Immediate Effects of Altered Auditory Feedback on Associated Motor Behaviors of People Who Stutter

Kyriaki Kyriakou[1*] and Brenda Seal[1]

[1]Department of Hearing Speech and Language Sciences, Gallaudet University, Washington DC, USA.

Authors' contributions

This work was carried out in collaboration between both authors. Author KK reviewed the literature, designed the study, performed the statistical analysis and wrote the manuscript. Author BS reviewed and approved all drafts of the manuscript and provided guidance.

Original Research Article	*Received 29 April 2020* *Accepted 05 July 2020* *Published 23 July 2020*

ABSTRACT

Aims: This investigation explored the immediate effects of an altered auditory feedback device on motor behaviors associated with stuttering in monologue and conversation with and without the device and it also investigated the effects of an AAF device on stuttering frequency.

Methods: Fifteen adults with a diagnosis of stuttering and exhibited associated motor behaviors participated in this study. The author analyzed associated motor behaviors by type and frequency and statistically compared associated motor behaviors per frequency of stuttering events during monologue and conversation with and without an altered auditory feedback device.

Results: An analysis of associated motor behaviors during monologue and conversation with and without altered auditory feedback showed a predominance of associated motor behaviors involving the eyes, head, lips and hands. Altered auditory feedback significantly reduced the overall frequency of these four behaviors in monologue and conversation. Altered auditory feedback also decreased the frequency of associated motor behaviors per stuttering event in both monologue and conversation. An analysis of effect sizes associated with the statistical results revealed a larger magnitude of effect on reducing the frequency of associated motor behaviors than on reducing associated motor behaviors per stuttering event in the altered auditory feedback condition. Additionally, the Pearson correlation test designated the following positive correlations between the

_____

Corresponding author: E-mail: kyriakou@nova.edu;

percentage of syllables stuttered and AMBs (r=.76 and r=.74) and percentage of syllables stuttered and AMBs per stuttering event (r=.56 and r=.41 in monologue and conversation respectively).
Conclusions: People who exhibit motor behaviors associated with their stuttering may more confidently and frequently use an altered auditory feedback device to decrease the associated motor behaviors of their stuttering in order to more easily communicate and socialize and consequently improve the quality of their life.

1. INTRODUCTION

Stuttering causes difficulty in communicating, socializing, and participating in occupational activities and is often accompanied by secondary behaviors that interrupt communication by drawing increased attention to an individual's communication difficulty. Adults who stutter produce an average of 2.33 secondary behaviors per stuttering event [1]. Secondary behaviors of stuttering are also called "concomitant," "associated," and "accessory" behaviors. They include motor behaviors common to all communicators (e.g., eyes blinking, head nodding, hand gestures [2]), but the magnitude of these motor behaviors and their intrusion during stuttering draw additional attention to the individual who stutters, negatively influencing communication turns. The most common secondary behaviors are motor behaviors that involve the eyes, especially blinking, squeezing, lateral and vertical movements and avoiding eye contact [3,4].

Bloodstein [5] described two roles of secondary behaviors, avoidance and escape behaviors. Avoidance behaviors occur in anticipation of a stutter in order to prevent or mitigate the stutter. Escape behaviors occur during the moment of stuttering in order to get out of or stop the stuttering event. Brutten and Shoemaker [6] also described that based on Two Factor Theory secondary behaviors are "voluntary coping responses of avoidance and escape behaviors that are secondary to stuttering". These motor behaviors (e.g., shaking the head, moving the hands, tapping the feet, raising the shoulders, bending the head, etc.) are viewed as part of the characteristics of stuttering and may help people who stutter escape or avoid stuttering temporarily but their accumulative use adversely affects communication [5].

Sparse research exists on secondary behaviors that accompany stuttering. In addition to Zebrowski's and Kelly's [3] analysis of the type of Associated Movement Behaviors, Conture and Kelly [7] compared motor behaviors in children who stutter with those in children who do not stutter. Results indicated that young persons who stutter produce significantly more motor behaviors (e.g., head turns left, eye blinks and upper lip raising) during stuttering than fluent children. Specifically, young persons who stutter demonstrated 445 instances of associated motor behaviors per 300 words compared to 190 instances of motor behaviors per 300 words in children who did not stutter. Moreover, Vanryckeghem et al. [4] investigated speech-associated coping responses that adults who stutter frequently employ to cope with the anticipation and/or presence of speech disruptions and adults who do not stutter may use to cope with the occasional speech disruptions that sometimes occur in their speech. Results revealed that adults who stutter reported a significantly greater number of speech-associated coping responses (0-59 in adults who stutter versus 0-28 in adults who do not stutter) and a greater use of them than adults who do not stutter. For example, adults who stutter versus those who were fluent reported "they substituted words (82% versus 28%), avoided eye contact (64% versus 21%), looked away (49% versus 17%), interjected the sound 'ah' or the word 'the' (64% versus 17%) and used a phrase like ' let me see' or 'well now' (59% versus 17%)".

The scarcity of experimental research on secondary behaviors is understandable. Logically, we assume that any effort to reduce the frequency of stuttering also reduces the frequency of the secondary behaviors that accompany stuttering. This logic, however, has not been investigated in detail. This study explored the immediate effects of an altered auditory feedback (AAF) device on motor behaviors associated with stuttering, which are defined as motor behaviors such as eye blinking, head nodding and others that occur right before or during a stuttering event, by statistically comparing the frequency of associated motor behaviors, in monologue and conversation with and without AAF.

Research has indicated the effectiveness of assistive devices in reducing stuttering [8, 9, 10] but has not investigated the effect of assistive devices (e.g., AAF) on secondary behaviors in persons who stutter. An AAF device offers an electronic manipulation of speech, such that a person who stutters perceives his/her speech differently in some way. A common type of AAF tool is a delayed auditory feedback (DAF) device. A delayed auditory feedback device is an electronic tool in which the user hears his/her voice through headphones after a fixed time delay of a few milliseconds. A second type of AAF, a frequency-altered feedback (FAF) device, alters the pitch electronically so the user hears his/her voice via headphones in a different pitch [11]. Several AAF devices are currently available, including SpeechEasy and the Fluency Coach (both manufactured by Speech Easy); the DAF Assistant for Iphone & Ipod Touch; the Complete Pocket DAF Solution and the DAF/FAF Assistant for Windows (made by Artefact Soft); and the Smalltalk and the Basic Fluency System (both manufactured by Casa Futura Technologies). The availability of these assistive devices to hand-held phones and computer devices suggests their wide-spread availability to people who stutter, and a robust literature [8, 9,10,12,13,14,15,16,17] suggests their effectiveness in reducing stuttering.

Unger et al. [8] examined the immediate effects of the VA 601i Fluency Enhancer (VoiceAmp) and the SmallTalk (Casa Futura Technologies) on stuttering during oral reading and spontaneous speech. Results showed a statistically significant decrease in the percentage of stuttered syllables (%SS) for all oral reading and spontaneous speech samples during active device conditions as compared to inactive device conditions, but with a small effect size (η^2= .145) [18]. Zimmerman et al. [9] explored the effect of the digital signal processor (digital signal processor, Casa Futura Technologies Desktop Fluency System Model BTD-400) on stuttering frequency during scripted telephone conversations. Alterations in the subjects' auditory feedback included shifting their speech one-half octave down in frequency along with a 50-ms delay. Results pointed out a significant reduction in the proportion of stuttering events with the AAF device, with a medium effect size (ω^2 = .59). Armson and Kiefte [10] studied the effects of SpeechEasy on stuttering frequency, stuttering severity self-ratings and speech rate on 31 adults who stutter with and without the device. Results pointed out that

stuttering frequency, stuttering severity self-ratings and speech rate were reduced in the device condition compared to the no-device condition. The effect size between the mean frequency of stuttering with and without the device was medium to large (η^2 = .724). Armson, et al. [12] examined the effect of SpeechEasy on stuttering frequency during reading, monologue and conversation in a laboratory setting in 13 adults who stutter and reported its use resulted in reduced stuttering frequency during reading, monologue and conversation with a small effect size (ω^2 = .108). Hudock and Kalinowski [14] examined stuttering frequency with one combination of delayed auditory feedback and frequency-altered feedback (i.e., 50-ms delay with a half octave frequency shift up) and two combinations of delayed auditory feedback and frequency-altered feedback (i.e., a 200-ms delay and a half octave spectral shift down in addition to a 50-ms delay with a half octave frequency shift up) in nine adults who stutter. Outcomes revealed that stuttering was significantly reduced during both AAF conditions with a large effect size (η^2=0.95) and specifically with a greater reduction during the second condition (74%) as compared with the first condition (63%). The variability in effect sizes between studies [8, 9, 10, 12, 14] may possibly be due to variations in the speech tasks tested (e.g., reading, monologue, conversation, scripted telephone conversations, etc.), differences in the duration of the AAF delay (e.g., 50mm, 60mm, 90ms, etc.), disparities in the size of the AAF frequency shift (e.g., 250Hz upward/downward, 500Hz upward, etc.) and differences in the sample size (e.g., number of participants).

Furthermore, Stuart and Kalinowski [13] explored the effects of delayed auditory feedback, speech rate and gender on speech production of 32 fluent adults. Findings showed that there were statistically significant differences in the number of disfluencies between the normal and fast speech rate in all delayed auditory feedback conditions except in the condition which the digital processor provided a delay of 0 msec. Particularly, significantly more disfluencies occurred at 25 and 50 msec delays at the fast rate condition while more disfluencies occurred at 100 and 200 msec in the normal rate condition. Ritto et al. [17] studied the effectiveness of AAF (i.e., SpeechEasy) in comparison with behavioral techniques in stuttering treatment. Findings disclosed that both approaches indicated approximately a 40% reduction of stuttered syllables when compared

with baseline measures. Additionally, there were no statistically significant differences between the group who used the AAF for 6 months and the group who received a 12-week treatment of combined fluency shaping and stuttering modification techniques. Foundas et al. [15] investigated the effects of the Speech Easy device in adults who stutter and adults who are fluent in control (non-active device in the ear), default (delayed auditory feedback: 60ms delay and frequency-altered feedback: +500Hz) and custom (delayed auditory feedback: 220ms delay and frequency-altered feedback: +500Hz) settings in reading, monologue and conversation. Outcomes indicated that there was a significantly greater reduction in stuttering with custom device settings than in non-AAF (control) condition and stuttering was reduced the most during reading, followed by monologue and conversation. Furini et al. [16] compared the frequency of disfluencies in spontaneous speech and reading in 30 adults, some who stutter and some who are fluent, in non-altered and delayed auditory feedback (100 milliseconds delayed) conditions. Results reported a statistically significant decrease in the frequency of stutter-like disfluencies between non-AAF and delayed auditory feedback in spontaneous speech.

In contrast to the abundance of investigations that indicated the effectiveness of AAF in reducing stuttering, some surveys showed no significant improvement in stuttering with the use of AAF. Armson and Stuart [19] examined the effectiveness of AAF in reducing stuttering frequency. They specifically assessed the effect of frequency-altered feedback during monologue and reported no statistically significant differences in the frequency of stuttering of 10 out of 12 participants. Buzzeti and Oliveira [20] explored the immediate effects of delayed auditory feedback on stuttering-like disfluencies in thirty individuals who stutter with and without the use of delayed auditory feedback. Results revealed that there was no significant decrease in most stuttering-like disfluencies except in word repetitions with the device in place when compared to no device. Design differences existed between Armson and Stuart [19] and Buzzeti and Oliveira's [20] investigations in comparison to other investigations that may have contributed to the differences in the results. First, the age of participants in Buzzeti's and Oliveira's [20] study were 8-46.11mos, whereas in other studies [14, 15] the participants were adults. Second, the condition examined in Armson's and Stuart's [19] investigation was frequency

altered feedback whereas in other studies [9,14, 15] both a delayed auditory feedback and frequency-altered feedback were investigated.

Besides studies that exist in the literature [9, 10, 12, 21] that investigated the immediate effects of AAF on stuttering frequency. There are a few investigations that explored both the immediate and long-term effects of AAF on stuttering. Stuart et al. [22] examined the effect of an AAF device on the proportion of stuttered syllables in reading and monologue following an initial fitting and at 4 months post initial fitting and indicated that the proportion of syllables stuttered was significantly decreased by approximately 90% during reading and 67% during monologue with the device in place and remained 4 months later. O' Donnell et al. [23] examined the immediate and longitudinal effects of SpeechEasy on stuttering frequency in laboratory and daily living situations. Results indicated that all seven out of seven and five out of seven participants exhibited an immediate decrease of stuttering in laboratory and daily living conditions respectively. Moreover, four and three participants exhibited a reduction in stuttering during long term use, 9-16 weeks later, in laboratory and daily living situations respectively.

Even though there are many studies that examined the effectiveness of AAF on the frequency of stuttering, there is a lack of studies that investigate the effectiveness of AAF on secondary behaviors of stuttering. The lack of research on the effects of AAF devices on secondary behaviors of stuttering and thus the effects of AAF on communication prompted this study. We expect any reductions in associated motor behaviors to parallel reductions in stuttering behaviors, but this needs to be investigated. The aims of the study are: 1. To analyze the associated motor behaviors of stuttering by type and frequency with and without the altered auditory feedback device 2. To examine the immediate effects of an AAF device (i.e., the SmallTalk) on motor behaviors associated with stuttering as measured by their frequency of occurrence per stuttering event and compare associated motor behaviors with the frequency of stuttering during monologue and conversation with and without the device. 3. To investigate the effects of an AAF device on stuttering frequency.

2. METHODS

2.1 Participants

Fifteen participants, 18 years and older, all reporting a diagnosis of developmental stuttering, served as subjects. They were recruited by flyers through stuttering support groups sponsored by the National Stuttering Association in the Washington, D.C. metropolitan area. All were native English (n=11) speakers or identified as later English learners (n=4) (other languages spoken by later English learners are: Nepalese, Hindi and Portuguese) who self-reported to have excellent English proficiency. Thirteen participants were first-time users of an AAF device and two participants had tried a different AAF device before but had not used a device for at least six months. The participants included five females and 10 males, nine Caucasian Americans, four African Americans, and two Asian Americans.

The 15 participants underwent a pre-experiment hearing screening at 25dB HL across 500 to 4000 Hz, with a portable Beltone Electronics 119 Audiometer. All passed the screening with normal hearing in both ears. The participants also were administered the *Stuttering Severity Instrument - Fourth Edition* (SSI-4) [24], a norm-referenced assessment that measures the severity of stuttering based on three areas of stuttering behavior: frequency of stuttering, physical concomitants exhibited by the person who stutters, and naturalness of one's speech. The degree of stuttering severity varied across the 15 participants. One participant identified as having very mild stuttering (i.e., SSI: 15), six identified with mild stuttering (i.e., SSI: 24, 18, 23, 18, 21 and 24), six with moderate stuttering (i.e., SSI: 25, 26, 25, 30, 26 and 26), one with severe stuttering (i.e., SSI: 33), and one participant with very severe (i.e., SSI: 44) stuttering on the SSI-4.

2.2 Instrumentation

In addition to the audiometer and the SSI-4 [24], each participant was fitted with the SmallTalk AAF device (Casa Futura Technologies) after choosing a topic of choice from a list of 10 possible monologue topics, and a topic of choice from 10 possible conversational topics (refer to Appendix A). The AAF device was set for a 50ms time delay and one octave downward frequency shift, as recommended by the manufacturer for first time AAF users. A Sony Handycam DCR-SX45/L Camcorder with a built-in microphone was set to record each participant's performance. An additional instrument, Form 7-4 Assessment of Associated Motor Behaviors [25] allowed for identifying and recording frequency counts of associated motor behaviors (e.g., behaviors that involve the eyes: blinking, shutting, upward movement; behaviors that involve the head: shaking, lateral movement to the right; behaviors that involve the lips: pursing, invert lower lip; behaviors that include the jaw: closing, opening; behaviors that involve the fingers: tapping, rubbing, clicking) that each participant exhibited from each video recording.

2.3 Procedures

Participants were scheduled with the first author to their individual appointments at a university speech-language pathology research lab. The purpose of the research, identified steps, explanation of the instrumentation, prescreening audiometric and severity ratings were discussed as part of the informed consent process. Participants were asked about their language background and about their stuttering treatment background to assure inclusion criteria were met. The lists of general monologue and conversation topics were presented and participants were told they could select other topics if desired (refer to Appendix A).

Four steps were followed for each participant. In step one, participants were asked to talk continuously for three minutes with a timer about a topic. In step two, each participant was asked to engage in a three-minute conversation with the researcher. In steps one and two the participants were not using the AAF device. At the end of these two steps, the participants were fitted with the AAF device and steps one and two were repeated as steps three and four. All monologue and conversation samples collected in steps one through four were videotaped for comparative analysis.

2.4 Data Retrieval and Analysis

The first author identified the participants' motor behaviors (e.g., eye blinking, head shaking, fingers tapping, etc.) associated with stuttering (i.e., motor behaviors that occurred either before or during the occurrence of a stuttering event) by frequency of stuttering in two device conditions, one without (the no-device condition, non-AAF) and one with the AAF device, and in two timed speaking conditions, monologue and

conversation. The first author identified and counted motor behaviors associated with stuttering using Form 7-4 [25] while watching the time-stamped videotaped samples. She also calculated associated motor behaviors per stuttering event and each type of associated motor behavior from the videotaped samples. Additionally, she computed the frequency of stuttering or percentage of syllables stuttered by dividing the number of stuttered events by the total number of syllables in each sample and multiplying it by a hundred. Each participant's data were entered into a Microsoft Excel spreadsheet that was later transferred to the Statistical Package for Social Sciences (SPSS), Version 18, for statistical analysis.

A one-tailed *t* test was used to determine the differences between the mean scores of associated motor behaviors, associated motor behaviors per stuttering event, and frequency of stuttering in the two device conditions (i.e., no device and device) and two speaking conditions (i.e., monologue and conversation). In addition to the t test, the Pearson correlation test was used to indicate significant correlations between the %SS and AMBs and the %SS and AMBs per stuttering event.

2.5 Reliability

Intra-rater reliability was calculated on 17% of the collected speech samples randomly selected and rescored by the primary investigator four months after the original scoring. Pearson correlation coefficients were highly correlated between the original and latter scorings of associated motor behaviors (r = 0.99). Inter-rater reliability was conducted on the same randomly selected recorded samples by a research assistant from the university who was unfamiliar with the experiment but knowledgeable with stuttering. Inter-rater reliability was high with associated motor behavior measures correlated at r = 0.99.

3. RESULTS

3.1 Analysis of Associated Motor Behaviors of Stuttering by Type and Frequency

We analyzed associated motor behaviors associated with stuttering events by type and frequency across the 15 participants in both monologue and conversation without and with the AAF device. Table 1 reveals that associated motor behaviors were common in all 15 participants, regardless of their stuttering severity. It also shows that the type of associated motor behavior was spread across all 16 body parts; but those occurring most frequently involved the eyes, head, lips, and hands. These four were also most responsive to the device in both monologue and conversation. Other associated motor behaviors occurred either infrequently (fractions of occurrences across the 15 participants [see nose and shoulder]) or with wide variance across few participants (standard deviations larger than the mean [see fingers and legs]).

3.2 Analysis of Average Number of Associated Motor Behaviors and the Average Number of Associated Motor Behaviors per Stuttering Event

Statistical analysis involved the frequency of associated motor behaviors averaged across all 15 participants' monologues and conversations and the average number of associated motor behaviors per stuttering event in the two speaking conditions. Fig. 1 shows average number of associated motor behaviors without the device was 94.27 (s.d. = 33.25) and average number with the device was 68.73 (s.d. = 32.09); paired sample t-test results were statistically significant: t (14) = 6.25, p<.01, d=0.78. The magnitude of this difference, the effect size [18] or clinical difference [26] between the mean frequency of associated motor behaviors during monologue with and without AAF is large, at 0.78. The mean number of associated motor behaviors without the device during conversation was 86.07 (s.d. = 29.06) and the mean number with the device was 62.47 (s.d. = 29.04). The difference is statistically significant: t (14) = 6.25, p<.01, d=0.81, again with a large effect size.

Fig. 2 shows a statistical difference between the average number of associated motor behaviors per stuttering event during monologue with (M= 2.59; s.d. = 0.83) and without the device (M= 3.04; s.d. = 0.75): (t (14) = 7.22, p<.01, d=0.57), with a medium effect size. Similarly, t-testing revealed a statistically significant difference between associated motor behaviors per stuttering event during conversation with (M= 2.62; s.d. = 0.80) and without the device (M= 3.05; s.d. = 0.87): t (14) = 5.2, p<.01, d=0.51), with a medium magnitude of difference.

Table 1. Number of instances of each type of associated motor behaviors of participants in monologue and conversation with AAF and non-AAF

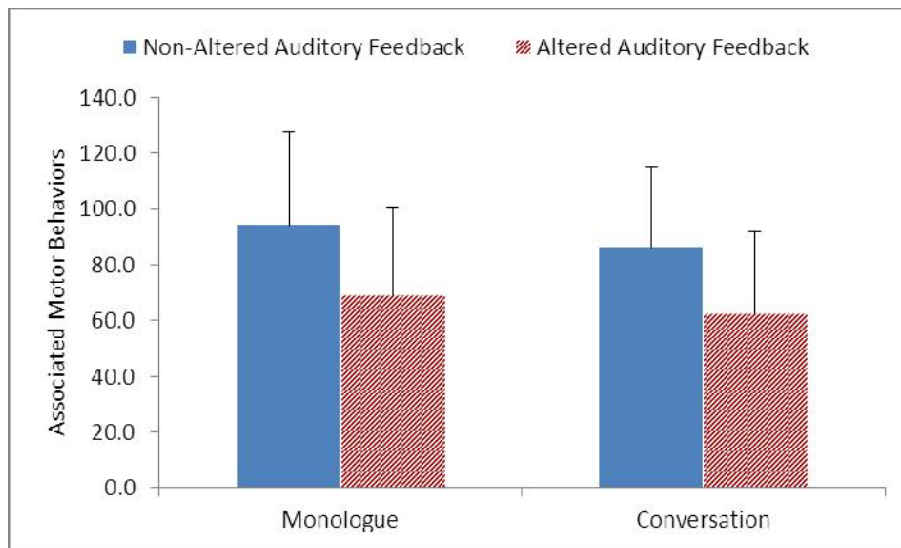| Type of associated motor behaviors	Monologue				Conversation			
	Non-AAF		AAF		Non-AAF		AAF	
	M	SD	M	SD	M	SD	M	SD
Eyes	29.3	14.6	20.2	11.4	24.5	11.5	19.5	11.1
Nose	0.1	0.5	0.3	0.7	0.1	0.5	0.1	0.4
Forehead	3.5	4.0	2.1	2.9	4.1	3.0	1.3	1.5
Head	17.1	11.3	11.1	9.8	19.1	11.4	12.5	7.6
Lips	9.7	4.3	8.0	6.0	7.5	3.7	6.7	5.2
Tongue	1.1	1.7	1.3	3.1	1.6	3.1	0.9	2.3
Jaw	4.7	7.0	3.1	4.2	3.3	5.3	2.8	4.1
Neck	0.2	0.4	0.1	0.3	0.1	0.3	0.0	0.0
Fingers	9.7	10.8	6.9	9.2	7.5	7.0	4.5	5.7
Hands	10.5	6.0	8.7	6.7	10.6	8.1	8.5	6.1
Arms	0.1	0.4	0.1	0.3	0.1	0.3	0.3	0.6
Leg	6.2	9.3	5.5	7.4	6.3	8.7	4.4	5.9
Breathing	0.5	0.9	0.6	2.1	0.5	1.8	0.1	0.3
Shoulder	0.3	0.7	0.4	0.6	0.1	0.4	0.4	0.5
Torso	0.1	0.3	0.0	0.0	0.3	1.0	0.0	0.0
Other	0.3	0.6	0.1	0.3	0.2	0.6	0.3	0.5

Fig. 1. Average number of associated motor behaviors under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF). Error bars show standard deviations

As indicated previously, the very nature of associated motor behaviors would suggest that if the frequency of stuttering diminishes, the frequency of associated motor behaviors decreases. Fig. 3 shows the percentage of syllables stuttered (%SS) with AAF averaged 6.7% (s.d. = 4.7%) and without AAF averaged 8.3% (s.d. = 6.2%) in monologue. The percentage of syllables stuttered during conversation averaged 6.2% (s.d. = 3.9%) with AAF and 7.2% (s.d. = 3.9%) without AAF. Both comparisons were statistically significant in monologue (t (14) = 2.30, $p<.05$, d=0.29) and in conversation (t (14) =2.45, $p<.05$, d=0.26), with a small-to-medium magnitude of difference in both conditions.
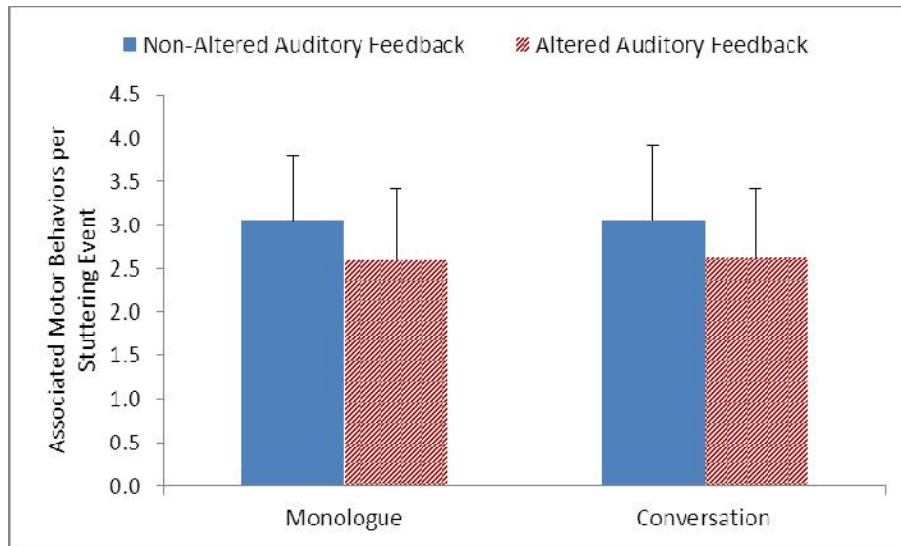
Fig. 2. Average number of associated motor behaviors per stuttering event under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF)
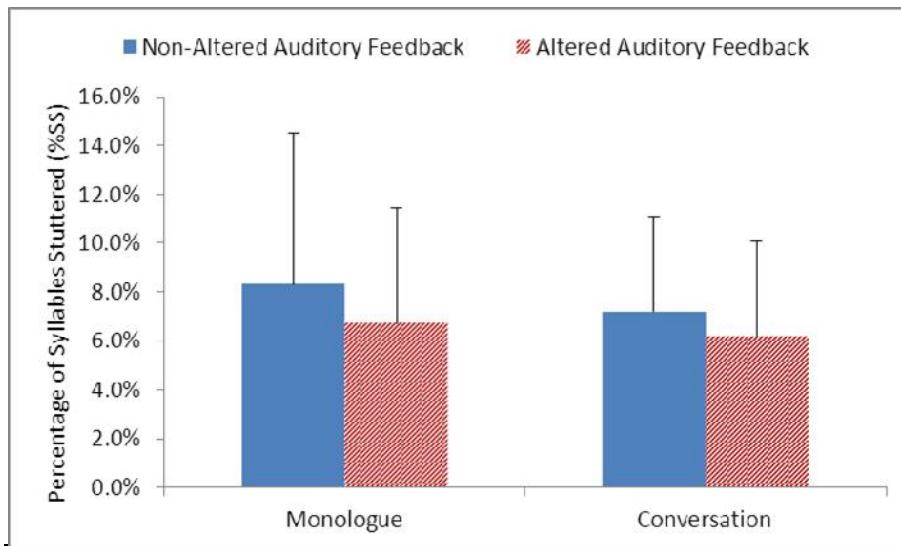

Fig. 3. Mean percentage of syllables stuttered (N= 15 participants) under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF)

Moreover, scatterplots of the individual percentage of syllables stuttered, associated motor behaviors and associated motor behaviors per stuttering event under different speaking conditions (i.e., monologue non-AAF, conversation non-AAF, monologue AAF and conversation AAF) are displayed in Figs. 4, 5 and 6 respectively. The diagonal lines represent the percentage of syllables stuttered, associated motor behaviors and associated motor behaviors per stuttering event of equal magnitude. The relative effect for improvement in the percentage of syllables stuttered, associated motor behaviors and associated motor behaviors per stuttering event is reflected in the amount of data points that fall below the diagonal line in each scatterplot. It is evident in each scatterplot that the majority of participants' syllables stuttered,

associated motor behaviors and associated motor behaviors per stuttering event improved during the AAF condition.

3.3 Correlations between the Percentage of Syllables Stuttered and AMBs and Percentage of Syllables Stuttered and AMBs per Stuttering Event

The Pearson correlation test was used to determine the following significant correlations between variables: The percentage of syllables stuttered (%SS) and AMBs were positively correlated during monologue $r(13)=.76$, $P<.001$ and conversation $r(13)=.74$, $P<.001$ as shown in Figs. 7(a) and 7(b). The %SS also exhibited a significant positive relationship with AMBs per stuttering event in monologue: $r(13)=.56$, $P<.01$ and conversation: $r(13)=.41$, $P<.05$ (see Figs. 8(a) and 8(b).

4. DISCUSSION

4.1 Analysis of Associated Motor Behaviors of Stuttering by Type and Frequency

One aim of this investigation included an analysis of secondary or associated motor behaviors common to stuttering. The most frequently occurring associated motor behaviors involved movements of the eyes, head, lips, and hands, and reductions of these same motor behaviors accounted for the biggest changes with the AAF in both monologue and conversation across the 15 participants. Infrequently occurring associated motor behaviors involving the nose, neck, tongue, shoulder, torso, and breathing showed little to no change with the AAF while movements of the forehead, jaw, fingers, and legs occurred with more intermediate frequency, but with such wide variability that the standard deviations were actually greater than the average data across the participants. These findings raise new questions about the immediate treatment effect of an AAF device on some associated motor behaviors and not on others and offer some thoughts and directions for discussion.

In speculating, we first offer some thoughts about associated motor behaviors involving the eyes and the head (refer to Table 1). We identified the most common associated motor behavior to involve the participants' eyes, consistent with earlier reports [2,3,4]. Variability in their eye movements, as shown in Shipley's Form 7-4, include blinking, shutting, upward, downward,

and vertical (up-down) movements, with counts of 29 and 25 in the monologue and conversational speaking conditions before the AAF reduced to 20 and 20 respectively with the AAF. The second most frequently occurring associated motor behavior involved the head, also with five possible movements that include shaking the head, upward, downward, and lateral movements to the left side or to the right with counts of 17.1 and 19.1 in the monologue and conversational conditions before the AAF reduced the counts to 11.1 and 12.5 respectively with the AAF. As mentioned in the introduction, eye blinking, head nodding and hand gestures are common communication behaviors that occur in those who stutter, as well as in those who do not stutter [2]. It is their intrusion during stuttering that negatively influences perceptions of stuttering severity.

One direction for discussion involves interpreting our associated motor behavior analysis of the eyes and head movements, and potentially those involving the lips and hands, as movements typically associated with auditory activity during talking and hearing oneself talk. Kalinowski and Saltuklaroglu [27] suggested that the second speech signal that is the DAF or FAF signal is analogous to the effect of choral reading that is reading in unison with others, which may increase one's fluency. Specifically, Kalinowski and Saltuklaroglu [27] speculated that AAF helps the speaker to connect his speech production with sensory perception via the mirror neuron system in which the firing of one motor neuron occurs while watching the movement performed by another motor neuron. The effect of altered audition or the impact of an AAF device on hearing oneself differently, creating a choral effect, could well be at play in explaining these outcome differences in adults who stutter.

4.2 Analysis of Average Number of Associated Motor Behaviors and the Average Number of Associated Motor Behaviors per Stuttering Event

Another aim of this study involved an assessment of the immediate effects of AAF devices on reducing stuttering frequency and associated motor behaviors in 15 adults who stutter. Our findings are consistent with previous reports that support the immediate ameliorative effects of AAF devices in reducing stuttering frequency [8,9,10,12,13,14, 15,16,17,19, 21, 22, 28, 29, 30, 31, 32, 33, 34]. Our outcomes revealed a 6.7% and 8.3% syllables stuttered in

monologue with and without the device respectively and a 6.2% and 7.2% SS in conversation with and without the device correspondingly. Findings reported here differ from those of previous researchers, however, in that the focus of the research is on the associated motor behaviors. Results revealed a 27% and 27.4% decrease in associated motor behaviors with the AAF during monologue and conversation respectively (see Fig. 1). These findings offer some thoughts and directions of discussion.
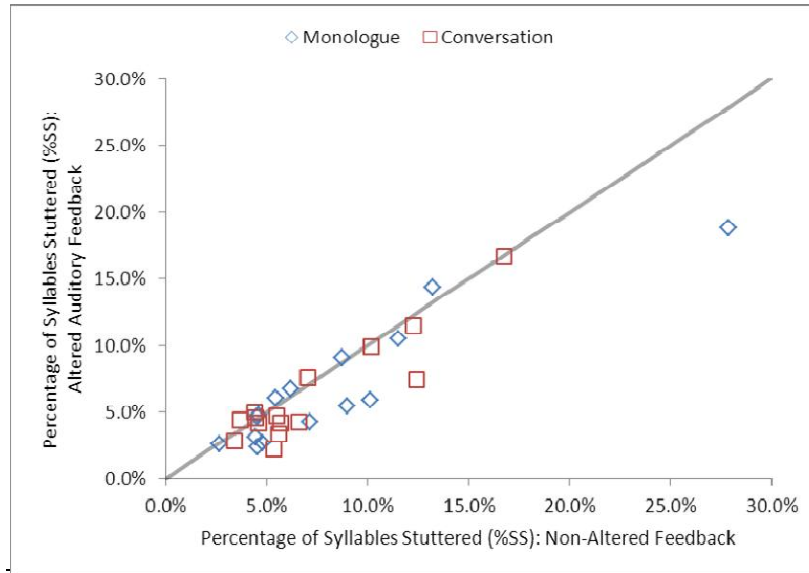

Fig. 4. Individual percentage of syllables stuttered (N= 15 participants) under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF). Diagonal line represents percentage of syllables stuttered of equal magnitude

Fig. 5. Individual associated motor behaviors under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF). Diagonal line represents associated motor behaviors of equal magnitude
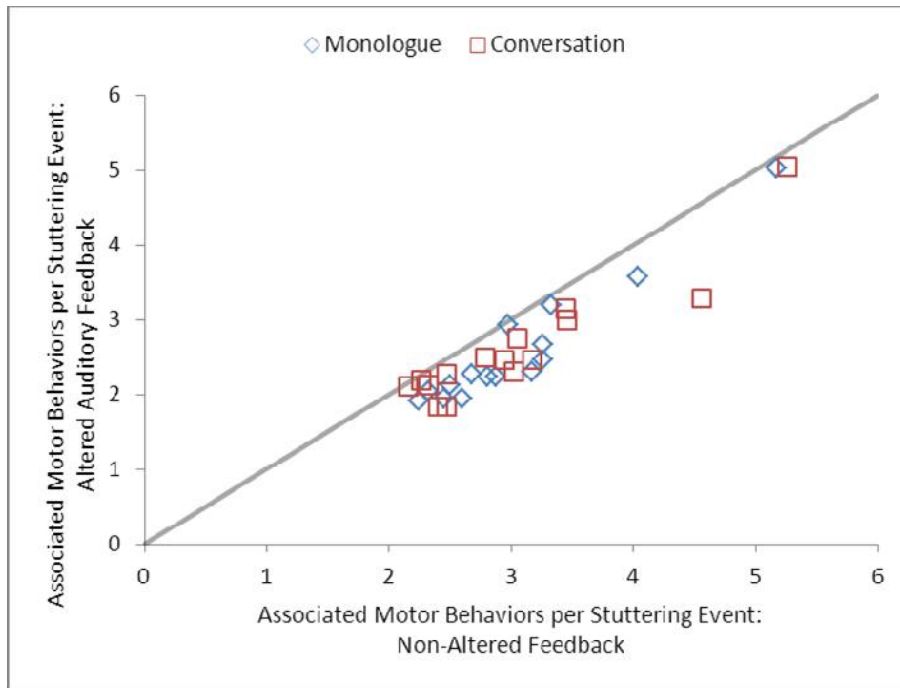
Fig. 6. Individual associated motor behaviors per stuttering event under different speaking conditions (Monologue non-AAF, Conversation non-AAF, Monologue AAF and Conversation AAF). Diagonal line represents associated motor behavior per stuttering event of equal magnitude
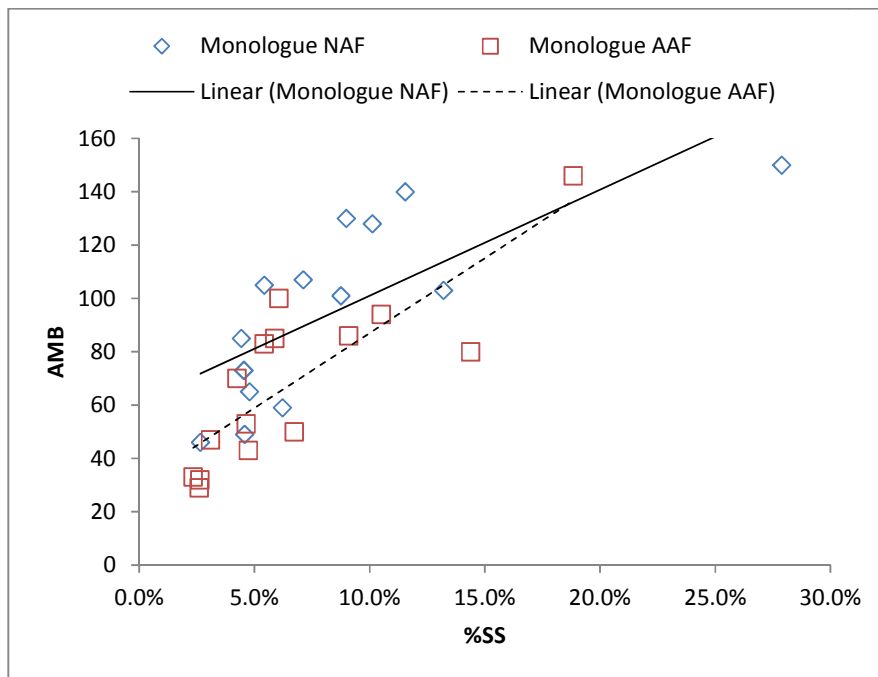

Fig. 7(a). AMB for individual participants (N= 15 participants) for different speaking conditions (Monologue NAF and Monologue AAF) as a function of percentage of syllables stuttered. The lines show the linear regression lines for the Monologue NAF and AAF data
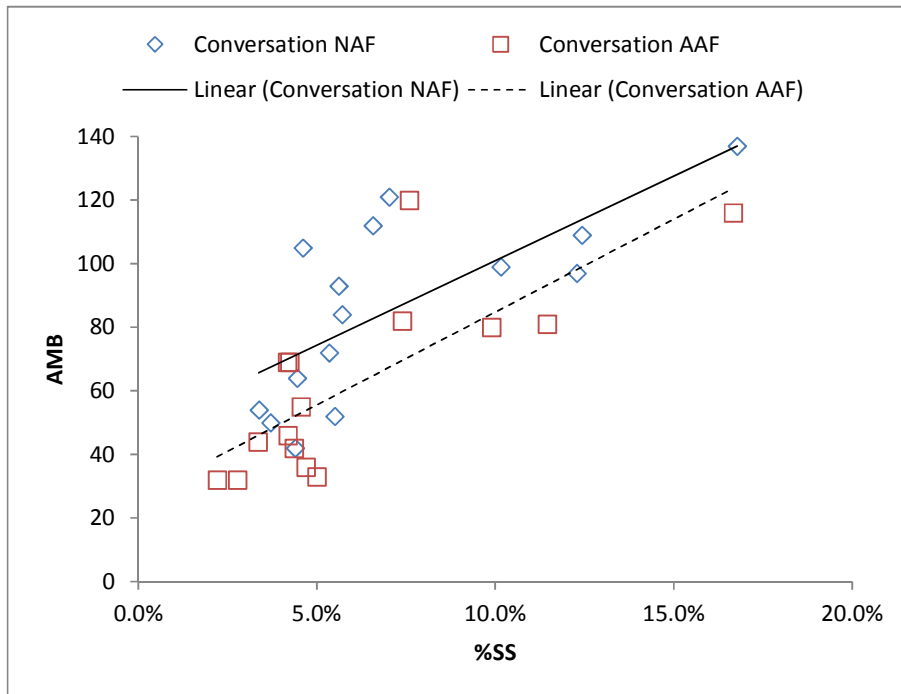
Fig. 7(b). AMB for individual participants (N= 15 participants) for different speaking conditions (Conversation NAF and Conversation AAF) as a function of percentage of syllables stuttered. The lines show the linear regression lines for the Conversation NAF and AAF data
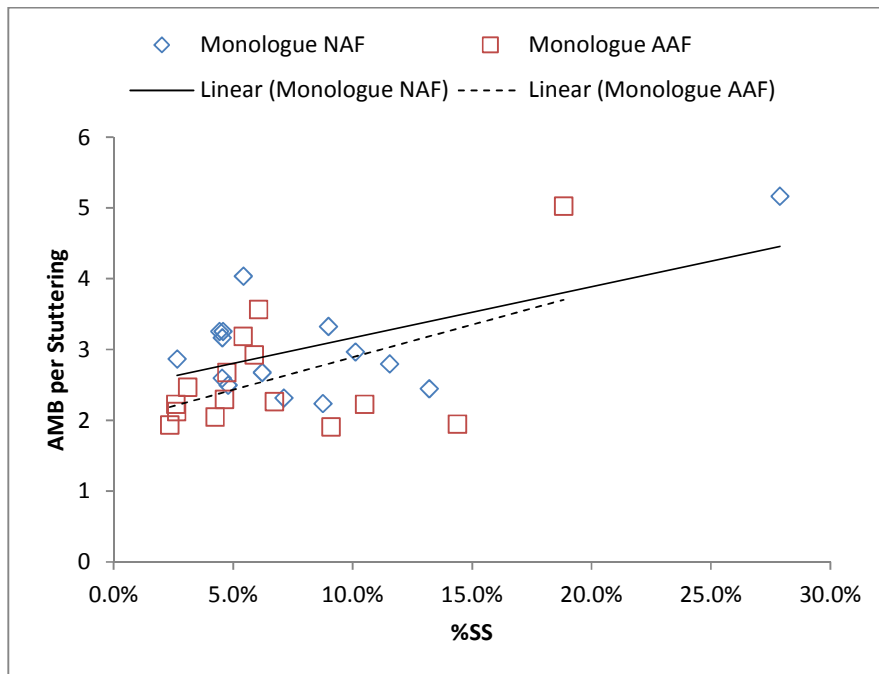

Fig. 8(a). AMB per Stuttering for individual participants (N= 15 participants) for different speaking conditions (Monologue NAF and Monologue AAF) as a function of percentage of syllables stuttered. The lines show the linear regression lines for the Monologue NAF and AAF data
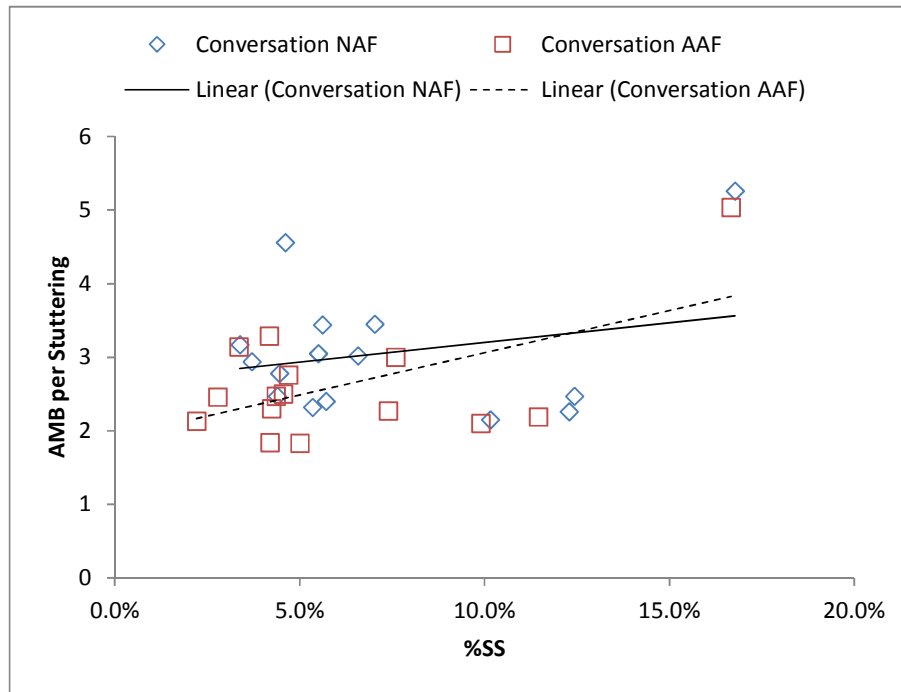
Fig. 8(b). AMB per Stuttering for individual participants (N= 15 participants) for different speaking conditions (Conversation NAF and Conversation AAF) as a function of percentage of syllables stuttered. The lines show the linear regression lines for the Conversation NAF and AAF data

One direction for discussion involves interpreting our findings with a focus on effect size, rather than on statistical significance. The effect size between the overall frequency of associated motor behaviors associated with all stuttering events with and without the AAF in monologue and conversation was large while effect size between the frequency of associated motor behaviors per stuttering event with and without the AAF was moderate. From this research, we suggest that the larger effect sizes on the reduction of associated motor behaviors across all stuttering events and that the medium effect sizes on the reduction of associated motor behaviors per stuttering event lend greater support for the role of AAF in reducing stuttering events and associated motor behaviors altogether.

Attention to effect size is not new in experimental research involving stuttering. Herder et al. [35] reported on a systematic review of the effects of behavior interventions on persons who stutter. Their longitudinal or cumulative analysis of effect size, sample size and standard error began with Boudreau's [36] randomized control treatment. Over time, they showed that by adding cumulative intervention effects, a shift to statistically significant effect sizes occurred in the late 1980s.

We suggest that new insights can come from comparing the clinical effects of AAF devices on motor behaviors associated with stuttering in non-randomized within-subjects research. Secondary motor behaviors can add to the perception of stuttering severity by drawing a communicator's attention to the behaviors, potentially distracting the communicator and reducing motivation to continue as a communication partner. Associated motor behaviors have long been reported to serve two roles: one, to reduce stuttering events altogether, and two, to "escape" or shorten a stuttering event once it has begun. In our research, the larger and medium effect sizes on the reduction of AMBs across all stuttering events and AMBs per stuttering event respectively supports the effectiveness of AAF in reducing AMBs which may lead to decreasing the perception of stuttering severity, reducing the communicator's distractibility and increasing his/her motivation to continue communicating.

We also analyzed associated motor behaviors associated with stuttering for differences between means during monologue and conversation with the AAF device (M=68.73; M=62.47) and without it (non-AAF M=94.27; M=86.07). The AAF condition generated a 27.0% and 27.4% decrease in associated motor behaviors during monologue and conversation respectively (see Fig. 1) and a 14.8% and 13.8% decrease in associated motor behaviors per stuttering event during monologue and conversation (see Fig. 2). These results are consistent with previous research which indicated that changing the way people who stutter perceive or hear their own speech back to them can change or diminish stuttering [8, 9, 10], as well as, associated motor behaviors in our study. Setting the AAF to alter both speech perception rate and speech perception pitch changed how persons who stutter heard themselves speaking (e.g., slower speech rate, lower pitch) [2] and resulted in reduced stuttering and associated motor behaviors in the 15 participants who stuttered.

Similarly, to other studies that exist in the literature [9, 10, 12, 21] our study investigated the immediate effects of AAF on stuttering frequency. To the best of our knowledge, our investigation is the first to explore the immediate effects of an AAF device on the associated motor behaviors of stuttering. Additionally, even though there are a few studies that examined the long term effects of AAF on stuttering frequency [22, 23], there are no longitudinal studies that we know of that studied the long-term effects of AAF devices on associated motor behaviors.

4.3 Correlations between the Percentage of Syllables Stuttered and AMBs and Percentage of Syllables Stuttered and AMBs per Stuttering

One more aim of the study investigated the effects of an AAF device on stuttering frequency. Outcomes revealed that there were significantly positive correlations between the %SS and AMBs and %SS and AMBs per stuttering event. Particularly, as the %SS increased the AMBs and AMBs per stuttering event during monologue and conversation increased and as the duration of stuttering increased, the AMBs and AMBs per stuttering event had the tendency to increase as well. These positive correlations help explain the results of the t-test which indicated a significant decrease in %SS, AMBs and AMBs per stuttering event when using an AAF device.

Particularly, the findings of the Pearson correlations and t-tests follow logically that the use of an AAF device reduces the frequency of stuttering in PWS, and the reduced frequency of stuttering results in a reduced frequency of associated motor behaviors. In other words, PWS do not need to use as many AMBs to escape from or to avoid stuttering when using an AAF device because an AAF device decreases the frequency of stuttering. This explanation may also account for the lack of research in the area of AMBs.

5. IMPLICATIONS/CONCLUSIONS

A conclusion that the results and discussion offered here involves the positive implication AAF can have on persons who stutter. For instance, sharing the results with people who stutter could result in more confident and frequent use of AAF, not just to decrease the frequency of stuttering, but also to decrease the associated motor behaviors that contribute to perceptions of stuttering severity. Individuals who stutter may find it easier to communicate and socialize with expectations of reduced intrusive behaviors associated with stuttering. Use of AAF, then, could help diminish the fear and avoidance of social situations that require them to talk [37, 38] and could lead to more frequent communication events with others that serve to increase confidence in social situations as Boyle et al. [39] revealed self-esteem is a significant predictor of communicative participation (e.g., expressing knowledge, information, feelings, etc.) in adults who stutter. Increased confidence in social situations could then decrease the fear of stuttering.

5.1 Limitations and Recommendations for Future Research

A limitation of the current study is that the study design did not control for any possible order effect that could have affected the number of stuttering events and motor behaviors. A follow-up study is recommended with a larger number of subjects to investigate AAF outcomes on associated motor behaviors in relation with stuttering severity with two-minute conversations between conditions without AAF in order to diminish any possible order effect. This should provide insight into whether AAF effectiveness in decreasing associated motor behaviors in persons who stutter depends on stuttering severity. Another recommendation is to conduct a follow-up study with a larger number of

participants with different stuttering severities in order to examine the relationship between the effects of AAF on associated motor behaviors in people with stuttering in experimental and control groups. Investigating the effects of AAF on associated motor behaviors associated with stuttering types (e.g., repetitions, prolongations, blockages, etc.) would also contribute answers to questions about AAF effectiveness across stuttering behaviors. Pursuing prospective longitudinal studies on the long-term effects of AAF devices on associated motor behaviors would provide insight into whether using an AAF device results in long-term reductions in associated motor behaviors in persons with stuttering. Finally, experimenting with different auditory delays and different pitch alterations is important in determining whether the two combined or either one treatment in isolation accounts for the biggest drop in associated motor behaviors. Longitudinal investigations and altered auditory timing and pitch characteristics are easily adapted to single subject designs that could well serve the greatest clinical impact.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

As per international standard or university standard, participants' written consent has been collected and preserved by the author(s).

ACKNOWLEDGEMENTS

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Prins D, Lohr F. Behavioral dimensions of stuttered speech. Journal of Speech , Language, and Hearing Research. 1972;15:61-71.
2. Guitar B. Stuttering an integrated approach to its nature and treatment, Baltimore. Lippincott Williams & Wilkins; 2014.
3. Zebrowski PM, Kelly E. Manual of stuttering intervention. Clifton Park, NY, Singular; 2002.
4. Vanryckeghem M, Brutten GJ, Uddin N, Van Borsel J. A comparative investigation of the speech-associated coping responses reported by adults who do and do not stutter. Journal of Fluency Disorders. 2004;29(3):237-250.
5. Bloodstein O. Conditions under which stuttering is reduced or absent. Unpublished doctoral dissertation, University of Iowa, Iowa City, IA; 1948.
6. Brutten EJ, Shoemaker DJ. The modification of stuttering; 1967.
7. Conture E, Kelly E. Young stutterers' nonspeech behaviors during stuttering. Journal of Speech, Language, and Hearing Research. 1991;34:1041-1056.
8. Unger J, Gluck C, Cholewa J. Immediate effects of AAF devices on the characteristics of stuttering: A clinical analysis. Journal of Fluency Disorders.20125;37:122-134.
9. Zimmerman S, Kalinowski J, Stuart A, Rastatter M. Effects of AAF on people who stutter during scripted telephone conversations. Journal of Speech, Language, and Hearing Research.1997;40:1130-1134.
10. Armson J, Kiefte M. The effects of Speech Easy on stuttering frequency, speech rate, and speech naturalness. Journal of Fluency Disorders. 2008;33:120-134.
11. Nicolosi L, Harryman E, Kresheck J. Terminology of communication disorders. Baltimore, Williams & Wilkins; 1996.
12. Armson J, Kiefte M, Mason J, De Croos D. The effect of Speech Easy on stuttering frequency in laboratory conditions. Journal of Fluency Disorders. 2006;31:137-152.

13. Stuart A, Kalinowski J. Effect of delayed auditory feedback, speech rate, and sex on speech production. Perceptual and motor skills.2015;120(3):747-765.

14. Hudock D, Kalinowski J. Stuttering inhibition via AAF during scripted telephone conversations. International Journal of Language & Communication Disorders.2014;49(1):139-147.

15. Foundas AL, Mock JR, Corey DM, Golob EJ, Conture EG. The Speech Easy device in stuttering and nonstuttering adults: Fluency effects while speaking and reading. Brain and language.2013;126(2):141-150.

16. Furini J, Picoloto LA, Marconato E, Bohnen AJ, Cardoso ACV, Oliveira CMCD. The role of auditory temporal cues in the fluency of stuttering adults. Revista CEFAC.2017;19(5):611-619.

17. Ritto AP, Juste FS, Stuart A, Kalinowski J, de Andrade CRF. Randomized clinical trial: the use of SpeechEasy® in stuttering treatment. International Journal of Language & Communication Disorders.2016;51(6):769-774.

18. Cohen J. Statistical power analysis for the behavioral sciences, 2nd ed (Hillsdale, NJ: Lawrence Erlbaum Associates); 1988.

19. Armson Joy, Stuart Andrew. Effect of extended exposure to frequency-altered feedback on stuttering during reading and monologue. Journal of Speech, Language, and Hearing Research, 1988;41(3):479-490.
DOI: 10.1044/jslhr.4103.479

20. Buzzeti PB. M d. M, Oliveira CMCD. Immediate effect of delayed auditory feedback on stuttering-like disfluencies. Revista CEFAC. 2018;20(3):281-290.

21. Macleod Jennifer, Kalinowski Joseph, Stuart Andrew, Armson Joy. Effect of single and combined AAF on stuttering frequency at two speech rates. Journal of Communication Disorders. 1995;28(3),217-228.
DOI:http://dx.doi.org/10.1016/0021-9924(94)00010-W

22. Stuart Andrew, Kalinowski Joseph, Rastatter, Michael P, Saltuklaroglu Tim, Dayalu Vikram. Investigations of the impact of AAF in-the-ear devices on the speech of people who stutter: initial fitting and 4-month follow-up. International Journal of Language & Communication Disorders. 2004;39(1):93-113.
DOI: 10.1080/13682820310001616976

23. O'Donnell JJ, Armson J, Kiefte M. The effectiveness of Speech Easy during situations of daily living. Journal of Fluency Disorders. 2018;*33*(2):99-119.

24. Riley G. Stuttering severity instrument fourth edition (SSI-4), Austin, Pro-Ed; 2009.

25. Shipley K, Mcafee J. Assessment in speech-language pathology a resource manual, San Diego, Singular Publishing Group, Inc; 1992.

26. Morgan SE, Reichert T, Harrison TR. From numbers to words: reporting statistical results for the social sciences. Boston (Mass.): Allyn and Bacon; 2002.

27. Kalinowski J, Saltuklaroglu T. Choral speech: the amelioration of stuttering via imitation and the mirror neuronal system. Neuroscience & Biobehavioral Reviews. 2003;*27*(4):339-347.

28. Armson JOY, Foote Sheila, Witt Colleen, Kalinowski Joseph, Stuart Andrew. Effect of frequency altered feedback and audience size on stuttering. International Journal of Language & Communication Disorders. 1997;32(3):359-366.
DOI: 10.3109/13682829709017901

29. Hargrave Stephanie, Kalinowski Joseph, Stuart Andrew, Armson Joy, Jones Kathleen. Effect of frequency-altered feedback on stuttering frequency at normal and fast speech rates. Journal of Speech, Language, and Hearing Research. 1994;37(6):1313-1319.
DOI: 10.1044/jshr.3706.1313

30. Ingham Roger J, Moglia Richard A, Frank Peter, Ingham Janis Costello, Cordes Anne K. Experimental investigation of the effects of frequency-aaf on the speech of adults who stutter. Journal of Speech, Language, and Hearing Research. 1997;40(2):361-372.
DOI: 10.1044/jslhr.4002.361

31. Kalinowski Joseph, Armson Joy, Stuart Andrew. Effects of alterations in auditory feedback on stuttering frequency during fast and normal speech rates. The Journal of the Acoustical Society of America. 1993;93(4):2338-2338.
DOI: http://dx.doi.org/10.1121/1.406280

32. Stuart Andrew, Kalinowski Joseph, Armson Joy, Stenstrom Robert, Jones Kathleen. Fluency Effect of Frequency Alterations of Plus/Minus One-Half and One-Quarter Octave Shifts in Auditory Feedback of People Who Stutter. Journal

of Speech, Language, and Hearing Research. 1996;39(2):396-401.
DOI: 10.1044/jshr.3902.396

33. Stuart Andrew, Kalinowski Joseph, Rastatter Michael P. Effect of monaural and binaural AAF on stuttering frequency. The Journal of the Acoustical Society of America.1997;101(6):3806-3809.
DOI: http://dx.doi.org/10.1121/1.418387

34. Stuart Andrew, Kalinowski Joseph, Saltuklaroglu Tim, Guntupalli Vijay K. Investigations of the impact of AAF in-the-ear devices on the speech of people who stutter: One-year follow-up. Disability and Rehabilitation. *2006;*28(12):757-765.
DOI: 10.1080/09638280500386635

35. Herder C, Howard C, Nye C, Vanryckeghem M. Effectiveness of Behavioral Stuttering Treatment: A Systematic Review and Meta-Analysis.

Contemporary Issues in Communication Science and Disorders. *2006;33*.

36. Boudreau LA, Jeffrey CJ. Stuttering treated by desensitization. Journal of Behavior Therapy and Experimental Psychiatry, 1973;4(3):209-212.

37. Bricker-Katz G, Lincoln M, Cumming S. Stuttering and work life: An interpretative phenomenological analysis. Journal of fluency disorders. 2013;38(4):342-355.

38. Erickson S, Block S. The social and communication impact of stuttering on adolescents and their families. Journal of fluency disorders. 2013;38(4):311-324.

39. Boyle MP, Beita-Ell C, Milewski KM, Fearon AN. Self-esteem, self-efficacy, and social support as predictors of communicative participation in adults who stutter. Journal of Speech, Language, and Hearing Research. 2018;61(8):1893-1906.

APPENDIX A

MONOLOGUE AND CONVERSATION TOPICS

CONVERSATION TOPICS

1. Describe your favorite sport. Are you an active participant or an observer? Why do you like the sport? How did you get interested in the sport?
2. Which is your favorite season of the year? Which is your least favorite? Why do you like and dislike these particular times of the year?
3. If you decided to move to a new location, how important a factor would the climate be in your decision? What kinds of weather do you like and dislike?
4. We have a wide selection of foreign-made cars to choose from in this country, yet some people buy only American cars. What has been your practice and why?
5. Do you own a computer? Why or why not? What do you think about computers? Are they truly helpful, or more of a status symbol?
6. What are the advantages and disadvantages of a one-story versus a two-story house? Which do you prefer?
7. In your opinion, what are the characteristics of a good friend? In other words, what do you expect of friends? What personal qualities do you look for? What would you find intolerable from a person who wanted to be a friend?
8. Do you like movies? If not, why not? If you do, tell me about one of your favorites.
9. Select a real person, dead or alive, whom you consider to be a hero. Tell me why you think of this person as a hero.
10. Who has been the best United States president during your lifetime? On what criteria did you base your choice?

MONOLOGUE TOPICS

1. How old were you when you learned to ride a bicycle? Who taught you? Tell me about that experience. Do you remember your first bike? Describe it to me.
2. If you have brothers or sisters, tell me what you remember about your relationship as children. (If you have neither brothers nor sisters, talk about what you liked and/or disliked about not having siblings.) What special treatment did they get that you didn't? Describe the games and pastimes you remember. Did you tease each other? Who won your fights?

3. Have you ever traveled through US or elsewhere? When did you travel? With whom did you travel? What was the occasion? Tell me about some memorable things you did and saw there.
4. Tell me about a memorable sporting event you attended as a fan. Where was it? What happened? Whom were you with?
5. When did you first visit a large theme park? Describe the experience. How often do you make such trips?
6. Have you ever had (or given) a surprise birthday party? Tell me about it. Would you like another one?
7. Have you ever been to a 50th wedding anniversary party? Whose was it? How many couples do you know who have been together that long?
8. Tell me about a vacation you remember from your childhood. Where did you go? What did you do? Who was there? What was the highlight of the vacation?
9. Describe a neighbor you remember from childhood. How did you meet? What do you remember about the neighbor's home or yard? What happened to the neighbor?
10. Describe the house you grew up in. Give details about your bedroom, dining area, living room, and so forth. Is your house still standing? When was the last time you saw it? Would you like to see it again?