesis that syllables tend to be of the same duration in syllable-timed languages and that stress-delimited feet tend to be of equal duration in stress-timed languages. A third type of rhythm, called, “mora-timing”, was proposed by Bloch (1942), Han (1962), and Ladefoged (1975).

The two most developed quantification of rhythm is by using measures of the relative durations of vowels and consonants. Ramus, Nespor, and Mehler (1999) suggested the use of three measures: the standard deviation of vowel, and consonant durations, and the proportion of the total utterance comprising vowel durations. These measures were shown to be significantly different when applied to the perceptually and classically defined syllable- and stress-timed languages. The Pairwise Variability Index (PVI) popularized by Low, Grabe, and Nolan (2000) makes use of a similar comparison to that of Ramus et al. Essentially the PVI compares the duration of successive vocalic and intervocalic durations.These metrics of speech rhythm work on the assumption that rhythm arises from the phonological structure of a language (Grabe and Low, 2002). The

PVI measure has so far been used to describe the rhythm of language, its varieties and make comparisons between them.

Savithri, Sanjay Goswami, and Kedarnath (2007) aimed at studying the rhythm in two unrelated languages, Indo- Aryan language (Hindi) and Dravidian language, Kannada. Ten male and ten female normal native speakers of each language in the age range of 18-25yrs participated in the study. Spontaneous speech and a 1000 word passage in their respective languages were audio recorded. Using the Cool Edit pro software, the duration of both vocalic and intervocalic interval and then the nPVI and rPVI were computed. In the reading task, there was a significant difference between the language groups on rPVI, but no significant difference on nPVI. In spontaneous speech, there was no significant difference between language groups in rPVI, but there was a significant difference on nPVI. The results indicated low nPVI in both the languages and low rPVI in Kannada and high rPVI in Hindi, thus labeling Kannada as a Mora timed language and Hindi as a Syllable Timed Language.

There are several studies which quantify the rhythm using PVI metrics in various disordered population. The research on rhythm in different disordered population mainly include of Dysarthria, Right Hemisphere Damage, Parkinson's Disease and Hearing Impaired. Still the research on rhythm quantification in disordered population using rhythm metrics is sparse.

Liss, Spitzer, Lansford, Choe, Kennerley, Mattys, White and Caviness, (2007) carried out a study where they tried to differentiate various forms of dysarthria using metrics designed to quantify linguistic rhythm on a stress-timed versus syllable-timed continuum. They compared rhythm metrics of the utterances of hypokinetic, ataxic, hyperkinetic, or mixed flaccid-spastic dysarthria. Differences among groups were discovered for %V (percentage of utterance duration comprised of vocalic intervals), VarcoV (rate-normalized standard deviation of vocalic interval durations), and nPVI-V (normalized Pairwise variability index for vocalic intervals). All dysarthric groups produced rhythm patterns less stress-timed than the control American English speakers, with lower VarcoV and nPVI-V and higher %V. Those with flaccid-spastic dysarthria secondary to amyotrophic lateral sclerosis exhibited a syllable-timed pattern more extreme than even control Spanish speakers, indicating minimal differentiation of stressed and unstressed syllables. These results show that the various types of rhythmic disturbance accompanying dysarthria can be effectively described and distinguished within a stress-/syllable-timed continuum and relative to healthy speech.

Liss, White, Mattys, Lansford, Lotto, Stephanie, and Canciness et al., (2009), examined whether rhythm metrics is capable of distinguishing among control and dysarthric speakers of American English with perceptually distinct rhythm patterns. There were 55 speakers across 5 dysarthric groups who were made to read 80 short phrases followed by five full sentences. Acoustic measures of vocalic and consonantal segment durations were obtained and were used to calculate standard and new rhythm metrics. The authors found that there was good success with nearly 80% correctly classifying speakers into their appropriate group. This study confirmed the ability of rhythm metrics to distinguish control speech from dysarthrias and to discriminate dysarthria subtypes. Rhythm metrics show promise for use as a rational and objective clinical tool.

In order to study the rhythmic disturbances in ataxic dysarthrics, Henrich, Lowit, Schalling, and Mennen, (2006) collected a variety of speech samples from six speakers with ataxic dysarthria and from six age and gender matched control speakers. They analyzed with four different rhythm measures: the Pairwise Variability Index (PVI), the Proportion of Vocalic Intervals (%V), the Scanning Index (SI), and the Inter stress Interval measure (ISI). Perceptual ratings of degree of rhythmic disturbances were also carried out. Results varied between different measures and speech tasks, but the PVI and ISI measures seem to be the measures most suitable to characterize rhythmic changes in ataxic dysarthria. These two measures yielded significant differences between the speakers with ataxic dysarthria and the control group, and they also correlated better with the perceptual evaluation of rhythm compared to other measures.

Dahmani, Selouani, O'shaughnessy, Chetouani, and Doghmane (2013), investigated the rhythm abnormalities in the dysarthric speech by using the rhythm metrics. The subjects included eleven young adult males with dysarthria caused by cerebral palsy (CP) or head trauma (HT) and one non-dysarthric adult male. They were asked to read nonsense sentences with embedded names and verbs. The mean and the standard deviation of vocalic and consonantal interval durations clearly confirms that the durations of both intervals are greater for Dysarthric Patients than the Healthy Control. The study revealed that the main effect of group for Vocalic-rPVI and Vocalic-nPVI was statistically significant. The relevance of the Pairwise Variability Index to assess dysarthrias was investigated through bi-dimensional representations. The feature space shows that Healthy Control are relatively well grouped around higher vocalic-nPVI values and mid intervocalic-nPVI, while Dysarthric Patients are more scattered in this space.

Rachael, Knight, and Cocks (2007), investigated the differences between the rhythm of a person with RHD and a neurologically normal control, and to see if any differences are in the direction of more syllable- or stress-timed rhythm. One RHD male patient and a age, gender, education matched, normal subject A sample of speech from a structured interview with each participant was analysed. The vocalic and intervocalic intervals were measured. PVI measure was applied. The results of the analysis show that the control participant had higher overall PVI scores for both vocalic and intervocalic measures than the speaker with RHD. There was a significant difference between the normal control and the right hemisphere damaged patient for the rPVI but not for the n PVI. The results showed that the significant difference between the two speakers comes from the more regular intervocalic intervals used by the participant with right hemisphere damage.

Rashika, Pooja, and Santosh (2013) evaluated the sensitivity of different rhythm metrics (for the quantification of speech rhythm) in documenting rhythmic abnormalities in individuals with Right Hemisphere Damage (RHD). Six Hindi speaking males with right hemisphere damage, and six age and gender matched control subjects were asked to read five meaningful sentences in Hindi. Using these, vocalic and intervocalic intervals, following rhythm metrics were derived: Pairwise Variability Index (rPVI and nPVI), percentage of vocalic intervals, standard deviation of both vocalic and intervocalic intervals, and variable coefficient of vowel and consonants (VarcoV & varcoC). The mean values of all the rhythm metrics were higher in individuals with

RHD than neuro-typical individuals. However, the results showed statistically significant difference between the groups only for nPVI, rPVI, standard deviation of consonant intervals, and variable coefficient of consonants. There was no significant difference between the groups for other parameters. The results highlight that different rhythm metrics can be successfully used to document rhythm abnormalities in individual with RHD.

Amulya (2013) investigated the speech rhythm of Kannada speaking persons with idiopathic PD on a reading task. 12 subjects, 6 males and 6 females with idiopathic PD were Classified into early and middle stage of idiopathic PD. 12 age, gender, language, education matched control subjects were also taken. The reading samples of five sentences were audio recorded and were subjected to acoustic analysis in PRAAT software. Pairwise variability index was calculated for the vocalic nPVI-V and the intervocalic nPVI-C segment duration. The values were then subjected to statistical analysis. The results revealed that there was a significant difference between the nPVI values of the clinical and the control group indicating that there were more clustering in the productions and prolonged phonemes in the clinical group than in the control group.

Henwasin, Meghana, and Theaja, (2014), studied the rhythm in cochlear implant users. The fifteen subjects (10 CI users & 5 normal) in the age range of 18- 22yrs were asked to do a picture description task. The speech sample was audio recorded and then using PRAAT software, the vocalic and intervocalic segments were measured and the nPVI and rPVI were calculated. The results of the study revealed a mean score of nPVI for CI were higher compared to the normal subjects. There was a significant difference in the rPVI scores between both the groups i.e., CI had higher scores than the normal subjects. Thus it can be concluded that Cochlear implant users has an altered rhythm.

Rhythm and stuttering

Stuttering is considered to be a disorder of rhythm and is attributed to lack of or reversal of cerebral dominance (Orton & Travis, 1937). Many researchers have examined stuttering from a prosodic perspective, and have provided considerable evidence to indicate that prosody is closely linked to stuttering and its associated symptoms. Prosodic factors have been incorporated in several prominent theories of stuttering. For example, Kent (1984) proposed that stuttering reflects impairment in the capacity to generate temporal programs that underlie sequential movement. Similarly, Perkins, Kent, and Curlee (1991) proposed that stuttering involves a breakdown in the integration or alignment of segmental and prosodic representations prior to speech initiation. With regard to the timing irregularities of stutterers' fluent speech, Agnello (1975), and Agnello, Wingate, and Wendell (1974) reported longer voice onset times (VOT) and longer voice termination times (VTT) in the fluent utterances of stutterers than in the Speech of normally fluent speakers.

Max, and Yudman (2003) checked the accuracy and variability of isochronous rhythmic timing across motor systems in stuttering versus non-stuttering individuals. Participants completed three rhythmic timing tasks, bilabial closing and opening speech movements, bilabial closing and opening non-speech movements, and flexion and extension movements for index finger–thumb opposition were performed in a synchronization- continuation paradigm with three different inter response interval durations. Responses consisted of bilabial contact in the syllable /pA/ during a speech task, bilabial contact in an orofacial non-speech task, and thumb-index finger contact in a finger movement task. Effectors' movements were transduced, and time points associated with minima in the derived lip or finger aperture signals were automatically extracted. Multiple analyses of timing accuracy and variability were completed for both the synchronization and continuation phases. The combined results from descriptive comparisons, statistical significance testing, and effect size computations suggest that the stuttering and non-stuttering participants showed highly similar levels of both timing accuracy and timing variability. This was true (a) for all three motor tasks, (b) at all movement rates, and (c) for synchronization as well as continuation movements. As one component of a systematic approach to investigating the role, if any, of timing difficulties in stuttering, these findings extend growing evidence that stuttering individuals do not differ from non-stuttering individuals in the ability to generate temporal movement patterns with a simple isochronous rhythm.

Swathi, Sameeksha, and Gagan (2014), explored the differences in the frequency of beat and iconic gestures among the individuals with or without stuttering. The participants in the study included ten normal individuals and 10 individuals with stuttering in the age range of 18-35yrs. The subjects were made to watch a video and later asked to narrate the events using gestures. The responses were video recorded and were analyzed for iconic and beat gestures. The authors found that the mean frequency of beat and iconic gestures were higher for non stuttering group than the stuttering group. Beat gestures which have been identified to have great temporal synchrony with speech. This has been proved in this study where stuttering group showed lesser use of beat gesture. Thus, concluding that there is an association of beat gestures with the speech fluency.

Santosh, Priyanka, and Sahana (2012), studied the speech rhythm in native Kannada speakers who stutter. There were ten male adults with stuttering and ten age and gender matched controls. The participants were given three tasks, to read a standardized 300 word reading passage in Kannada, conversation, and reading five sentences respectively. The initial two tasks were done for measuring the severity of stuttering and the third task was used for measuring the rhythm. Using PRAAT, the sentences were edited by removing the pauses and the dysfluencies and then, two kinds of rhythm metrics were calculated, Pairwise Variability Index (nPVI-V and rPVI-C) and internal measures (percentage of vocalic intervals, SD of vocalic and consonantal intervals and coefficients of variables for vocalic and consonantal intervals). The results of the study revealed that, there was significant difference between both the groups in all the interval measures, except, coefficient of variables for vocalic intervals. But no significant difference was found between the groups in both nPVI-V and rPVI-C, suggesting that, adults with stuttering are indistinguishable from control participants if we measure their rhythm using PVI measures.

From the above studies, it is evident that the persons with stuttering have a different rhythm when compared to persons with no stuttering and that the fluency of stutters gets enhanced under the influence of Altered Auditory feedback (AAF). If AAF is said to be fluency inducing, subsequently it would have an effect on the speech rhythm as well. There is a dearth of studies examining the efficacy of AAF in reading, with no conclusive indication concerning which among the combinations of AAF have the greatest effect on percentage of syllable stuttered and speech rhythm. Even though it is proven that rhythm in stutters are affected, most of the studies till date have not quantified the rhythm in persons with stuttering. Therefore, this study is aimed at quantifying the effects of different AAF conditions on speech rhythm in Persons with Stuttering.

CHAPTER 3

Method

Participants

A total of fourteen male, monolingual, Kannada speaking adults with stuttering in the age range of 18- 35 years were considered for the study. All the speakers spoke Mysore-Bangalore dialect of Kannada. A self reported questionnaire was completed by the participants. The questionnaire checked for the participant's history of stuttering, hearing, neurologic status, and the presence of other existing communication disorders. Based on the questionnaire, apart from stuttering, they did not have any other speech, language, hearing or neurological problems. They all had their onset of stuttering in early childhood. Their stuttering severity was assessed using Stuttering Severity Instrument for Children and Adults (Riley, 1994). Participants with the severity within the range of mild– very severe stuttering were only considered. Out of fourteen participants, eight of them were with moderate stuttering, 3 with severe stuttering, and one each with very severe stuttering, mild stuttering and moderately severe stuttering respectively (table1).

Table 1: Demographic data of each participant showing their age, SSI scores and the severity of stuttering participants

Participants	Age (in years)	SSI Scores	Severity of stuttering
1	26	26	Moderate
2	18	34	Severe
3	18	38	Very Severe
4	20	27	Moderate
5	32	27	Moderate
6	21	34	Severe
7	20	26	Moderate
8	21	27	Moderate
9	25	35	Severe
10	26	28	Moderate
11	20	18	Mild
12	18	27	Moderate
13	35	25	Moderate
14	19	29	Moderately Severe

Note: SSI- Stuttering Severity Instrument

Procedure

The participants were given two tasks: (a) a conversation task, and (b) reading a standardized Kannada Passage under 4 different altered auditory feedback (AAF) conditions. The conversation task and the reading sample under the NAF condition was used for calculating the severity of stuttering. Apart from calculating the severity of stuttering, percent of syllable stuttered was calculated for all the AAF conditions and for the NAF condition as well. The second task was used for measuring the rhythm. A reading task was considered in the study to analyze the rhythm since the passage used for reading would be phonetically and phonemically balanced, while in a monologue the phonemes may occur based on their frequency of occurrence in the language. Further, unlike a monologue which requires prior planning and programming, a reading task does not create a cognitive load on the person. The entire procedure was carried out in an environment free of distraction, comfortable for the participants, where only the examiner and participant were present.

Recording procedure

The microphone was placed at a distance of 5 cm from the mouth. The audio recording was done using PRAAT software, sampled at 16Hz and quantized at 16 bit sampling resolution at a nominal cutoff frequency. Altered auditory feedback (FAF, DAF, & DAF+FAF) were induced with FluencyCoach, manufactured by Speech Easy. FluencyCoach is a free software application that features two types of AAF: Delayed Auditory Feedback (DAF) and Frequency Altered Feedback (FAF). Both types of AAF essentially simulate the effect of “choral speech”, (speaking or reading simultaneously with another person) (Saltuklaroglu, Kalinowski, Robbins, Crawcour & Bowers, 2009). In the FluencyCoach the DAF could be adjusted between 25-220ms and FAF up to a maximum of one half octaves upward shift and one half octaves downward shift.

In each of the AAF condition, the subjects were asked to wear a headset consisting a microphone. The volume of the AAF was attuned prior to the beginning of the reading task according to the comfort level of the participants. During the NAF control condition the participants were not required to wear the headset. A Graduate speech-language pathologist experienced in analyzing stuttering measured the frequency of syllable stuttered using the recorded audio sample of conversation and the control NAF reading sample. The different reading conditions along with the respective AAF settings are listed in table 2.

Table2: Different AAF Reading Conditions

	AAF Condition	DAF Setting	FAF Setting
1	NAF (Control)	None	None
2	DAF	200ms	None
3	DAF+FAF	200ms	1/2-octave shift upward
4	FAF	None	1/2-octave shift upward

Note: AAF -Altered Auditory Feedback; NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback; DAF+FAF- Delayed Auditory Feedback + Frequency Altered Auditory Feedback.

The time taken for each participant to complete both the tasks were approximately 30 minutes. All ethical procedures were followed. A written consent was taken from all the participants before the data collection.

Analysis and rhythm Matrix Calculation

For the purpose of calculating the rhythm, five sentences from the reading passage were chosen. First, the recorded samples were fed into the PRAAT software, sampled at 16Hz and quantized at 16 bit sampling resolution at a nominal cutoff frequency. The recorded sentences were edited by removing the silences between the words (Grabe & Low, 2002) and also omitting the disfluencies in AWS. By the concurrent examination of the waveform and the spectrogram in PRAAT software, the vocalic and intervocalic intervals were measured. The vocalic duration is the duration of the vowel (including glides, liquids and glottal)/ diphthong/ semivowel. The intervocalic measure is the duration between the offset of one vowel/ diphthong/ semivowel and onset of another vowel/ diphthong/ semivowel, between which, any number of consonants can be present i.e., it is the duration of the consonantal segment between two vocalic segment (Grabe & Low, 2002). The rules that governed the segmentation of the sounds were based on former studies on rhythm analysis and acoustic analysis (Peterson & Lehiste, 1967). The boundary between the vocalic and the consonantal interval was indicted by a significant drop in the amplitude and a break in the second formant structure. The primary indicator of the boundary between a vowel and a consonant is the end of the pitch period which precedes a split in formant structure coupled with a major fall in the amplitude of the waveform. Silent pauses and disfluencies were excluded and summation of the interval durations was done. The identification of consonant boundaries was made easy by the cues obtained from the spectrogram which was associated to the manner of production of that sound. Apart from this standard criterion, a few other factors were considered to obtain consistency in the measurements. As it is difficult to determine the boundaries of approximants reliably, they were taken as a part of vocalic interval (White & Mattys, 2007). Pre- vocalic glides were included in the consonantal duration and the post vocalic glides were included in the vocalic duration (Ramus et al., 1999). Aspiration following the stop release was taken in the consonant duration (White & Mattys, 2007). Even though there was significant lengthening noticed in the phrase final position, it was not excluded from the analysis (White & Mattys, 2007). Further, it was difficult to mark the glottal sound /h/, and hence it was also taken as a part of vocalic interval for uniform analysis.

In order to get a regularity linking the sentences, the consonant in the initial position of the sentence, if present, were eliminated from analysis.

Rhythm metrics were calculated based on acoustic measure of the durational characteristics of vocalic and intervocalic (consonantal) intervals. Specifically the variability in these durations were calculated in rate- normalized (nPVI) form for vocalic and intervocalic segments. For each sample nPVI- V and nPVI- C were derived using the following formula:

$$nPVI = 100 \times \left[\sum_{k=1}^{m-1} \frac{|d_k - d_{k+1}|}{(d_k + d_{k+1})/2} /(N - 1) \right]$$

Where, N is the number of intervals, and d is the duration of the k^{th} interval.

PVIs were calculated using Microsoft Office Excel program. PVI measures have been used, since they do not pick up the false variations produced within the segments due to speech rate differences (Ramus, 2002). Hence it adjusts the variation in rate. Grabe and Low (2002) also stated that the inclusion of normalization reduces the effect of standardized rate variations.

Statistical analysis

The analyzed data were entered in SPSS (20.0 version) software and quantitative analysis was done. The following statistical analysis was carried out:

1) Repeated measures ANOVA was carried out to compare both frequency of syllable stuttered and speech rhythm measures across the AAF conditions.
2) Bonferroni multiple comparison's test was carried in order to compare the effect of each AAF condition on the frequency of syllable stuttered and speech rhythm.

CHAPTER 4

RESULTS

1. *Percentage of syllable stuttered across four AAF conditions*

The results indicated a significant decrease in the mean percentage of syllable stuttered across the AAF conditions (NAF, DAF, FAF, DAF+FAF). Repeated measures ANOVA indicated a significant difference across the four AAF conditions [$F(3,39) = 14.040$, $P < 0.05$]. The results of the Bonferroni multiple comparison test showed significant differences between the AAF conditions, NAF Vs.FAF, NAF Vs. DAF+FAF, NAF Vs. DAF ($P < 0.05$). The NAF condition had the highest percentage of syllable stuttered (26.69%), followed by DAF (19.33%) and DAF + FAF condition (17.23%) , with the least percentage of syllable stuttered in the FAF condition (13.45%), respectively (Figure 1). Figure 2- 4 show, the comparison of the percentage of syllable stuttered across four AAF condition in each individual.

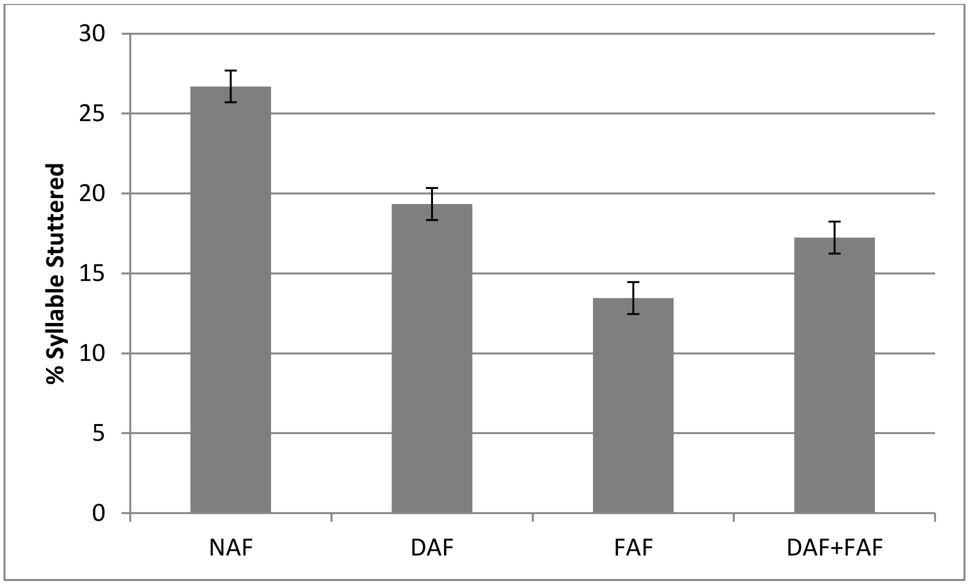

Figure 1: Comparison of mean and standard deviation of percent syllable stuttered across the four AAF conditions (error bars indicate standard deviations).
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback.

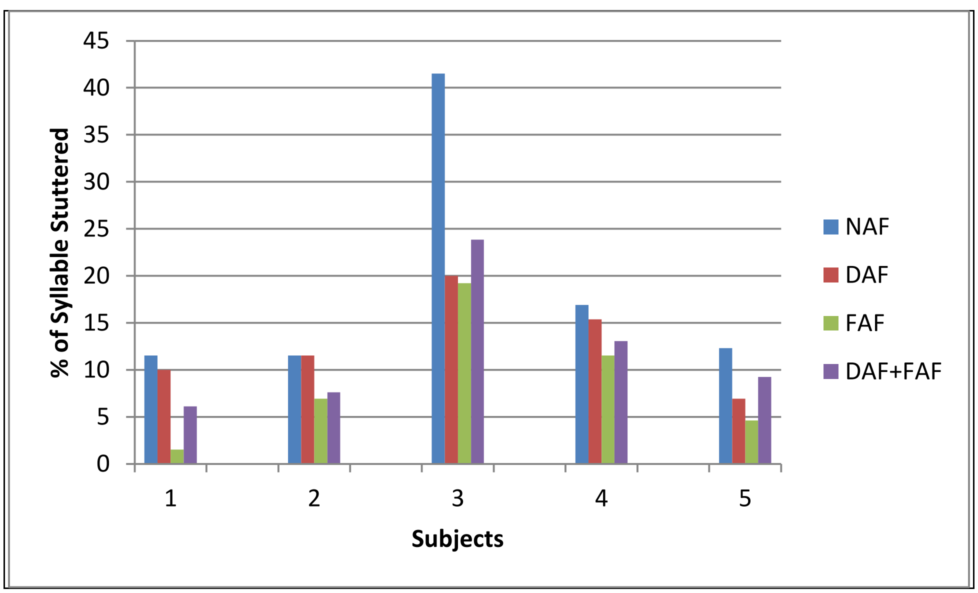

Figure 2: Percentage of syllable stuttered by the participants (1-5) across the four AAF conditions.
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback.

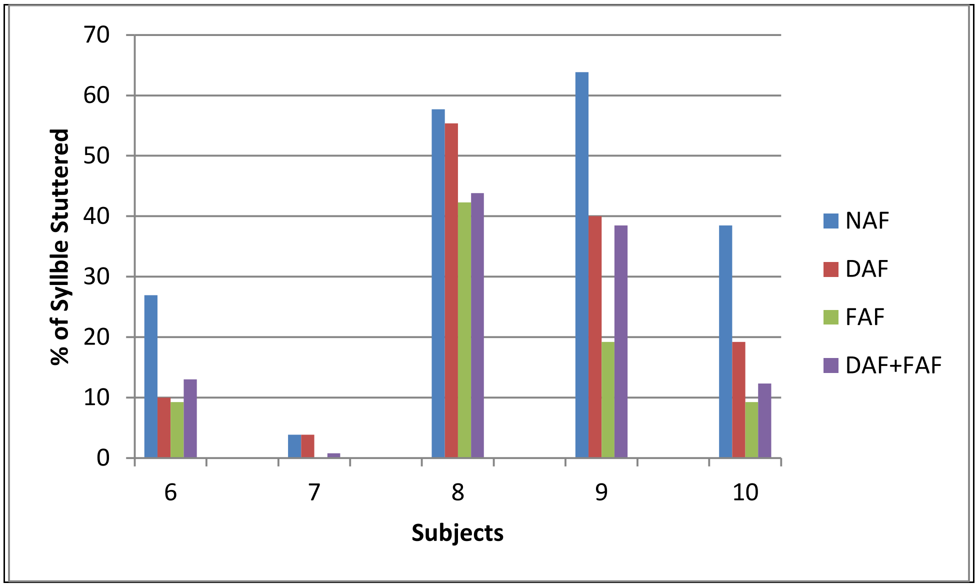

Figure 3: Percent of syllable stuttered by the participants (6-10) across the four AAF conditions.
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback.

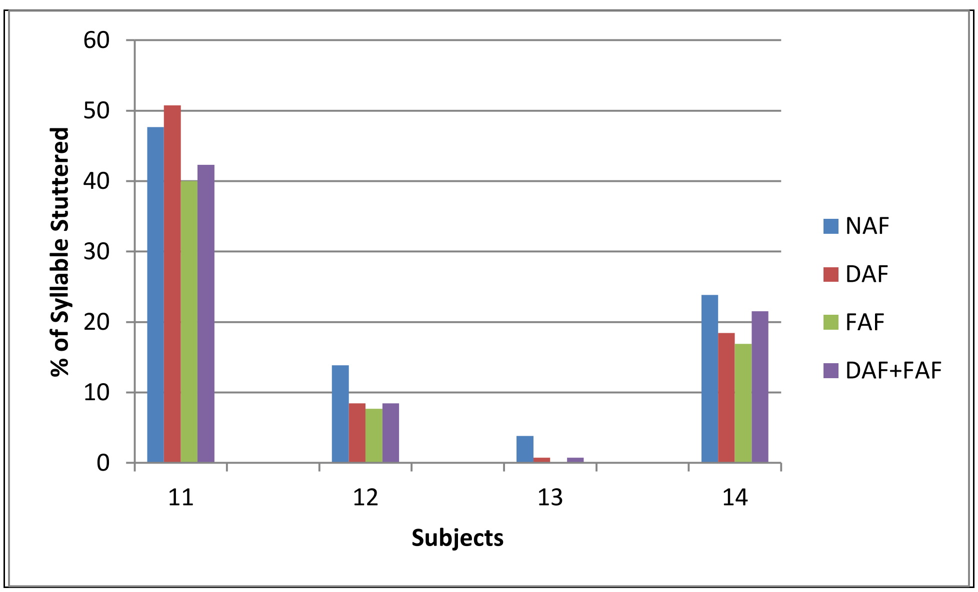

Figure 4: Percent of syllable stuttered by the participants (11- 14) across the four AAF conditions.
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback.

2. *Speech Rhythm across four AAF conditions*

2.1 Normalized pair-wise variability index for intervocalic intervals(nPVI-C)

The results indicated a slight variation in the mean scores of nPVI- C values across the different AAF conditions (NAF, DAF, FAF, DAF+FAF). Repeated measures ANOVA indicated significant differences across the four AAF conditions [$F(3,39)=196.372$, $P < 0.05$]. Bonferroni multiple comparison tests revealed significant difference ($P < 0.05$) only between DAF and FAF conditions. There was no significant difference between other AAF conditions. DAF condition had a mean nPVI- C value of 53.290 followed by DAF+FAF condition (53.290), FAF condition (52.482) and FAF condition (47.879), respectively (Figure 5).

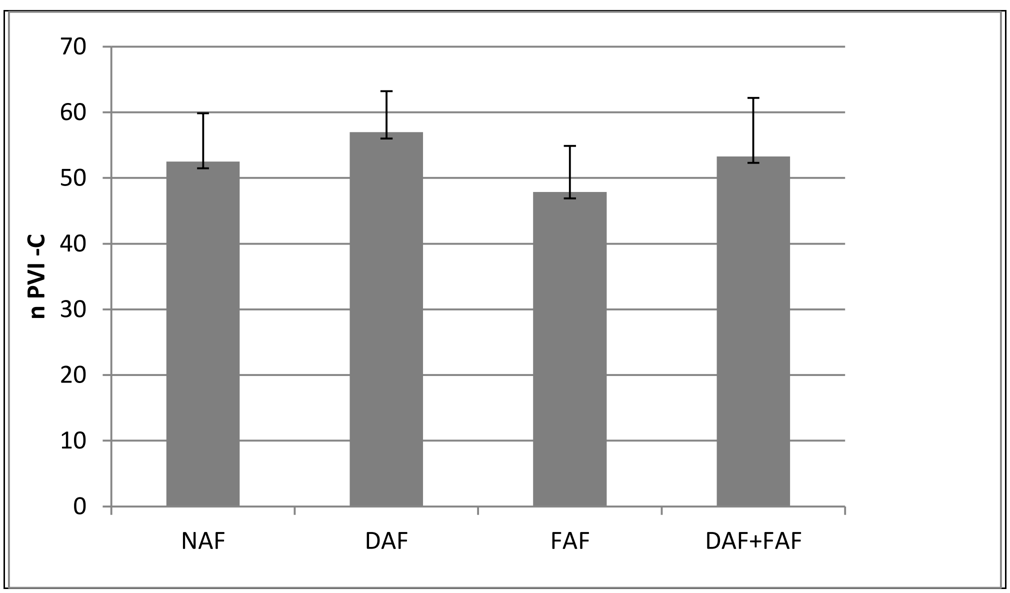

Figure 5: Comparison of the mean and standard deviation of n PVI- C across the four AAF conditions. (error bars indicate standard deviations).
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback;

2.2 Normalized pair-wise variability index for vocalic intervals(nPVI-V)

The Npvi_V values across four AAF conditions were similar. Repeated measures ANOVA indicated no significant difference across the four AAF conditions [F(3,39)=0.929, P > 0.05]. The results indicated no significant variation in the mean scores of nPVI- V values across the different AAF conditions (NAF, DAF, FAF, DAF+FAF). NAF condition had a mean nPVI- V value of 52.739 followed by DAF+FAF condition (52.878), FAF condition (52.611) and DAF condition (52.276), respectively(figure 6).

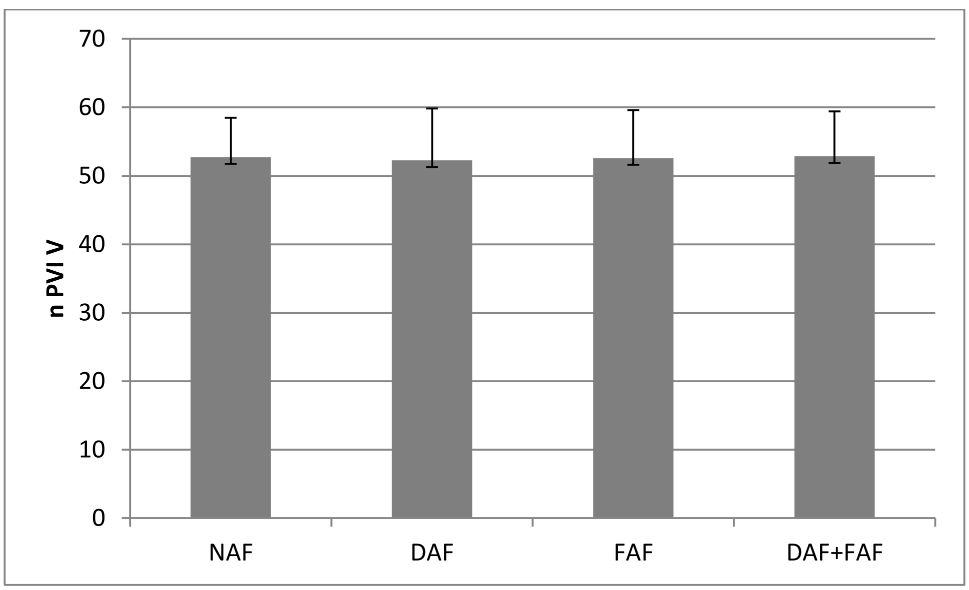

Figure 6: Comparison of the mean and standard deviation of n PVI- V across the four conditions. (error bars indicate standard deviations).
NAF- Non-Altered Auditory Feedback; DAF- Delayed Auditory Feedback; FAF- Frequency Altered Auditory Feedback;.

CHAPTER 5

DISCUSSION

The aim of the study was a) to compare frequency of stuttering between normal auditory feedback and different AAF conditions, b) to compare speech rhythm between normal auditory feedback and different AAF conditions. The results revealed several points of interest.

First, the results indicated a significant decrease in the mean percentage of syllable stuttered across the different AAF conditions, with a significant differences between the AAF conditions, NAF- FAF, NAF-DAF+FAF, DAF- NAF. This result is consistent with previous research that studied the effect of different AAF conditions on the frequency of syllable stuttered, with a maximum reduction (65-85%) noted in the frequency of syllable stuttered occurred during the FAF condition (Hargrave et al, 1994; Kalinowski et al, 1996. Kalinowski, Stuart, Wamsley, and Rastatter, 1999; Lincoln, Packman, Onslow, Jones, 2010;Macleod, Kalinowski, Stuart, Armson; 1995). In the present study, it was seen that a greater decline in frequency of stuttering under FAF condition than any of the other conditions. This is consistent with the previous research, where they compared effect on frequency of syllable stuttered between the AAF conditions (Kalinowski et al., 1999; Lincoln, Packman, Onslow, & Jones, 2010). Considering previous research and the results of this study, it is proposed that there may be two inter-reliant factors that are accountable for fluency enhancement: alteration of auditory feedback and modification of speech production. It is suggested that the fluency enhancing effects of DAF and FAF as a manifestation of the “double speaker phenomenon”, which simply states that stuttering is reduced significantly in any context in which a speaker who stutter talks along with second speech signal (Kalinowski et al., 1996).

Second, overall, there was no change in the speech rhythm across the four AAF conditions. Present results add on to already existing literature (Kalinowski et al ,1993) where studies have reported that under the different AAF conditions there is no change in the rate of speech. The present study is the first of its kind wherein the speech rhythm in persons with stuttering are quantified. This adds to the finding that rhythm is not altered in the different AAF conditions. This finding that is rhythm is not significantly altered in stutters during AAF speech, supports studies which have focused on the rhythmic changes in domains other than speech (non- speech rhythmic timing tasks) in stutters and non stutters. They also found that both the group of participants demonstrate a highly parallel levels of timing accuracy as well as timing variability (Hulstijn, Lieshout, & Peters,1992; Zelaznik Smith, & Franz, 1994; Max, Elana, Yudman, 2003). As one factor of a systematic approach to explore the function, if any, of timing difficulties in stuttering, these findings could broaden the emerging evidence that individuals with stuttering and individuals with no stuttering do not differ from each other in the ability to produce temporal movement patterns with a simple isochronous rhythm.

CHAPTER 6

SUMMARY AND CONCLUSION

The objectives of the study were a) to compare the frequency of stuttering under different AAF conditions, and b) to compare speech rhythm under different AAF conditions. The participants of the study included fourteen native Kannada speaking monolingual adults with (developmental) stuttering in the age range of 18- 35 years.

The participants were given two tasks, one was a conversation task and the second was to read a standardized Kannada Passage under 4 different AAF conditions (DAF, FAF, DAF+FAF & NAF). The first task along with the reading sample under the NAF condition was used for calculating the severity of stuttering. The second task was used for measuring the rhythm. Rhythm metrics were calculated based on acoustic measure of the durational characteristics of vocalic and intervocalic (consonantal) intervals. Specifically the variability in these durations were calculated in rate- normalized (nPVI) form for vocalic and intervocalic segments. Mean and standard deviation were computed, repeated measures ANOVA and Bonferroni multiple comparison test were carried out to compare the rhythm values across and between the four AAF conditions.

The findings of the study showed a reduction in the percent of syllable stuttered, indicating that fluency is induced under the AAF conditions. Further, results also revealed that there is no significant difference in the rhythm when individuals with stuttering read under different AAF conditions (FAF, DAF, & DAF+FAF). This suggests that rhythm is not altered under AAF conditions.

Future Directions

1. Similar studies using (peak) F_o to quantify rhythm can be studied in future.
2. Further, studies can be carried out to find the influence of adaptation effect, choral reading on speech rhythm.
3. Similar study can be replicated in other Indian languages.

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