The Effects of Delayed Auditory Feedback on Spasmodic Dysphonia

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ABSTRACT

This study was conducted in order to investigate the perceptual and acoustic vocal qualities of individuals with adductor spasmodic dysphonia (ADSD). The research participants included one male, 60 years old, and one female, 47 years old. The participants read a phonetically balanced passage under three experimental conditions: non-altered auditory feedback (NAF), delayed auditory feedback (DAF) at 50 ms, and DAF at 150 ms. When DAF is utilized, the speaker/reader hears his/her own voice with a delay. The participants were given the DAF device to utilize at home and instructed to read a news article for 5 minutes each day for 1 week with DAF set at a 50 ms delay. Upon returning to the speech lab after one week of at-home DAF vocal exercises, the participants were subjected to the same conditions as the pre-treatment trial. Acoustic data were recorded through KayPENTAX Computerized Speech Lab and statistically analyzed in the areas of cepstral peak prominence, low/high spectral ratio, fundamental frequency, and sound pressure level. In addition, three speech-language pathologists perceptually rated the vocal quality of six speech samples per participant based upon the following criteria: overall severity, strained-strangled voice quality, abrupt voice initiation, and expiratory effort. The male participant's vocal quality showed little benefit from the use of DAF. However, the results of the perceptual ratings indicated that the female participant exhibited superior vocal quality when using DAF at a 50 ms delay. The pre-treatment perceptual data for the female participant also revealed that the utilization of DAF with a 150 ms delay yielded the worst vocal quality. Nevertheless, the perceptual ratings indicated that the female participant improved in vocal quality when using DAF regardless of the delay. These results reveal that DAF, with a specific delay, may serve as a possible management technique for persons with ADSD.

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Chapter I

INTRODUCTION

The voice is a variable instrument, changing with the time of day, diets, dehydration, emotion, and many other factors. Speech is also the most prominent mode of communication in humans. Therefore, individuals rely heavily on the dynamic vocal mechanism. In order to produce sound, there is a complex synchrony of neurological signals, respiratory processes, vocal fold vibrations, and musculoskeletal anatomical variations that must occur. Disruptions to any part of this system can create voice disorders which have been defined by Justice (2010, p. 110) as "when the pitch, loudness, or phonatory quality differs significantly from that of persons of a similar age, gender, cultural background, and racial or ethnic group."

Spasmodic dysphonia is a type of neurogenic voice disorder affecting the laryngeal system with interruptions of involuntary movements or "spasms," which in turn negatively affect the vocal quality (Greene, 1989). The name "spastic dysphonia" was originally given to this disorder, yet inadequately so, as the term "spastic" signifies an origin in the pyramidal system. Although still unsure of the precise neurological locus, evidence has indicated that the structures affected in spasmodic dysphonia are part of the extrapyramidal system (Colton & Casper, 1996). Not until 1968 did someone advocate for a name change; Aronson, Brown, Litin, and Pearson proposed "spasmodic" dysphonia in order to reduce the confusion.

There are three types of spasmodic dysphonia: adductor, abductor, and mixed (Dworkin & Meleca, 1997). Adductor spasmodic dysphonia (ADSD) causes the ventricular folds and the vocal folds to become hyper-adducted during the closing (adducting) of the vocal folds, generating a strained-strangled voice quality that usually is accompanied by intermittent vocal arrests (Colton & Casper, 1996). Those with abductor spasmodic dysphonia (ABSD) experience a sporadic "breathy" voice and extended breathiness on voiceless consonants due to the vocal folds remaining open during phonation. Mixed spasmodic dysphonia presents itself as a combination of ADSD and ABSD with the vocal folds intermittently hyper-adducting and hyper-abducting (Watson et al., 1991). By far, the most common type of spasmodic dysphonia among individuals is adductor spasmodic dysphonia (Finnegan, Hoffman, Hemmerich, & Van Daele, 2009).

A regular complaint among individuals with ADSD is fatigue from talking due to the increased tension in the vocal folds (Justice, 2010), as connected speech tends to lead to more recurrent and intense laryngeal spasms (Roy, Gouse, Mauszycki, Merrill, & Smith, 2005). Speakers with ADSD also demonstrate difficulties initiating speech (Boone, McFarlane, Von Berg, & Zraick, 2013). However, upon whispering, crying, or laughing, persons with ADSD do not exhibit signs of the dysphonia; the hyper-adduction solely occurs upon voluntary communicatory phonation (Aronson, 1990). Although there are visible manifestations of ADSD such as tension and facial grimaces (Johnson & Jacobson, 1998), the auditory perceptual characteristics are the most salient features of the disorder. According to Colton and Casper (1996, p. 140), "Perceptual signs include strain/struggle, sudden interruption of voicing, tension, loudness and pitch variations, pitch breaks, and stoppages of phonation." "Currently, the diagnosis of ADSD relies almost exclusively on auditory-perceptual features" (Roy et al., 2005, p. 1). However, it may be difficult to diagnose as it has similar symptoms to other voice disorders, such as muscle tension dysphonia (MTD) (Roy et al., 2005). Through the use of a rigid or flexible endoscope placed into the mouth and toward the back pharyngeal wall, one can see the movements of the vocal folds to help identify ADSD. Primarily, diagnosis involves the use of otolaryngologists or trained speech-language pathologists that utilize various phonatory tasks to gather pertinent information on the perceptual aspects of the voice (Yeung et al., 2011).

Chapter II

REVIEW OF LITERATURE

Treatment of ADSD

Though there is no cure for spasmodic dysphonia (SD) as of yet, treatments exist for the disorder that help manage the symptoms. Nonetheless, these treatments are often associated with various levels of success and/or poor carryover beyond clinic use. Typically, botulinum toxin (Botox) injections, surgery, and behavioral interventions are employed as treatments for ADSD (Boone et al., 2013). As described by Boone et al. (2013, botulinum toxin type, p. 124), botulinum toxin type A is “the gold standard for treating SD” and involves unilateral or bilateral injection into the vocal folds or interarytenoid muscles. The muscles that are hyper-contracting in SD are believed to be temporarily paralyzed when injected with Botox (Blitzer, Brin, & Stewart, 1998). However, there are certain concerns associated with the use of Botox as a treatment for SD. As Botox is only a temporary treatment, multiple injections a year are required to maintain the desired effect (Finnegan et al., 2009). These injections can be expensive and not all individuals with SD can afford this treatment technique. Others that may be located in more rural areas might not even have access to receive Botox. Another concern is the possible side effect of dysphagia as a result of the laryngeal muscles being paralyzed (Finnegan et al., 2009). Even if an individual can afford Botox and chooses to risk the possible side effects, some individuals with ADSD do not positively respond to the treatment (Boone et al., 2013).

As previously mentioned, behavioral therapy is also a treatment option for SD. Behavioral therapy is often utilized in conjunction with botulinum toxin injections. Patients have typically formed a vocal hyper-functional behavior in an attempt to produce a normal voice quality amidst the strain of ADSD (Boone et al., 2013, p. 125). As stated by Boone et al. (2013), “Even though such excessive effort is no longer needed after injection, the patient’s habit set of vocal hyper-function continues.” Behavioral therapy is designed to reduce the need of this effortful speech by raising the individual’s awareness to the habit. After achieving increases in awareness, therapy typically progresses to acquiring an ideal breath support system for speech. Similar to Botox injections, not everyone responds to behavioral therapy (Boone et al., 2013).

The most invasive of all the treatment techniques is the recurrent laryngeal nerve (RLN) section surgery. The RLN branches off from the branches of CN X, the vagus nerve, which innervates provides motor innervation to the larynx. Specifically, the RLN plays a major role in vocal fold adduction and abduction as it innervates eighty percent of the intrinsic laryngeal muscles. Extensive diagnostic evaluation of the patient must be completed before the decision to proceed with surgery can be made, as not all SD patients are appropriate candidates for RLN sectioning. The surgery consists of permanently cutting the RLN in order to paralyze the innervated laryngeal musculature, similar to the desired effect of Botox. Unfortunately in some cases, regeneration of the RLN has been documented, as well as failure to maintain the improved vocal quality (Boone et al., 2013).

Stuttering and ADSD

Studies have shown similarities between stuttering and ADSD (Ludlow & Loucks, 2003) and this is perhaps why some authors have described spasmodic dysphonia as a “stuttering of the vocal cords” (Johnson & Jacobson, 1998, p. 660). Although there are parallels between the two disorders, it is important to note that they are considered to be “distinct and separate disorders” (Cannito et al., 1997, p. 628). Certain salient characteristics that are analogous between persons who stutter (PWS) and persons with ADSD include their task specific nature, their focal nature, and common abnormal electromyographic (EMG) readings. For stuttering and ADSD, the term “task specific” denotes that the disorder is only present during the task of speech (i.e., not laughing, crying, whispering, or singing) (Roy et al., 2005; Blitzer, Brin, & Ramig, 2009). The two disorders share a focal quality, in that the disorders only lie within the laryngeal musculature and are not found in other motor systems. Lastly, and most importantly for the purposes of this study, are the findings of comparable disturbances, as explained below, in EMG activity that point to the linked relationship between stuttering and ADSD (Ludlow & Loucks, 2003).

In a study completed by Borden, Dorman, Freeman, and Raphael (1977), EMG data were collected on the laryngeal muscles of PWS during the event of a stuttering block. Borden et al. investigated the activation of an antagonistic muscle pair of the laryngeal system which consisted of the posterior cricoarytenoid muscle and the interarytenoid muscles. The posterior cricoarytenoid (PCA) muscle is used to abduct the vocal folds, and is the only muscle designated for the function of abduction. Contraction of the PCA allows for unobstructed airflow for respiration, as well as airflow for the phonation of voiceless phonemes. The interarytenoid (IA) muscles, comprised of the transverse arytenoid muscle and the oblique arytenoid muscle, function to adduct the vocal folds. These muscles are biologically designed to protect the airway during a swallow, but they also function to trap air below the vocal folds until enough subglottic pressure is generated to overcome the muscular resistance. This in turn causes the vocal folds to vibrate and produce sound. The PCA muscle and the IA muscles are thus deemed "antagonistic pairs" since the contraction of one muscle means the opposing muscle is at rest when the system functions properly (Seikel, King, & Drumright, 2010). The EMG data revealed that the antagonistic pairs were working in conjunction during a stuttering block, similar to a stalemate in tug of war, in that the vocal folds opposing movements are met with equal force causing an impasse. Thus, the PWS experienced disfluencies possibly due in part to the malfunction of the antagonistic muscle pairs.

Delayed Auditory Feedback

Borden et al. (1977) then gathered data on the EMG activity of PWS while utilizing delayed auditory feedback (DAF), a known fluency enhancer in those who stutter. Raphael, Borden, and Harris (2011, p. 312) defined delayed auditory feedback as "a delay in hearing one's own speech produced artificially." Originally, this effect was produced by utilizing a magnetic tape recording that was looped to reproduce the speaker's voice through headphones (Bloodstein, 1995). However, this hardware device is not still commonly used, due to developments in technology which have produced software that is also capable of delaying auditory feedback. The device can range from a specifically designed speech manipulation unit to an app on a smart device. In normally fluent speakers, this device causes disfluent patterns of speech, thought to be a ‘‘temporal asynchrony between speech production and its feedback to the auditory system'' (Hashimoto & Sakai, 2003, p. 22). Repetitions are a common disfluency when normally fluent individuals are utilizing DAF. Bloodstein (1995, p. 91) theorized that the delay leads the brain to believe there is missing feedback and described the repetitions as resulting from an individual believing that: "if you say it and you don't hear it, you think you haven't said it, so you say it again." These disfluencies of "artificial stuttering," as referred to by Lee (1950), were diminished by the use of a metronome, in which the normal speaker timed their speech with the rhythm of the metronome, and also by synchronizing their voice with another's while reading aloud (Brandt & Wilde, 1977). However, studies have revealed that individuals who commonly produce disfluencies, such as those exhibited in stuttering, experienced increased fluency with the use of DAF because the DAF aided in coordination of the antagonistic muscle pairs (Borden et al., 1977).

Altered auditory feedback, such as DAF, masking auditory feedback, and frequency-altered feedback, has long been used to aid in the treatment of stuttering (Lincoln, Packman, & Onslow, 2006). When utilizing DAF as a stuttering treatment, Kalinowski, Stuart, Sark, and Armson (1996, p. 256) stated that the "minimal delay necessary for maximum fluency enhancement" was a 50 ms delay." In one study by Van Borsel, Reunes, and Van den Bergh (2003), the authors investigated how repeated exposure to DAF over a period of time affected the fluency of PWS. Following the experiment, the number of stuttering events for the participants was noted to be significantly less which proved that it was an effective stand-alone treatment

Purpose of the Study

Very little published research exists on DAF and spasmodic dysphonia. However, based on the culmination of the previously mentioned studies, parallels do exist between the physiological symptomatology of stuttering and SD. Furthermore, DAF has been demonstrated to act upon the potential locus of this dysfunction in PWS. This treatment technique has not been extended to those with SD. The purpose of the current experimental study was to investigate the relationship between the application of DAF and the vocal quality of those with ADSD. This study will use perceptual and acoustic measures to aid in determining vocal quality. The current study was designed to answer the following experimental question: what are the effects of delayed auditory feedback on the vocal quality of individuals with adductor spasmodic dysphonia? Although the abnormal laryngeal muscle movement of ADSD is comparable to that of a stuttering block in a person who stutters (PWS), similar treatment techniques have not been implemented for both disorders. Based on research that indicated benefits of DAF in PWS as a result of increased synchronization of the laryngeal muscle movements, the next question became whether DAF would a have similar effect on persons with ADSD due to the similar musculature malfunctions. It was hypothesized that the participants' vocal quality would increase in conjunction with the use of delayed auditory feedback compared to non-altered feedback conditions.

Chapter III

METHODS

Selection of Participants

This study was exempted by the Valdosta State University Institutional Review Board (IRB) (see Appendix A).The participants of this experiment were a 59-year-old male and 46-year-old female with a diagnosis of adductor spasmodic dysphonia prior to participation in this study. The participants' voices are vital to both their professions, as one is a professor and the other is a receptionist. Both participants had previously used Botox treatments prior to the current study but had not received the injections within the past 5 years. While one participant could no longer afford the treatment, the other participant experienced no perceptual difference with the use of Botox. Hearing levels were assessed prior to the initiation of the participant's participation duration and all auditory feedback was set within each individual's comfortable listening range.

Procedure

All of the reading samples in the current study were obtained with the participants seated in a sound-treated booth reading from the first paragraph of the Rainbow Passage (Fairbanks, 1960). The speech samples were obtained by utilizing the KayPENTAX Computerized Speech Lab and an Audio Technica ATM75 headset omnidirectional microphone placed 6 cm at an angle from the participant's mouth. A Plantronics GAMECOM1 PC Headset model number 67003-01, with attached microphone, was placed on the participant. The headphones were connected to KayPENTAX Facilitator model 3500, which was used to produce the DAF. Before reading, the participant was advised to use comfortable speaking loudness. The Rainbow Passage was read once under each condition: first under non-altered feedback, then under DAF with a 50 ms delay, and lastly under DAF with a 150 ms delay. The headset and microphone were worn during the NAF setting as well, to ensure equal conditions between all three contexts. The KayPENTAX Facilitator model 3500 was used to produce the DAF along with the headset and microphone plugged directly into the device. The participants produced 2 minutes of unrecorded conversational speech for each condition to allow for acclimation. The participants were also required to complete 2 minutes of rest time between each recording to reduce any effects of fatigue. The participants were then given the headset with microphone and KayPENTAX Facilitator (for DAF production) to take home and instructed to read a news article for 5 minutes of each day for 1 week before returning to the speech lab. After completion of the week long at-home vocal exercises, the participants completed the same array of tasks as were completed prior to the experimental treatment.

Acoustic data was analyzed for the following measures: fundamental frequency, sound pressure level, cepstral peak prominence (CPP), and low/high (L/H) spectral ratio. When analyzing non-pathological voice productions, one would note the consistent vibratory patterns (periodicity) of the vocal folds with minimal change in the frequency or amplitude (Heman-Ackah, Deirdre, & Goding, 2002). The dynamic qualities of connected speech, especially connected dysphonic speech which has a notable lack of periodicity, make it difficult to ascertain accurate data; however, studies have demonstrated the significance of L/H ratio in "predicting perceived dysphonia severity in connected speech” (Garrett, 2013, p. 20). Decreased L/H ratio is an indicator of dysphonic speech as this suggests the participant’s voice is produced using higher frequency noises, instead of the more harmonic, lower frequency energies. CPP has also been shown to more accurately portray data for connected speech, as both of the measures (CPP and L/H ratio) compare data over time, rather than cycle-to-cycle variation (Garrett, 2013). CPP “is described as a powerful method for extracting the F_0 of a speech signal,” thus measuring the strength of the voice (Fowler, Awan, Gorham-Rowan, & Morris, 2011, p. 642). CPP has been found to be especially useful for gathering information about roughness, hoarseness, and breathiness of a dysphonic voice (Fowler et al., 2011). Fundamental frequency is determined by the number of vibratory cycles per second, which correlates with how high or low one’s vocal pitch is perceived (Garrett, 2013).

Three licensed and certified speech-language pathologists at Valdosta State University were asked to independently rate each of the individual speech samples. All raters were placed in separate rooms and listened to the 12 audio recordings. The raters were given a standardized measure for assessing the perceptual symptoms of ADSD: the Unified Spasmodic Dysphonia Rating Scale (Stewart et al., 1997) (see Appendix A). This form was used to rate the participant’s severity of vocal quality under each condition. The scale was first explained to the raters by the experimenter. A rating of 1 indicated “no instance” of occurrence, 2 indicated “mild” severity, 3 indicated “mild-to-moderate” severity, 4 indicated “moderate” severity, 5 indicated “moderate-to-severe” severity, 6 indicated “severe,” and 7 indicated “profound” severity (Stewart et al., 1997). However, for the purposes of this experiment, several categories were removed from the actual rating form based off of data from the pilot study due to ineffective results and the raters only judged vocal quality in the areas of: overall severity, strained-strangled voice quality, abrupt initiation, and expiratory effort. All raters expressed comfort in their understanding of the rating form and their ability to rate vocal qualities of ADSD. The order of presentation of the audio recordings was randomly assigned to each rater. The raters were blind to which feedback condition the speech sample was obtained under. The raters judged each speech sample and recorded results on the standardized voice rating scale given for a total of 36 ratings (12 per SLP x 3 SLPs).

Identification and Control of Variables

The independent variable of this study was the auditory feedback condition (NAF vs. DAF). The dependent variables of the study were the vocal quality, as determined by the ratings in severity and the acoustic measures obtained by the CSL.

Data Analysis and Interpretation

Both perceptual and acoustic data were obtained on six speech samples from each participant. A series of chi-square goodness-of-fit analyses were conducted on the perceptual data in order to investigate the distribution of the ratings in the following areas: overall severity, strained-strangled voice quality, abrupt voice initiation, and expiratory effort. The acoustical data were subjected to a series of repeated measures ANOVAs in order to investigate mean differences in cepstral peak prominence (CPP), low/high spectral ratio (L/H spectral ratio), fundamental frequency (F_0), and sound pressure level (SPL). All data were analyzed using Statistical Packages for the Social Sciences (SPSS) program.

Chapter IV

RESULTS

In order to investigate if there were significant differences in the acoustical measures of vocal quality, a series of repeated measures ANOVAs were conducted on the data as a function of feedback condition (NAF, DAF 50 ms, DAF 150 ms) and treatment condition (pre-treatment, post-treatment). The following acoustical measures were obtained and subjected to analysis: CPP (see Figure 1), L/H spectral ratio (see Figure 2), F_0 (see Figure 3), and SPL (see Figure 4). No significant differences were found on the mean acoustic data.

In order to investigate if there were significant differences in the distribution of the four perceptual vocal quality ratings as a function of feedback (NAF, DAF 50 ms, and DAF 150 ms) and treatment (pre-treatment and post-treatment), a series of chi-square goodness-of-fit analyses were performed on the perceptual data. The scores were equally distributed among the various conditions; therefore, no statistically significant findings were revealed.

Conclusively, individual analyses were conducted on each individual's acoustic and perceptual data. No discernible pattern was observed for the male participant (Participant 1). However, a pattern of improvement was noted for the female participant (Participant 2) when using delayed auditory feedback, especially when using a delay of

50 ms. Observation of the acoustic data revealed that Participant 2 improved in terms of CPP from 3.491 dB (pre-treatment NAF) to 4.881 dB (post-treatment DAF at 50 ms). However, the L/H spectral ratios yielded inconsistent results. Finally, fundamental frequency results also improved from the pre-treatment NAF condition (196.85 Hz) compared to the post-treatment DAF 50 ms post-treatment condition (207.05 Hz) which is more within the normal range for an adult female.

The perceptual individual analyses once again revealed no discernible pattern for the male participant. However, further investigation of the female data revealed clinically significant improvements in perceived vocal quality.

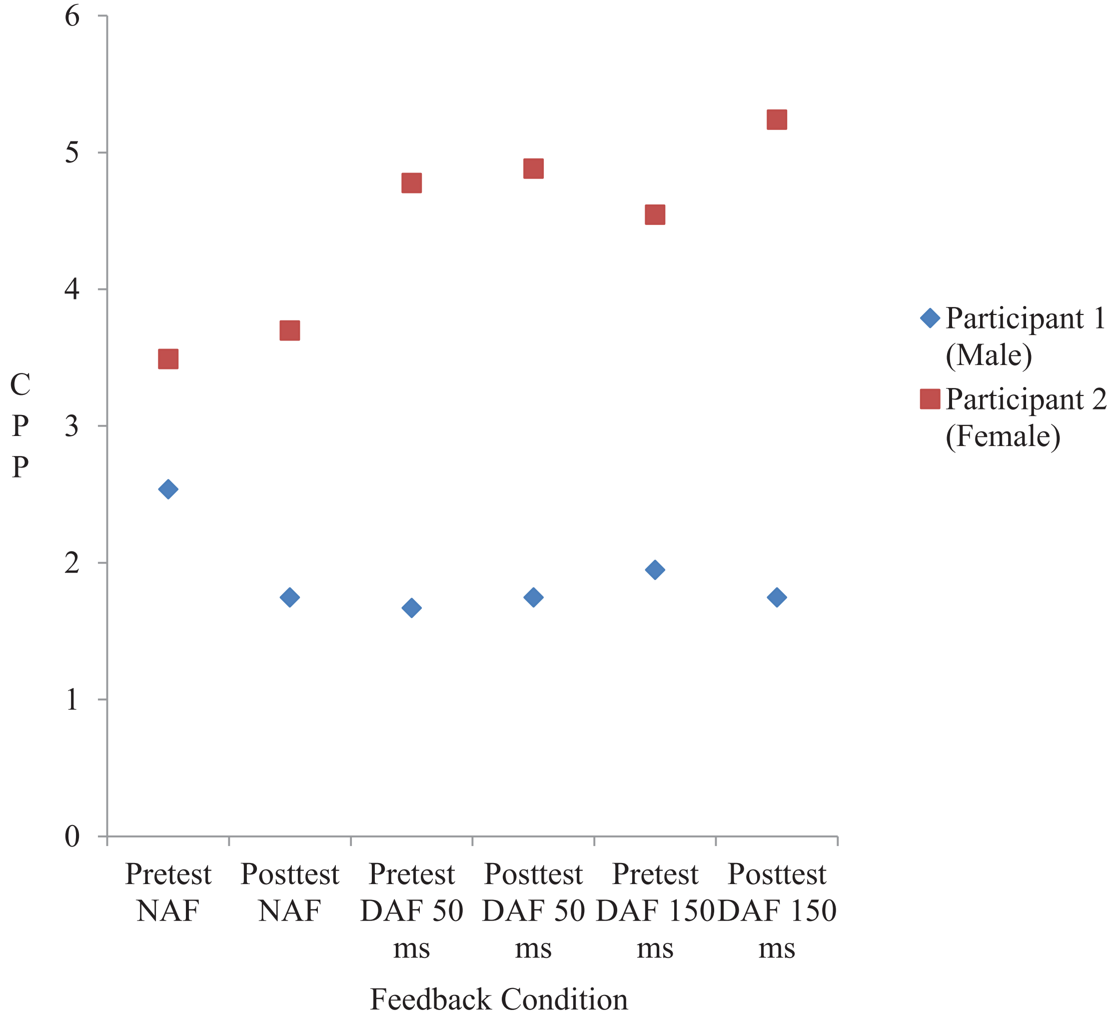

Figure 1. CPP (dB) data of male and female participants, pre-treatment and post-treatment, under all conditions (NAF, DAF 50 ms, DAF 150 ms).

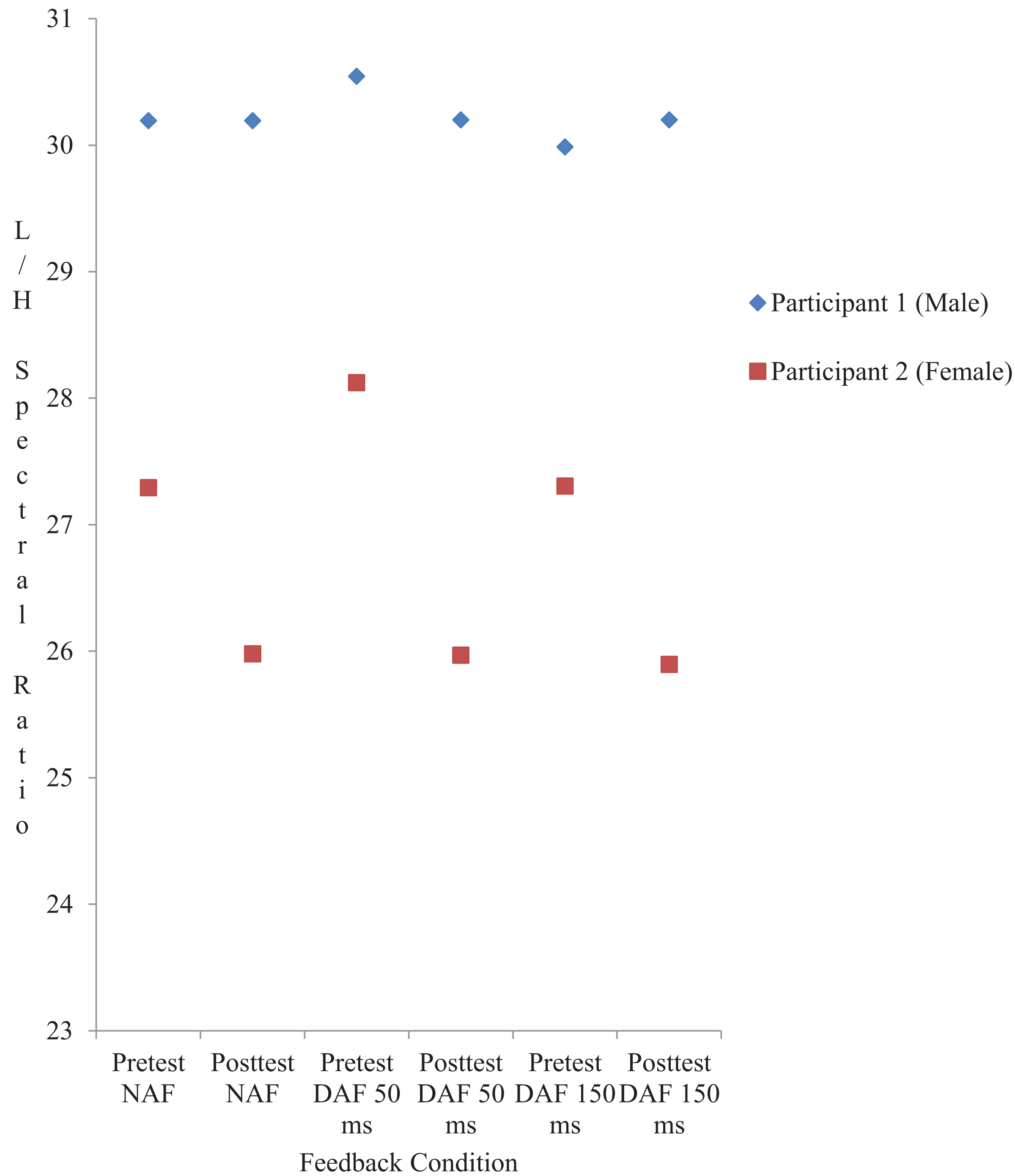

Figure 2. L/H Spectral Ratio (dB) data of male and female participants, pre-treatment and post-treatment, under all conditions (NAF, DAF 50 ms, DAF 150 ms).

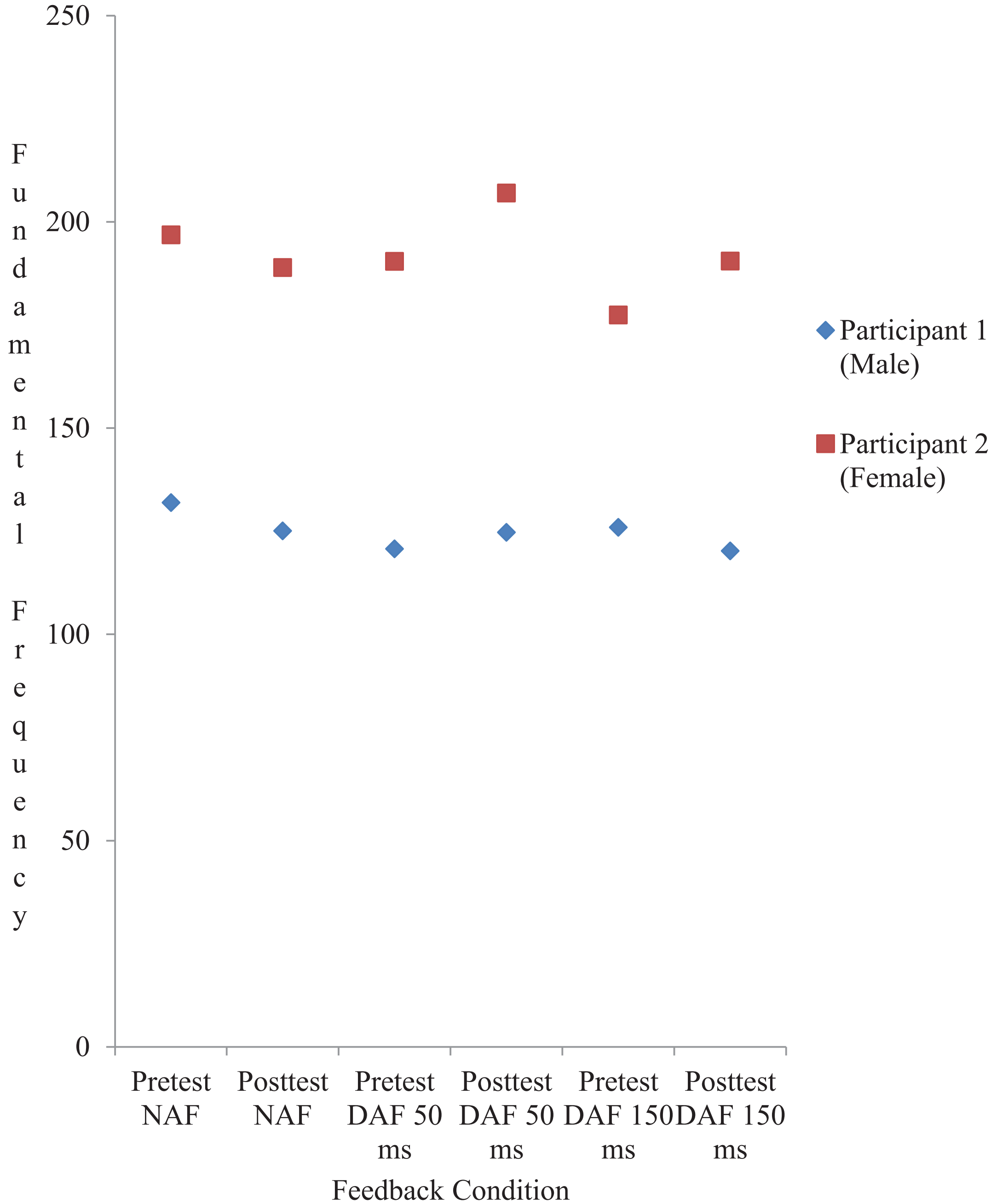

Figure 3. Average speaking fundamental frequency (SFF) (Hz) of male and female participants, pre-treatment and post-treatment, under all conditions (NAF, DAF 50 ms, DAF 150 ms).

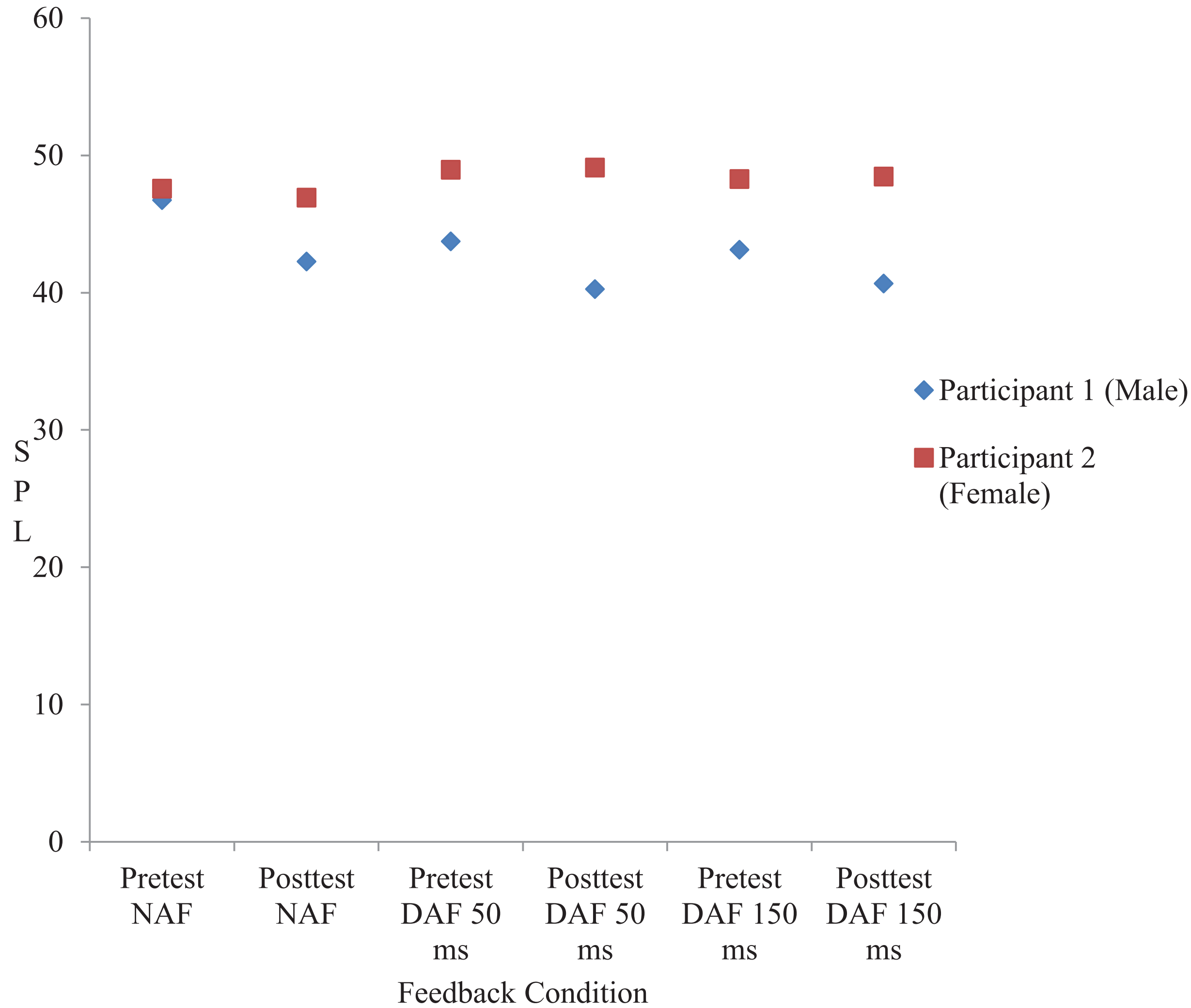

Figure 4. SPL (dB) of male and female participants, pre-treatment and post-treatment, under all conditions (NAF, DAF 50 ms, DAF 150 ms).

Chapter V

DISCUSSION

This study investigated the effects of delayed auditory feedback on the vocal quality of two participants with adductor spasmodic dysphonia. The results of this study suggest that through the use of delayed auditory feedback with a short delay, the perceptual vocal quality of persons with ADSD may increase for some, but further research is needed in this area. It is possible that differential effects were observed on the basis of the gender of the two participants. Although few gender related differences have been observed in the case history or epidemiology profiles of male and female individuals with SD (Izdebski, Dedo, & Boles, 1984), sex differences have been observed in the reactions of normally fluent individuals to delayed auditory feedback (Bachrach, 1964; Corey & Cuddapah, 2008). For example, Corey and Cuddapah (2008) found that males were more negatively affected than females by the utilization of DAF. They found that males produced more stuttering-like disfluencies, spoke slower, and read less accurately than females at various delays. Corey and Cuddapah (2008) did not obtain a vocal quality measure nor did the current study obtain a fluency measure, but it is possible that both fluency and vocal quality share some crossover characteristics which could lead to a positive correlation between the two variables. Therefore, it is possible that what the raters perceived as lower levels of vocal quality when the male participant was using DAF was influenced by decreases in overall fluency. Future research should address this speculation.

Although no statistically significant results were found for the female participant, clinically significant findings were observed. According to the adapted version of the Universal Spasmodic Rating Scale (Stewart et al., 1997), the female participant's overall severity rating while using DAF at a 50 ms delay (post-treatment) was determined to be mild-to-moderate (mean rating 3.000) (see Table 1); whereas, she was rated as having a moderate severity (mean rating 4.000) under non-altered feedback conditions prior to the treatment.

Table 1

Means and Standard Deviations of Overall Severity Rating Obtained from Unified Spasmodic Dysphonia Rating Scale

Condition	Participant 1 Mean (SD)	Participant 2 Mean (SD)
NAF pre-treatment	3.667 (.33)	4.00 (.577)
NAF post-treatment	3.667 (.88)	5.00 (.577)
DAF 50 ms pre-treatment	4.667 (.88)	4.33 (.882)
DAF 50 ms post-treatment	3.667 (.33)	3.00 (.577)
DAF 150 ms pre-treatment	5.000 (1.0)	4.33 (.667)
DAF 150 ms post-treatment	4.000 (.577)	3.33 (.363)

This information is perhaps suggestive of a benefit for using DAF longer-term. Further evidence supporting this theory is based on the female participant obtaining a severity rating of mild (mean rating 2.000) (see Table 3) for abrupt voice initiation during the 50 ms post-treatment session compared to her pre-treatment NAF rating of mild-moderate. In both of these conditions, the participant's perceptual ratings improved the most to DAF at 50 ms, which corroborates the findings in the study by Kalinowski et al. (1996) regarding DAF and PWS.

Table 3

Means and Standard Deviations of Abrupt Voice Initiation Rating Obtained from Unified Spasmodic Dysphonia Rating Scale

Condition	Participant 1 Mean (SD)	Participant 2 Mean (SD)
NAF pre-treatment	3.333 (1.202)	3.000 (.577)
NAF post-treatment	2.667 (1.202)	4.333 (.882)
DAF 50 ms pre-treatment	4.000 (1.155)	4.333 (.882)
DAF 50 ms post-treatment	3.333 (.333)	2.000 (.577)
DAF 150 ms pre-treatment	4.667 (.882)	3.000 (1.155)
DAF 150 ms post-treatment	3.667 (.333)	3.333 (.882)

The female participant experienced the least change in expiratory effort from NAF pre-treatment to DAF post-treatment; a borderline mild severity rating (mean rating 1.667) under non-altered feedback conditions but a mild severity rating for both DAF conditions, 50 ms and 150 ms (see Table 4). This is the only instance in which she received a better rating for NAF compared to DAF. However, her post-treatment DAF severity rating for expiratory effort was lower than her post-treatment NAF rating (mean rating 2.667).

Table 4

Means and Standard Deviations of Expiratory Effort Rating Obtained from Unified Spasmodic Dysphonia Rating Scale

Condition	Participant 1 Mean (SD)	Participant 2 Mean (SD)
NAF pre-treatment	2.667 (.667)	1.667 (.333)
NAF post-treatment	2.000 (.577)	2.667 (.667)
DAF 50 ms pre-treatment	3.667 (.333)	3.000 (.577)
DAF 50 ms post-treatment	3.667 (.882)	2.000 (.000)
DAF 150 ms pre-treatment	4.333 (.882)	3.667 (.882)
DAF 150 ms post-treatment	2.333 (.333)	2.000 (.000)

Although she received the lower severity ratings while using DAF post-treatment for strained-strangled voice quality compared to NAF pre-treatment (see Table 2). The female participant's severity rating dropped from moderate to borderline mild. This interestingly enough occurred when the delay was set at 150 ms. It is noteworthy, however, that the severity rating for DAF at 50 ms post-treatment was mild. In terms of immediacy, all DAF post-treatment conditions display superior vocal ratings than NAF post-treatment conditions for this participant. The largest differences in ratings were seen in overall severity (from moderate-to-severe to mild-to-moderate) and abrupt voice initiation (dropping -2.333 in severity).

Table 2

Means and Standard Deviations of Strained-Strangled Voice Quality Rating Obtained from Unified Spasmodic Dysphonia Rating Scale

Condition	Participant 1 Mean (SD)	Participant 2 Mean (SD)
NAF pre-treatment	4.000 (.577)	4.000 (.577)
NAF post-treatment	4.000 (1.0)	4.333 (.333)
DAF 50 ms pre-treatment	3.333 (.882)	4.000 (.577)
DAF 50 ms post-treatment	3.667 (.667)	3.000 (.577)
DAF 150 ms pre-treatment	4.333 (.667)	4.333 (.667)
DAF 150 ms post-treatment	4.333 (.333)	2.667 (.333)

The male participant showed slightly better severity ratings for strained-strangled voice quality from NAF to DAF at 50 ms, both pre- and post-treatment (see Table 2). However, all other findings for this participant indicate neither clinically significant nor statistically significant findings.

As stated earlier, persons with ADSD have problems initiating voice appropriately (Justice, 2010); however, when using DAF set at 50 ms, the abrupt voice initiation category received the lowest severity ratings over the other two conditions. These results are in congruence with the findings of Borden et al. (1977), which summarized that PWS experienced voice initiation problems, but under DAF the PWS exhibited decreased blocks (i.e., increase in appropriate voice initiation). This change likely occurs due to the speech signal being stretched. This further insinuates the similarities between ADSD and stuttering because the ADSD results are similar to those that one would expect from stuttering results.

It is important to note that when using an increased delay time (150 ms) while under DAF, the participants' severity ratings became more variable and did not demonstrate consistent improvement over the two NAF conditions (pre- and post-treatment). This is possibly due to a number of factors. The male participant stated that, with the delay at 150 ms, he became more distracted and could not focus on his productions. In turn, the participant responded more like a person without a voice disorder would at that delay interval, potentially due to the brain attempting to overcompensate for the time-lag, as explained by Hashimoto and Sakai (2003). This explanation could be seen as further evidence for the previously proposed gender disparity argument. It has been observed that increases in delays are associated with increases in the vocal disfluencies produced by normally fluent individuals (Stuart, Kalinowski, Rastatter, & Lynch, 2002). Once again, the relationship between vocal quality and fluency may exist within certain shared dimensions.

The female participant demonstrated the most benefit in improved phonatory quality from DAF in terms of raw data collected from the acoustic measures. She experienced an increase, both in the pre-treatment and post-treatment data collection sessions in her CPP measures, L/H ratio, and F_0. Her NAF measures for CPP, L/H ratio, and F_0 were all at the low-end of the average range for females. Following the application of DAF at 50 ms, the aforementioned measures all increased. The CPP and L/H ratio data suggest that she experienced a more prominent fundamental frequency and improved harmonic output. These findings were likely associated with increased periodicity of vocal fold vibration secondary to reduced occurrence of the adductor spasms, and correlate to an increase in power and strength of the voice (Garrett, 2013). The increase in fundamental frequency is associated with an increase in pitch of approximately 30 Hz which can be viewed as a clinically significant difference (M. Gorham-Rowan, personal communication, October 22, 2014). It is likely that the participant was utilizing compensatory strategies, as in muscle tension dysphonia, to aid in the stabilization of vocal fold spasms which disrupt the vibratory cycle by contracting infrahyoid muscles that pull the larynx down, creating an excess in tension. When the DAF was applied at 50 ms, the data imply that she decreased the amount of laryngeal tension by decreasing the use of the infrahyoids, and thus increasing her fundamental frequency.

As mentioned, the male participant showed neither an increase in vocal quality perceptually or acoustically. However, pilot data with the same participant showed an increase in vocal quality with DAF at a 50 ms delay. It should also be stated that this participant is on an undisclosed medicine to reduce vocal spasms and therefore interaction effects between the medicine and DAF are unknown. The male participant also reported that he did not adhere directly to the protocol as instructed by the experimenter. With these confounds in mind, it is also possible that the gentleman's results were merely a result of the variable nature of the symptoms of ADSD.

Implications

The implications of this study suggest that more research needs to be completed in this area. In order to further describe the interactions between altered auditory feedback and the vocal qualities of individuals with ADSD more data must be collected in an effort to explain the variable (and sometimes conflicting) results that were obtained with the current research protocol. Specifically, further data should be obtained that provide information on potential gender differences in the efficacy of DAF while investigating the relationship between fluency and vocal quality.

Clinically speaking, the implementation of DAF as a clinical tool continues to remain a potentially viable option. As RLN sectioning is considered an invasive surgery with the normal risks that are involved with such, it also has limited success due to nerve regeneration. Studies have documented nerve regeneration to occur in as little as 4 months post-surgery. Behavioral therapy has been utilized for ADSD to help reduce vocal hyper-functionality associated with the spasms (i.e., increased laryngeal tension, ventricular fold phonation), but left many patients unsatisfied because it did not produce long-lasting effects (Pearson & Sapienza, 2003). The most common treatment for ADSD is Botox injections with temporary results, if any at all. Other than Botox, "there are no known drugs that are prescribed to specifically treat voice disorders" (Dworkin & Meleca, 1997, p. 125). Delayed auditory feedback could potentially be used in therapy or in combination with other treatments, especially for people who do not benefit from Botox or prefer not to use it.

As addressed by Greene (1989), people with spasmodic dysphonia exhibit more severe symptoms throughout the day and when using the telephone. Perhaps the symptoms would decrease if a DAF app could be downloaded to the smartphone and turned on while conversing through the telephone using a headset. Also, if the individual's profession requires the individual to speak for long periods of time, as in teaching or telemarketing, it is possible that DAF could be beneficial in decreasing the severity or symptoms by use of wearing the DAF processor and a headset/earpiece during the long sessions.

Limitations

A limitation of this study is the small sample size used for data collection. It is difficult to generalize across the intended population when utilizing two participants. Secondly, it is possible that by utilizing the same speech passage for each speech sample, the participants could have become habituated to the auditory feedback or to the same passage which could have an effect on the results. Also, as the treatment sessions were unsupervised to more readily accommodate the schedules of the participants, participant accountability proved to be a limitation as not all participants were able to follow daily protocol. Lastly, since the entire study is based on auditory feedback, the hearing levels of the participants could be more rigorously monitored to more accurately ensure no hearing loss which could affect results.

Recommendations

It would be helpful to include different objective measurements when examining the vocal quality in future studies. For example, one might take electromyographic recordings and combine those results with the perceived vocal quality ratings. A variation of the current study would be to use a combination of DAF and frequency altered feedback (FAF) in conjunction to examine if pitch matching could result in improvements in vocal quality. Also, a more supervised treatment of the DAF protocol should be utilized to decrease the possibility of error from external factors, such as participant reliability. One might also consider a more long-term study to identify any benefits of DAF over time. Future studies could also address the relationship between gender and treatment effects in a study similar to the current one. Lastly, it would be interesting for future studies to investigate the effects of delayed auditory feedback on other vocal pathologies.

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Appendix A

Institutional Review Board Exemption Form

Institutional Review Board (IRB)

for the Protection of Human Research Participants

PROTOCOL EXEMPTION REPORT

PROTOCOL NUMBER: **02984-2013** **INVESTIGATOR:** **Dr. Matt Carter**

PROJECT TITLE: **The Effects of DAF on the Vocal Quality of Individuals with Spasmodic Dysphonia**

INSTITUTIONAL REVIEW BOARD DETERMINATION:

This research protocol is **exempt** from Institutional Review Board oversight under Exemption Category(ies) 2. You may begin your study immediately. If the nature of the research project changes such that exemption criteria may no longer apply, please consult with the IRB Administrator (irb@valdosta.edu) before continuing your research.

ADDITIONAL COMMENTS/SUGGESTIONS:

Although not a requirement for exemption, the following suggestions are offered by the IRB Administrator to enhance the protection of participants and/or strengthen the research proposal:

NONE

☐ If this box is checked, please submit any documents you revise to the IRB Administrator at irb@valdosta.edu to ensure an updated record of your exemption

Elizabeth W. Olphie **10/29/13** ***Thank you for submitting an IRB application.***

Elizabeth W. Olphie, IRB Administrator Date ***Please direct questions to irb@valdosta.edu or 229-259-5045.***

Revised: 12.13.12

Appendix B

Unified Spasmodic Dysphonia Rating Scale Form

UNIFIED SPASMODIC DYSPHONIA RATING SCALE

Conversational Speech and Rating Form

Patient Name ________________________________ Date / / Rater:

Scale for rating severity: (circle one)

1 no instance
2 mild
3 mild-to-moderate
4 moderate
5 moderate-to-severe
6 severe
7 profound

Overall Severity	1 2 3 4 5 6 7
Rough Voice Quality	1 2 3 4 5 6 7
Breathy Voice Quality	1 2 3 4 5 6 7
Strained-Strangled Voice Quality	1 2 3 4 5 6 7
Abrupt Voice Initiation	1 2 3 4 5 6 7
Voice Arrest	1 2 3 4 5 6 7
Aphonia	1 2 3 4 5 6 7
Voice Loudness	1 2 3 4 5 6 7
Bursts of Loudness	1 2 3 4 5 6 7
Voice Tremor	1 2 3 4 5 6 7
Expiratory Effort	1 2 3 4 5 6 7
Speech Rate	1 2 3 4 5 6 7
Speech Intelligibility Reduced	1 2 3 4 5 6 7