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Effects of altered auditory and oro-sensory feedback on speech naturalness in persons with and without stuttering

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Abstract

Stuttering is one of the disorders of speech fluency influenced by many factors affecting the naturalness of speech. One of the major goals in stuttering management is providing natural sounding speech irrespective of the technique(s) adopted. The naturalness is measured with respect to various fluency parameters such as rate, continuity, effort, stress, intonation and rhythm, articulation and breathing pattern. There are many fluency inducing conditions of which altered auditory feedback (AAF) strategies are widely used with various wearable devices, especially in adults with stuttering who will not benefit much with the traditional approaches. The present study aimed to examine the speech naturalness induced by 3 AAF conditions [delayed auditory feedback (DAF), frequency altered feedback (FAF) and masking auditory feedback (MAF)] and altered oro-sensory feedback in adult persons with and without stuttering (PWS and PWNS). The fluent speech samples from 25 PWS and 25 PWNS in the age range of 18 to 25 years under different AAF and altered oro-sensory feedback conditions were given to experienced speech-language pathologists (SLPs) for judging speech naturalness compared to baseline without altered feedback condition. The analyses of results revealed that speech naturalness ratings were significantly poorer in PWS compared to PWNS in all the conditions. The results are discussed with regard to the nature of variability and the influence of various feedback conditions on speech naturalness.

Key words: *Naturalness, altered auditory feedback, orosensory feedback*

Introduction

Stuttering is one such puzzling disorder of speech fluency which is evading the researchers in terms of understanding its nature, cause and management issues. It is also a complex disorder in which the symptoms may be manifested by a failure to convert linguistic intent into fluent output (Smith, Sadagopan, Walsh & Weber-Fox, 2010).

Current treatment programs for stuttering employ prolongation, feedback modification, rhythm, or rate control to help PWS reduce or eliminate the core stuttering behaviors. Altered Auditory Feedback (AAF) is a well known phenomenon. Several investigations in stuttering intervention have substantiated that delayed auditory feedback (DAF) at short delays and frequency-altered feedback (FAF) bring about immediate reduction in stuttering frequency (Hargrave, Kalinowski, Stuart, Armson & Jones, 1994; MacLeod, Kalinowski, Stuart & Armson, 1995; Kalinowski, Stuart, Sark & Armson, 1996; Stuart, Kalinowski, Armson, Stenstrom & Jones, 1996; Stuart, Kalinowski & Rastatter, 1997; Armson & Stuart, 1998). DAF is a condition where speakers hear their own speech with a short time delay. These delays are usually less than a quarter of a second (50–250 ms shift in the time domain) (Kalinowski et al 1996; Van Borsel, Reunes, & Van den Bergh, 2003). DAF was viewed primarily as a tool for assisting the instatement of the prolonged speech pattern. DAF is the only such stimulus that comprises marked disfluency-inducing effects in fluent speakers (Fukawa, Yoshioka, Ozawa, & Yoshida, 1988; Stuart, Kalinowski, Rastatter, & Lynch, 2002). Stuart et al. (2002) also reported that the speech disruptions during DAF largely attribute to the temporal alterations in the auditory feedback signal which impact the speech motor control system differently for PWS and PWNS. This highlights the strong association of auditory processing in fluent speech production both in people who stutter and in fluent controls (Fukawa et al 1988; Sutton, Roehrig, & Kramer, 1963). Fukawa et al (1988)

also observed that PWS were more likely to be affected by DAF than PWNS, and normal males were more vulnerable to the effect than females.

FAF is a form of AAF where the frequency range of the speaker is shifted up or down that leads to changes in pitch and hence shifts the entire speech spectrum. It is the shift in the frequency of a speaker's fed back voice up or down the scale, usually between one-fourth to one octave upper or lower and the speaker hears his own voice at a higher or lower pitch depending on whether the shift in octave is above or below one's voice. FAF was first studied by Howell, El-Yaniv, and Powell, (1987), who concluded that FAF was much more effective than DAF. Natke, Grosser and Kalveram (2001) compared 10 PWS and 10 PWNS in spontaneous speech task under FAF with +1/2 and −1/2 octave shift and observed that in PWS downward shift of frequency led to significant fluency enhancement. Though fluency was enhanced by 21%, in the upward shift condition, the level of significance could not be reached. However, there was no reduction in the rate of speech under FAF. These findings were contrary to that by Armson and Stuart (1998) who found increased fluency in reading compared to monologue task.

The Masked Auditory Feedback (MAF) to reduce stuttering is also quite popular. Significant decline in disfluencies has been observed with masked auditory feedback [MAF]. Frequency of stuttering events was reported to have decreased consistently in PWS across speaking tasks, on wearing a portable voice-activated masking device called the Edinburgh Masker (Block, Ingham & Bench, 1996). Keyhoe (1998) argued that successful carryover of fluency can be achieved with the combination of fluency enhancing techniques with the use of masker.

Kinesthetic sensation is another important feedback known to be integrally involved in achieving the movement goals. Oral sensory and perceptual integrity are important

feedback components needed for the regulation and refinement of the patterns of oral manipulation. In the oral cavity there is an intimate interaction of sensory and motor functions for speech production. Disturbances in oral sensory perception have been found to be associated with disturbances in speech fluency in normal individuals and PWS. Research has shown significant contribution of oro-sensory information during both planning and execution of speech movements (Gracco, 1991; Gracco & Abbs, 1989). The oral sensory deprivation by anesthetization of the oral structures or temporary oral anesthesia (TOA) may act as a fluency facilitator in PWS. Uthappa, Shailat and Geetha (2010) reported a significantly reduced frequency of disfluencies in PWS under TOA, in comparison with the normal condition.

These therapeutic procedures using altered feedback conditions, although fluency enhancing, appear to be detrimental to speech naturalness. Limited literature has been reported on the nature of the speech quality that emerges from stuttering intervention using these procedures. But the few studies offer evidence that these therapeutic procedures result in speech that is different perceptually from the speech of normal speakers (Ingham & Packman, 1978; Runyan & Adams, 1978, 1979). These techniques are criticized on the basis that they might produce stutter-free speech, but post therapy speech is characterized as slow, monotonous, lacking in expression or unnatural and could be discriminated from the speech of PWNS (Onslow & Ingham, 1987).

Speech naturalness is defined as speech output that sounds normal or natural to the listener (Parrish, 1951). It is a vital quality for a good speaker. Sanders, Gramlich and Levine (1981) defined speech naturalness as the speech produced by speakers using the normal and customary speech patterns accepted by the community. Speech naturalness has a great significance to the success of treatment in fluency disorders. Measurement of speech

naturalness is "basic" and "obligatory" in the assessment procedure of stuttering (Curlee, 1993). The ultimate success of any stuttering intervention program is dependent on successful therapy outcomes, one of which is speech naturalness. Establishment of a natural sounding speech along with a reduction in core stuttering behaviors should be the treatment target in stuttering intervention (Franken, Boves, Peters & Webster, 1992; Kalinowski, Noble, Armson & Stuart, 1994; Onslow, Costa, Andrews, Harrison & Packman, 1996).

Martin, Haroldson and Triden (1984) were the first to systematically investigate naturalness of speech in PWS. Using a nine-point rating scale (one designated as highly natural and nine highly unnatural), the naturalness of speech samples from PWS and normal speakers under non-altered feedback (NAF) and under 250 ms of DAF was rated by naïve listeners. The speech of PWS was rated as significantly more unnatural than that of normal speakers regardless of speaking under NAF or DAF. The naturalness ratings of the speech samples from PWS under NAF did not differ significantly compared to DAF in spite of the finding that the samples under DAF had no instances of stuttering. Numerous investigations have demonstrated that DAF as well as MAF may slow down speech rate (Wingate, 1976; Perkins, 1979; Costello-Ingham, 1993), bring about an increase of fundamental frequency (Soderberg, 1959; Lechner, 1970), vocal intensity (Howell, 1990), and induce vowel elongation (Howell, Wingfield & Johnson, 1988; Howell, 2004), making the speech sound unnatural.

Several researchers have reported that listeners consider the post-therapy speech of PWS as sounding unnatural relative to the speech of typical individuals. Ingham, Gow & Costello, 1(985) investigated the speech naturalness in spontaneous speaking samples of normal fluent speakers and PWS who had completed prolonged speech treatment program which were rated by thirty listeners. The speech of PWS after the completion of prolonged

speech treatment program was judged to be more unnatural as compared to the fluent speakers. Franken, Boves, Peters, and Webster (1992) compared pre-therapy, post-therapy, and 6-month follow-up speech samples of PWS with samples from typical speakers and reported that the speech samples of PWS at pre-therapy, post therapy and six months follow up were judged to be different from the samples from PWNS. Their results revealed that the perceptual quality of the clients' post-therapy speech was not improved compared to their pre-therapy speech. Kalinowski, Noble, Armson and Stuart (1994) investigated speech naturalness of 10 PWS (5 with mild stuttering and 5 with severe stuttering) before and after the successful completion of a Precision Fluency Shaping Program (PFSP). Even though post-therapy speech samples were nearly or completely free of disfluencies, raters perceived them as significantly less natural.

There is scientific literature ascertaining the establishment of a stutter-free natural sounding speech in PWS as a consequence of stuttering intervention programs. Onslow, Costa, Andrews, Harrison and Packman (1996) evaluated speech naturalness of PWS who underwent prolonged speech treatment, on multiple occasions up to 12 months post-therapy. Post-treatment naturalness scores were comparable to the scores of normal speakers. Post-treatment normal or near normal speech rates were associated with lower, more natural scores. Ingham, Kilgo, Ingham, Moglia, Belknap and Sanchez (2001) also reported that PWS, after the completion of a stuttering treatment program that trained PWS to reduce the frequency of short phonation interval during connected speech across speaking tasks and conditions known as Modifying Phonation Intervals (MPI), successfully established and maintained stutter-free natural-sounding speech.

The research has shown that AAF need not result in abnormally slow or unnatural sounding speech (Stuart, Kalinowski, Rastatter, Saltuklaroglu & Dayalu, 2004; Armson &

Kiefte, 2008). Stuart et al. (2004) found that the speech of PWS was more natural while they were wearing a Speech Easy device which delivers both DAF and FAF, compared to without the device. Stuart and Kallinowski (2004) investigated the effect of PFSP therapy and AAF on the perception of speech naturalness of PWS. The results revealed that the speech of PWS under AAF was judged to be significantly more natural than speech under MAF and speech produced during FAF condition was rated as more natural sounding than that produced under DAF. PWS having a mild degree of disfluencies were judged to have more natural sounding speech than those with severe degree under AAF. These findings support the argument that AAF benefits PWS through a reduction of stuttering with a gain in perceived speech naturalness. Similar results were reported by Stuart, Kalinowski, Saltuklaroglun and Guntupalli (2006) in a study examining the effect of an altered auditory feedback using in-the-ear device on the speech of PWS. Naive listeners rated the naturalness of reading and monologue speech samples, obtained with and without the device, in PWS, at initial fitting, after 4 months and at 12 months follow-up. Feedback delivered encompassed both DAF and FAF. Speech samples produced with the device for both reading and monologue were rated to be significantly more natural compared to those without the device. Speech naturalness ratings were significantly better for the samples at 12 months follow-up than at the initial and 4-month period. The study results by Borsel and Eeckhout (2008) revealed that the speech samples from typically fluent speakers were considered as more natural sounding as compared to the speech samples from PWS speaking under DAF.

Determining naturalness has significant implication in a clinical context that make use of unusual speech patterns such as prolonged or rhythmic speech, particularly for measuring and transforming speech quality during stuttering intervention. From a clinical perspective, it is imperative to understand as to what degree changes under AAF or other fluency enhancing techniques influence speech naturalness. It is a finding filled with possibilities for stuttering

treatment research. Naturalness scores could be used not only to evaluate speech quality but also to modify speech quality. Speech naturalness scores might be used as functional contingencies to modify the post-therapy speech quality in PWS.

Despite the fact that the speech naturalness of treated PWS is a frequently voiced concern in the stuttering therapy literature, there are only very few studies that have investigated the impact of fluency enhancing techniques on speech naturalness. Divergent findings reported by these studies question the effectiveness of stuttering treatment techniques in establishing a natural sounding stutter-free speech. There are many individuals with stuttering who are unable to maintain fluency under prolongation or other evidence based procedures. For them often the wearable devices with DAF, FAF, and MAF in isolation or combinations are recommended. There are limited studies comparing the naturalness of speech under different types of AAF at different settings or under oral sensory feedback conditions. There are no studies which have investigated the effect of AAF and TOA on the speech naturalness in PWS compared to PWNS. It is well known fact that PWNS are highly disfluent under DAF and other AAF conditions while PWS fare better. It would be interesting to see what naturalness parameters are affected under different condition in both groups. Such study would provide better insight into the theoretical and clinical aspects of AAF therapies. Hence, the present study was undertaken as a part of a larger project with an aim to investigate the effect of AAF and altered oro-sensory feedback on speech naturalness in PWS with respect to typically speaking individuals with specific objectives being:

i. To investigate the effect of DAF across different delay times (150, 200 & 250 ms) on speech naturalness in PWS as compared to PWNS

ii. To investigate the effect of FAF across different FAF settings (+1 & -1 octave) on speech naturalness in PWS as compared to PWNS

iii. To investigate the effect of MAF on speech naturalness in PWS as compared to PWNS

iv. To investigate the effect of temporary oral anaesthetization (TOA) on speech naturalness in PWS as compared to PWNS

v. To compare speech naturalness across AAF and TOA conditions in PWS and PWNS

Method

Participants

The study included two groups of adult male participants within the age range of 18-30 years. The first group comprised of 25 PWS, 16 diagnosed as having moderate stuttering and 9 diagnosed with severe stuttering. The second group consisted of 25 fluent speakers (PWNS).

The participants in the clinical group were diagnosed by qualified speech language pathologists (SLPs) based on Stuttering Severity Instrument III (Riley, 1994). All the participants were informally screened to rule out any associated hearing, psychological or neurological problems and were required to have a minimum educational requirement of tenth standard pass and the participants were native speakers of Kannada.

Materials

The materials used for the study comprised of the following:

i. DAF/FAF Assistant software version 1.1 for the presentation of Delayed Auditory Feedback (DAF) and Frequency Altered Feedback (FAF) at different settings

ii. Computerized Speech Lab (module) software with Auditory Feedback Tools option to provide Masking Auditory Feedback (MAF)

iii. Xylocaine spray containing lidocaine topical aerosol 10% for providing temporary oral anesthesia (TOA) for altering the oral sensory feedback

iv. Multidimensional Speech Naturalness scale (Kanchan & Savithri, 1997) for rating the naturalness of the speech sample

v. Sony HD Video recording equipment to video record speech samples

vi. Different reading passages for different conditions

vii. SPSS software for data entry and analysis

viii. A checklist developed to collect demographic and other relevant information

ix. Stuttering Severity Instrument (SSI III; Riley, 1994)

Procedure

The participants were explained about the procedure of the study and an informed consent was obtained from all the participants before the commencement of the study. General demographic data was obtained from all the participants. In addition, stuttering onset related information was collected from PWS and stuttering severity instrument was administered.

The participants were seated in an acoustically treated room and speech samples were obtained from each participant. Baseline for monologue speech was recorded initially which was followed by various altered feedback conditions that were counterbalanced across the participants. For the masking auditory feedback condition 70 dB SPL white noise was delivered using auditory feedback tools option in Computerized Speech Lab (CSL-4500). The effect of DAF was investigated with the delays of 150, 200 and 250 milliseconds, and FAF was used in two frequency shifts of +1 and -1 units in octaves. DAF/FAF Assistant (windows version 1.1 from Artefactsoft) software was used to deliver DAF and FAF. Further, oral anesthetization was used to eliminate oral sensory feedback which was administered by the

otolaryngologist with Xylocaine spray containing lidocaine topical aerosol 10% anesthesia. The participants were asked to narrate stories or events to obtain the spontaneous speech sample across eight different conditions. The speech samples under normal and different feedback conditions were video recorded using Sony HD Handy cam recorder.

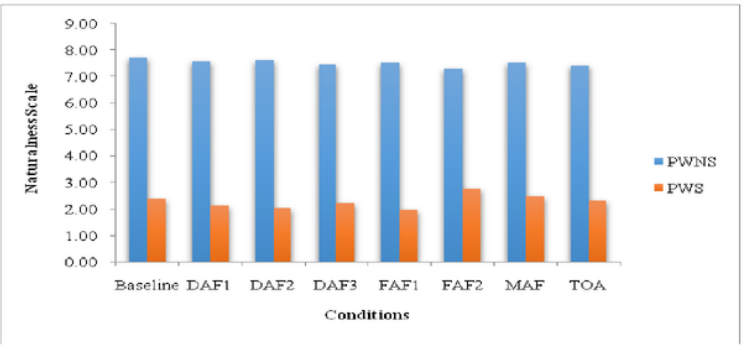
The video-recorded speech samples were edited to obtain a one minute fluent speech samples for each of the eight conditions (baseline and altered feedback) from all the participants (50*8=400 samples). This was randomized and given to three post-graduate SLPs, who were native speakers of Kannada, to judge for the speech naturalness using Multidimensional Speech Naturalness Scale (Kanchan & Savithri, 1997). This scale is based on 7 different fluency parameters (rate, continuity, effort, stress, intonation and rhythm, articulation and breathing pattern) to be rated on a two-point rating scale as natural and unnatural. None of the judges were informed regarding the purpose of the study.

The ratings obtained were tabulated and statistically analyzed using SPSS software (version 21). Differences in speech naturalness parameters between PWNS and PWS across different AAF conditions were analyzed using Mann-Whitney test. Friedman's test was used to check the significance across groups and Wilcoxon signed rank test was used to find significant difference in speech naturalness between specific groups.

Results and Discussion

The total scores obtained for each participant on all the parameters based on the average ratings by the 3 judges were compiled for comparison across groups and conditions. The speech naturalness of PWS and PWNS across baseline and different feedback conditions is depicted in Figure 1. It can be noted that speech of PWNS was highly natural compared to that of PWS irrespective of feedback condition, in spite of variations in their fluency and rate of speech. The overall ratings ranged from 7.29 to 7.71 for PWNS whereas it was from 1.97

to 2.48 in PWS. The differences were highly significant at 0.01 level for all the conditions. The results are in consonance with that of Borsel and Eeckhout (2008), which revealed that the speech samples from typically fluent speakers were considered as more natural sounding as compared to the speech samples from PWS speaking under DAF.



[Note- DAF1-150 ms; DAF2-200 ms; DAF3-250 ms; FAF1-+1 octave; FAF2- -1 octave; MAF- 70 dB white noise]

Figure 1. Mean naturalness scores under baseline, AAF and TOA conditions in PWS and PWNS for spontaneous speech task

Table 1 shows the average ratings of naturalness by the 3 judges for baseline and different AAF and TOA conditions between PWNS and PWS groups along with 'p' values.

Table 1. *Mean speech naturalness rating across baseline and different feedback conditions*

Conditions	PWNS	PWS	p
Baseline	7.71	2.37	0.01**
DAF1	7.59	2.12	0.01**
DAF2	7.62	2.02	0.01**
DAF3	7.47	2.23	0.01**
FAF1	7.53	1.97	0.01**
FAF2	7.29	2.76	0.01**
MAF	7.53	2.48	0.01**
TOA	7.43	2.32	0.01**

[Note- DAF1-150 ms; DAF2-200 ms; DAF3-250 ms; FAF1-+1 octave; FAF2- -1 octave; MAF- 70 dB white noise]

The results of Mann Whitney test revealed a significant difference between PWS and PWNS at 0.01 level. The different feedback conditions within PWS and PWNS were compared. The results of Friedman test indicated a significant difference across different feedback conditions in PWNS [χ^2 (7) = 24.98, $p \leq 0.05$], while there was no significant difference in speech naturalness across different feedback conditions in PWS [χ^2 (7) =7.39, $p \geq 0.05$]. Further, Wilcoxon signed rank test was used to find significant difference between specific conditions in PWNS, and the results of Wilcoxon signed rank test (table 2) indicated a significant difference between baseline and FAF2, and between baseline and TOA condition. However, there was no significant difference observed between baseline and three DAF conditions, MAF and FAF1 conditions. Findings imply that reduction in frequency and oral sensory feedback had a significant effect in PWNS group.

Table 2. *Results of Wilcoxon signed rank test for speech naturalness across feedback conditions in PWNS*

Across conditions	|z|	p
MAF vs. Baseline	1.08	0.28
DAF1 vs. Baseline	0.00	1.00
DAF2 vs. Baseline	0.10	0.93
DAF3 vs. Baseline	1.30	0.19
FAF1 vs. Baseline	1.90	0.06
FAF2 vs. Baseline	2.61	0.01**
TOA vs. Baseline	2.61	0.02*
DAF1 vs. DAF2	0.51	0.61
DAF1 vs. DAF3	1.07	0.29
DAF 2 vs. DAF3	1.50	0.14
FAF1 vs. FAF2	1.84	0.07

[Note- DAF1-150 ms; DAF2-200 ms; DAF3-250 ms; FAF1-+1 octave; FAF2- -1 octave; MAF- 70 dB white noise]

The results of this study were in agreement with Martin, Haroldson and Triden (1984). The speech of PWS was rated as significantly more unnatural than that of normal speakers, regardless of speaking under NAF or DAF. There was no significant difference between the naturalness ratings of the speech samples from PWS under NAF compared to DAF in spite of the finding that the samples under DAF had no instances of stuttering. The findings imply that the naturalness may not only be induced by changing the feedback condition, but also by several other factors. However, the findings of this study was not in agreement with findings of few other studies (Stuart et al., 2004; Armson & Kiefte, 2008) which stated that AAF does not necessarily result in abnormally slow or unnatural sounding speech.

From this study it can be noted that PWNS exhibited highly natural sounding speech under all the eight conditions which is surprising since AAF conditions are known to change various fluency measures in normal individuals. PWS had poor naturalness ranging between 2 to 3 on an eight point scale under all AAF and TOA conditions. The results indicate that PWS may have difficulty with fluency parameters such as rate, effort, stress, intonation, rhythm and breathing patterns even in their fluent utterances. This is in support with the study by Borsel and Eeckhout (2008), who reported that the speech samples from typically fluent speakers were considered as more natural sounding as compared to the speech samples from PWS speaking under DAF. However, among PWS, FAF2 and MAF conditions were slightly better in terms of speech naturalness than other conditions though not significant. This is in partial agreement with Stuart and Kallinowski (2004) who noted that speech produced during FAF condition was rated as more natural sounding than that produced under DAF. However, they observed that the speech of PWS under AAF was judged to be significantly more natural than speech under MAF.

Inter-judge and intra judge reliability for speech naturalness across different feedback conditions

The inter judge reliability was determined by comparing the speech naturalness ratings of three SLPs for different fluency parameters (rate, continuity, effort, stress, intonation and rhythm, articulation and breathing pattern) along with overall naturalness (totaling to eight). The inter judge reliability using Cronbach's alpha test ranged from 0.5 to 0.9 for PWS and 0.5 to 0.8 for PWNS which indicated fair inter judge reliability.10% of the samples were re-rated by all the three judges for checking intra-rater reliability. Intra-rater reliability ranged from 0.6 to 0.8 for PWS and 0.7 to 0.9 for PWNS, indicating fair intra rater reliability.

Conclusions

It can be concluded from the present study that the altered auditory feedback and TOA conditions did not affect the naturalness ratings in PWNS whereas PWS exhibited very poor naturalness ratings in all the eight conditions, although fluent speech segments were considered for rating. This was in spite of considering different settings of DAF and FAF, MAF & TOA. This is surprising since AAF conditions are known to induce disfluencies in normals and fluent speech in PWS. Although the samples under different conditions and those of PWS and PWNS were completely randomized, SLPs could still differentiate the naturalness on different parameter which is quite significant. The SLPs need to measure speech naturalness under the recommended conditions and train them in improving naturalness with respect to specific parameters that are affected. The clinicians should not only focus on the reduction in stuttering behavior but also aim at establishment of a natural sounding speech which results in the success of the intervention program.

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