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Perceptual, Acoustic, and Kinematic Effects of Sentence-Initial, Single-Phoneme Prolongation

in People Who Do and Do Not Stutter

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A thesis submitted to the faculty of
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ABSTRACT

Perceptual, Acoustic, and Kinematic Effects of
Sentence-initial Single-phoneme Prolongation
in People who Do and Do Not Stutter

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This study examined a sentence-initial one-second sound prolongation as a possible fluency-inducing condition in people who stutter. The effects of this prolongation technique on the single sentence utterances of five people who stutter (PWS) and five age- and gender-matched controls were investigated. Variables tested included stuttering percentages, speaking rate, duration of phonated intervals, and correlation between upper lip and lower lip/jaw. Results showed a non-significant trend for less stuttering to occur when participants used the prolongation technique. Significant findings included longer durations of phonated intervals and more negatively correlated upper- and lower-lip movements during the prolongation condition. Rate of speech was not affected. These findings suggest that the prolongation technique caused measurable changes in speech motor control, possibly leading to greater fluency for PWS.

ACKNOWLEDGEMENTS

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Description of Structure and Content

This thesis is presented in a hybrid format where current journal publication formatting is blended with traditional thesis requirements. The introductory pages are therefore a reflection of the most up to date university requirements while the thesis report reflects current length and style standards for research published in peer reviewed journals for communication disorders.

Introduction

One of the most intriguing aspects of developmental stuttering is that a number of conditions can immediately improve fluency. In a survey of 204 people who stuttered (PWS), Bloodstein (1950) received reports of a total of 115 conditions that reduced or eliminated stuttering in the respondents. These fluency-inducing conditions (FICs) included activities such as reading in unison, singing, and speaking to an infant. Bloodstein (1950) divided the FICs into six general categories based on shared features of the conditions. These generalizations were later modified to include the following six factors that influence the frequency of stuttering: (a) amount of communicative pressure, (b) attention to speech, (c) suggestion, (d) conditioned cues for stuttering, (e) generalized tension and anxiety, and (f) anticipation of stuttering (Bloodstein & Bernstein Ratner, 2008). The discovery of conditions that alleviate stuttering has led to greater understanding of the etiology of the disorder and the development of effective treatment approaches.

Traditionally, two theoretical camps are found in the field of stuttering treatment: *stuttering modification* and *fluency shaping*. The goal of stuttering modification is to reduce the severity and negative impact of stuttering by focusing on controlling and improving the reaction to stuttering. The goal of fluency shaping is to eliminate stuttering (and by default the negative reaction to it) by adopting a different pattern of speech production. Despite having different goals, both therapy approaches use FICs to help achieve their goals.

Stuttering modification therapy involves teaching techniques to modify or replace moments of stuttering with other behaviors that are under the control of the speaker and that are more conducive to fluency. Some of these techniques include *pull-outs* (relaxing the articulators to ease out of a tense moment of stuttering), *cancellations* (pausing for a few seconds and

repeating the stuttered word), and *easy stuttering* (intentionally producing relaxed stutter-like repetitions). These and other techniques are at the disposal of the PWS to use whenever he or she needs them. In other words, within stuttering modification, FICs are used to effectively respond to moments of stuttering, thereby decreasing their severity and negative impact on communication. In contrast, the FICs used in fluency shaping are designed to be permanently embedded into the individual's speech pattern. One of fluency shaping's core FICs that lends itself particularly well to therapy is prolonged speech.

Originally described by Goldiamond (1965), prolonged speech is a novel manner of speaking that involves a slow articulation rate, continuous/extended voicing, easy onset of voice, light articulatory contacts, and managed breath support. Several popular and successful treatment approaches based on prolonged speech have been developed since the time of Goldiamond's research (Andrews, Guitar, & Howie, 1980; Ingham, 1984; O'Brian, Onslow, Cream, & Packman, 2003; Onslow, Costa, Andrews, Harrison, & Packman, 1996). The basic protocol of most prolonged speech treatment approaches begins with teaching the PWS to eliminate stuttering by using prolonged speech. Gradually the rate of speech is increased while maintaining the other fluency-enhancing features of the speech pattern such as easy onset of voice, light articulatory contacts, and managed breath support. This new speech pattern is then transferred to the person's everyday communication. A recent systematic review of outcome research conducted between 1970 and 2005 found that therapy programs involving the use of prolonged speech appear to be among the most powerful and effective for producing long-term positive outcomes in adults and adolescents who stutter (Bothe, Davidow, Bramlett, & Ingham, 2006).

Although it is not known exactly how prolonged speech induces fluency in PWS, several plausible explanations exist. Returning to Bloodstein and Bernstein Ratner's generalizations of

FICs (2008), it appears that prolonged speech decreases communicative pressure by reducing demands on motor planning. Another explanation for the fluency gains during prolonged speech relates to motor coordination of speech in PWS. Evidence indicates that PWS often lack coordination within (Choo, Robb, Dalrymple-Alford, Huckabee, & O'Beirne, 2010 ; Smith, Sadagopan, Walsh, & Weber-Fox, 2010) and between (Loucks & De Nil, 2007; Max & Gracco, 2005; McClean & Tasko, 2004; Peters & Boves, 1988) the speech subsystems of respiration, phonation, and articulation. Prolonged speech could be facilitating greater coordination within and between these systems, resulting in decreased stuttering. Finally, some researchers have pointed to the duration of phonated intervals (PIs) as a key to increased fluency. A fairly consistent finding has been that the reduction of stuttering during FICs (including prolonged speech) is often accompanied by a reduction of short PIs, typically in the range of 30 – 200 ms. (Andrews, Howie, Dozsa, & Guitar, 1982; Davidow, Bothe, Andreatta, & Ye, 2009).

Despite its success in helping many PWS, prolonged speech is not without difficulties and criticisms. One undesirable effect that frequently occurs is that clients tend to emerge from therapy with greater fluency, but with speech that sounds noticeably unnatural to listeners (Metz, Schiavetti, & Sacco, 1990; Onslow, Hayes, Hutchins, & Newman, 1992). Several treatment programs have made an effort to overcome this obstacle (Ingham, Sato, Finn, & Belknap, 2001; Onslow et al., 1996), but sounding unnatural is still a serious concern for many PWS who have undergone therapy involving prolonged speech (Cream, Onslow, Packman, & Llewellyn, 2003). Another challenge is that clinicians are not able to reliably identify errors made in the target behaviors of prolonged speech (Onslow & O'Brian, 1998). Participants in treatment programs have also reported having difficulty transferring the skills they learned in therapy to everyday communication situations (Cream et al., 2003). Finally, learning to properly use prolonged

speech is a demanding and time-intensive task, making it difficult for children to use, especially in a school setting where clinicians have large caseloads and more limited time for each child (Bothe, 2002).

One means of overcoming some of the challenges of prolonged speech therapy is to identify the aspects of the speech pattern that are critical for inducing fluency, and eliminate unnecessary elements in therapy (Packman, Onslow, & van Doorn, 1994). For instance, studies have shown that when PWS simply slow down their rate of speech, they are able to speak more fluently (Andrews et al., 1982; Ingham, Martin, & Kuhl, 1974). In an effort to simplify treatment involving prolonged speech, Packman et al. (1994) found that when PWS were shown a video model of the desired speech pattern then instructed to use whichever aspects of the model they preferred, the participants significantly reduced their stuttering. Based on these findings, the Camperdown Program was developed, which provides a video-recorded model of prolonged speech to clients who then incorporate only the fluency-enhancing features they most prefer into their own speech (O'Brian, Packman, & Onslow, 2003).

Based on previous findings (Gow & Ingham, 1992), Ingham et al. (2001) developed a treatment approach that focused solely on reducing the number of short PIs. Participants were fitted with an accelerometer that measured PIs and were provided immediate feedback via computer. This feedback informed the participants of the amount of PIs that they were producing that fell within a target short-duration range. The authors found that participants could achieve fluent, natural-sounding speech by learning to reduce by at least 50% the number of PIs that fell within the target range. This was accomplished without any specific instructions for the participants on *how* to reduce the short PIs; they were simply instructed to rely on the biofeedback.

A topic that needs further investigation is whether an entire utterance needs to be prolonged in order to significantly reduce stuttering, or if similar gains in fluency can be achieved through prolonging isolated segments of speech, such as the first phoneme in a word. This kind of initial-sound prolongation is already used in some therapy approaches. For instance, the Successful Stuttering Management Program (Breitenfeldt & Lorenz, 1999) teaches participants to prolong the first sounds of sentence-initial words, as well as words on which they anticipate stuttering. This technique originates from Van Riper's idea of replacing fluent for abnormal preparatory sets, although Van Riper advocated the prolongation of the entire word rather than the first sound only (Van Riper, 1973). Considering that a high proportion of stuttering happens at the beginnings of sentences, especially shorter sentences (Griggs & Still, 1979; Soderberg, 1967), and over 90 percent of stuttering occurs on the initial sound of a word (Sheehan, 1974), it would seem that prolonging the first phoneme of a sentence would significantly reduce stuttering. It also appears that such a technique would be easier to learn and incorporate into speech outside of the clinic and less detrimental to speech naturalness.

This study aims to determine if prolongation of the initial phoneme in a sentence significantly reduces stuttering in a laboratory setting, and what acoustic and kinematic effects this technique has on the subsequent fluent speech of both adults who stutter and age- and gender-matched controls.

Method

Participants

The experimental group included five males who stutter, ranging in age from 22 to 25 years ($M = 23$, $SD = 1.2$). Control participants for the study included five males, with an age range of 21-25 years ($M = 23.8$, $SD = 1.6$).

All five PWS reported that their stuttering began in childhood and that they had received speech therapy at some point in their lives. One participant was currently in therapy, one participant had received speech therapy within one year prior to the study, two participants reported having received speech therapy between one and five years prior to the study, and one participant had received speech therapy more than five years before the study. Three of the five PWS reported having received stuttering therapy that used prolonged speech as a treatment method, and two participants reported that they continued to use prolongation of speech sounds as a technique to manage their stuttering. Only one of the control participants reported a history of speech-language disorders, which was articulation treatment for the /r/ sound in elementary school. None of the ten participants reported any history of neurological/motor problems.

Stimuli

Reading material consisted of 20 seven- to nine-syllable sentences, presented one by one on a computer screen. The length of seven- to nine-syllables was chosen because Soderberg (1967) found that the position effect (first words being stuttered more frequently) was much more pronounced in clauses of six or fewer syllables. If the sentences in this study were this short, then a large percentage of the gains in fluency could simply be attributed to the first word being spoken fluently. Ten sentences began with vowel sounds and ten sentences began with voiced consonants that are easily prolonged (nasals, liquids, and fricatives). Plosives and affricates were not used as prolonged sounds because by definition they cannot be prolonged. Voiced sounds were chosen so that respiration, phonation, and articulation would all be affected by the prolongation. To assist in the measurement of lip and jaw movements, the sentences were designed to contain several bilabial consonants. All sentences were statements that were subjectively judged to be neutral in content.

Instrumentation

Each participant was seated in a sound booth. Lip and jaw movements were measured with a head-mounted strain gauge system (Barlow, Cole, & Abbs, 1983). Two cantilever beams were attached using double-sided tape to the skin adjacent to the midpoint of the vermillion border of the upper and lower lips to track the lip movements of the speaker, with a third cantilever beam attached to the underside of the participant's chin. The kinematic signals were digitized with a Windaq 720 (DATAQ Instruments) analog/digital converter at 1 kHz. A microphone was attached to the strain gauge system to collect the speech signal, which was digitized at 25 kHz after being low-pass filtered (Frequency Devices 9002) at 12 kHz. Participants were also fitted with an electroglottograph (Glottal Enterprises EG2) to measure changes in the vocal fold contact area during speech, and this signal was digitized at 25 kHz.

Procedure

After reading and signing an IRB-approved consent form, participants were given a questionnaire to fill out, which asked about history of speech/language disorders and specifically about previous treatment for stuttering. Participants then read a 200-word passage and gave a 3-minute monologue on one of several possible topics. Percent syllables stuttered (%SS) and speaking rate were calculated for both of these tasks.

The experimenter then trained the participants on the prolongation technique, which consisted of prolonging the first phoneme of a sentence for a target time of one second. Participants imitated a model provided by the experimenter then tried the technique on several sample sentences with the experimenter observing to ensure that the technique was properly done. Throughout the process, participants were aided by a visual stimulus on the computer. The visual stimulus consisted of an animated cursor, which moved slowly over the prolonged

phoneme for a one-second duration, before stopping at the next phoneme, at which point the remainder of the sentence was highlighted. The participants were instructed to continue prolonging the sound until the cursor stopped and the remainder of the sentence was highlighted. All sentences were to be read at a comfortable rate and loudness with the exception of the prolonged phonemes. Participants were also instructed to avoid using any previously learned techniques to manage their stuttering.

After being trained on the prolongation technique, the participants were presented with the stimulus sentences, one at a time, in blocks of five. All five sentences in the block were either prolonged or not prolonged. In between each block the participants were asked to produce a monologue for one minute. Several topics were provided from which they could choose. This one-minute break was included so that participants could more easily transition from one condition to the next, and to reduce the adaptation effect. On the second time through the sentences, the conditions were reversed so that blocks which were prolonged on the first trial were not prolonged on the second trial, and vice versa. In the end, each participant repeated each sentence twice, using prolongation on one of the two repetitions. Repetitions of the same sentence were separated by all of the other 19 sentences in an effort to minimize adaptation to a particular sentence. After completing all 40 trials, participants were given a five-minute break, then repeated more sentences as part of a separate study.

Data Analysis

Counting disfluencies. Disfluencies were counted and coded for each participant during the reading passage, the 3-minute monologue, and the trial sentences. Two totals were calculated; one which included all types of disfluencies (interjections, revisions, phrase repetitions, word repetitions, partial-word repetitions, sound repetitions, prolongations, and

blocks), and one which only included stutter-like disfluencies (partial-word repetitions, sound

repetitions, prolongations, and blocks). From these stuttering totals, a percent disfluent syllables

(%DS) and percent syllables stuttered (%SS) were calculated, the former including all

disfluencies, and the latter including only stutter-like disfluencies. The only disfluencies not

counted in these totals were the intentional sound prolongations that were part of the

experimental condition.

Duration. Durations in seconds were used to provide a rough measure of speaking rate.

In the reading passage and three-minute monologue, the number of syllables was divided by the

length of durations to produce a measure of syllables per minute. For the experimental sentences,

durations were measured as the time between the beginning of the second word in the sentence to

the end of the final word. This time frame excluded the first word in the sentence in order to

provide a comparable sample from both experimental conditions.

Phonated intervals. Length of PIs was measured by analyzing the EGG signals of the

sentences using speech analysis software. A PI was defined as the time between the first and last

pulse in a segment of voicing as measured by the software program. Figure 1 shows an EGG

waveform of a phonated interval. Following the protocol used by Gow and Ingham (1992), PIs

separated by gaps of less than ten milliseconds were counted as one PI. In order to provide a

valid means of comparing the two experimental conditions, the first PI from each sentence was

excluded from the analysis, as the one-second sound prolongation during the experimental

conditions would have inflated the values for PI duration.
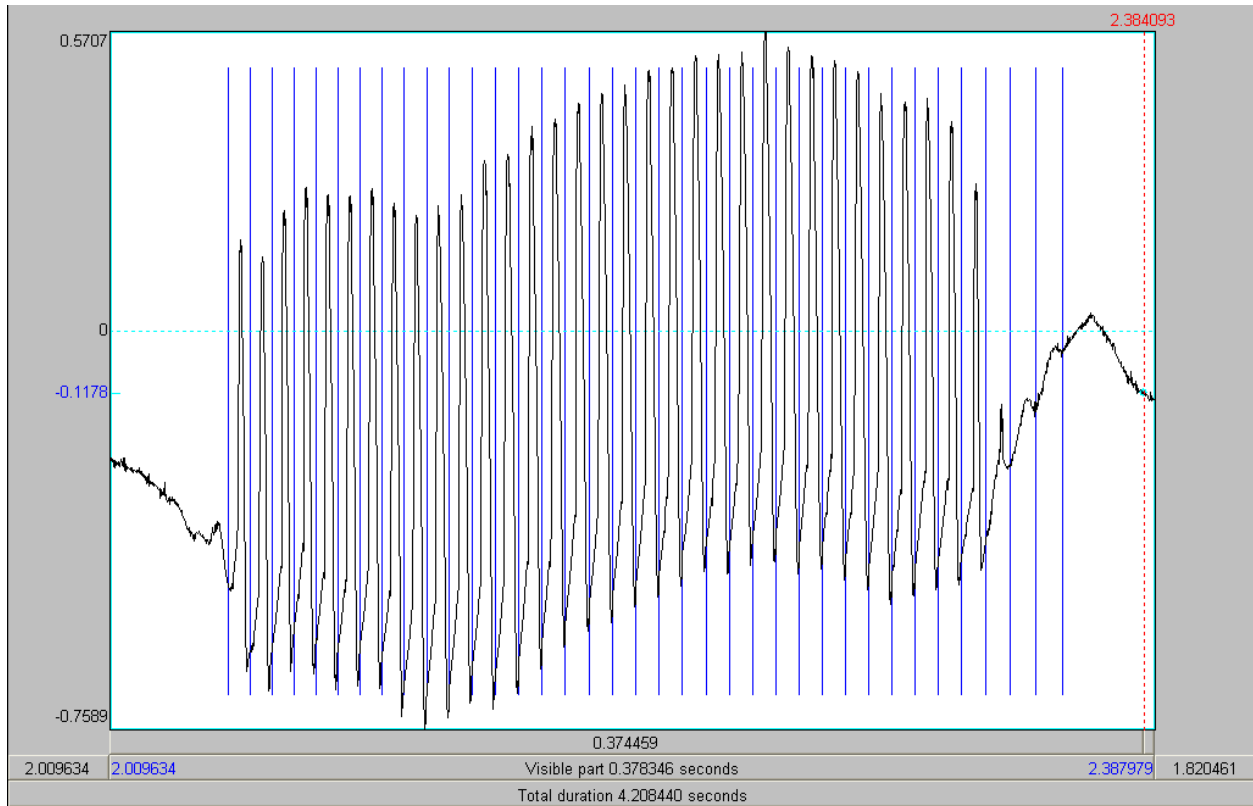
Figure 1. EGG waveform for a phonated interval with vertical lines designating separate pulses. The length of the phonated interval was calculated by subtracting the time in seconds of the first pulse from the time in seconds of the last pulse.

Upper and lower lip correlation. Correlation between upper and lower lip-plus-jaw displacement was computed using custom designed computer software (Matlab). Figure 2 displays plots of upper and lower-lip-plus-jaw displacement and correlation for a sample sentence. Similar to methods previously used to measure labial coordination (Dromey & Bates, 2005; Tingley & Dromey, 2000), it was inferred that correlation scores closer to -1 would indicate greater synchrony for lip approximation and separation, and thus a higher degree of coordination between labial movements. Once again, sentence segments chosen for correlation analysis excluded the first word of the sentence in order to avoid distortion of the data caused by the sound prolongation.
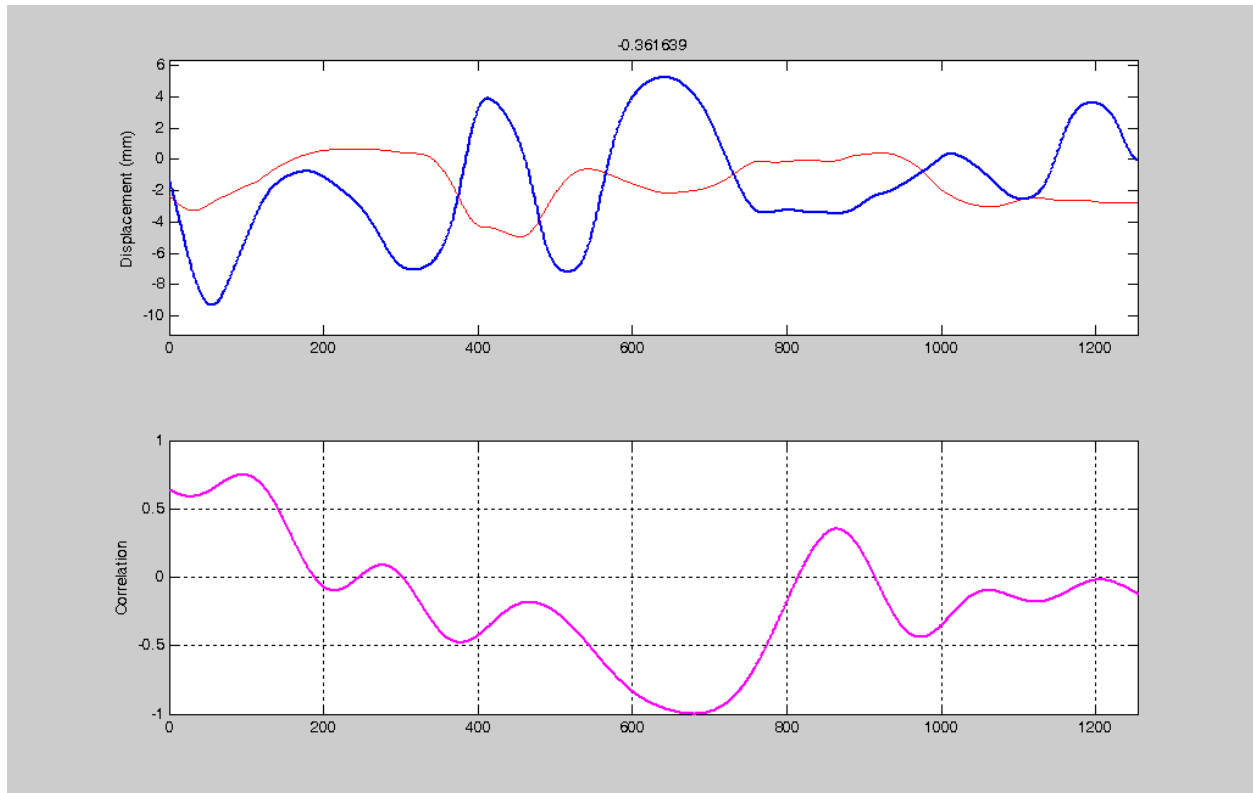
Figure 2. Displacements and correlation of upper- and lower-lip for one stimulus sentence. The upper pane plots lip displacement for the upper-lip (red) and lower lip-plus-jaw (blue). The lower pane plots the correlation between upper- and lower lip-plus-jaw movements. Theoretically, correlation scores closest to -1.0 suggest greater coordination.

Exclusion of tokens containing disfluencies. Because of the impact that disfluencies could have on the variables of duration, phonated intervals, and labial correlation, all sentences that contained identifiable disfluencies were excluded from the analysis of these variables. These exclusions included not only the actual token containing the disfluency, but also its companion sentence from the other condition. In other words, if a given subject stuttered on sentence X during the control condition, then sentence X under both conditions was excluded from the analysis, so that the experimental and control conditions contained congruent samples for

comparison. This allowed for comparisons between conditions, but it did not allow comparison between groups because different sentence pairs were excluded for different participants.

Statistical Analysis

A repeated measures ANOVA examined the effect that prolongation had on the following variables: (a) percentage of disfluent syllables (including normal disfluencies), (b) percentage of syllables stuttered (only counting stutter-like disfluencies), (c) duration in seconds of the sentence (excluding the first word), (d) mean phonated interval, and (e) correlation of the lower lip-plus-jaw and upper lip.

Results

Assessment of Stuttering

As expected, the PWS had higher rates of stuttering than the control speakers during both the reading and monologue conditions.

Stuttering severity. On the reading passage, the PWS averaged 3.01 %SS (*SD* = 2.59) with a range of 0.31 to 6.9. The control group averaged 0.5 % SS (*SD* = 0.36) on the reading passage, with a range of 0 to 0.94. For the three-minute monologue, the PWS averaged 3.45 %SS (*SD* = 2.39) with a range of 1.55 to 7.51, while the control group averaged 0.27 %SS (*SD* = 0.3), ranging from 0 to 0.72.

Speaking rate. A rough measure of speaking rate was obtained during the fluency assessment tasks by dividing the number of syllables spoken by the duration in minutes. During the reading passage, the PWS averaged 221.24 syllables per minute (SPM) (*SD* = 19.07), while the control group averaged 239.54 SPM (*SD* = 36.4). For the three-minute monologue, the PWS averaged 175.97 SPM (*SD* = 27.85) and the control group averaged 193.81 SPM (*SD* = 29.77).

Experimental Task

Disfluencies. During the no-prolongation condition, the PWS averaged 3.5 %DS, compared to 1.88 %DS during the prolonged condition. The control group had a %DS of 0.38 during the no-prolongation condition and 1.13 during the prolonged condition. The repeated measures ANOVA revealed no significant main effect for condition ($p = 0.34$) but a significant effect for group ($p = 0.04$) as well as a significant interaction between group and condition ($p = 0.03$).

Stuttering. When only stutter-like disfluencies were included in the analysis, the PWS averaged 2.88 %SS for the no-prolongation condition and 1.0 %SS for the prolonged condition. The control group had an average of 0.25 %SS during the no-prolongation condition and 0.13 %SS during the prolonged condition. The repeated measures ANOVA revealed a significant main effect for group ($p = 0.04$) and no significant effect for condition, although there was a non-significant trend for less stuttering to occur during the prolonged condition ($p = 0.07$).

Durations. The average durations for the PWS were 1.55 seconds during the no-prolongation condition and 1.61 seconds during the prolonged condition. Average durations for the control group were 1.64 seconds for the no-prolongation condition and 1.67 seconds for the prolonged condition. The repeated measures ANOVA revealed no significant effects or interactions for this variable.

Phonated intervals. The average lengths of phonated intervals for the PWS were 0.224 seconds during the no-prolongation condition and 0.235 seconds during the prolonged condition. In the control group, average phonated intervals were 0.211 seconds for the no-prolongation condition and 0.227 seconds during the prolonged sentences. A significant main effect for condition was found ($p = .002$), with the prolonged condition producing longer mean durations.

Paired samples t-tests revealed that the mean lengths of phonated intervals were significantly longer during the prolonged condition for both PWS ($p = 0.01$) and controls ($p = 0.04$).

Lip correlation. Average lip correlation for the PWS was -0.24 for both conditions. Average lip correlation for the control group was -0.29 during the no-prolongation condition and -0.37 during the prolonged condition. The repeated measures ANOVA showed a significant main effect for condition ($p = 0.03$) as well as a significant interaction ($p = 0.02$). A post-hoc paired-samples t-test showed that within the control group, significantly more negative lip correlations were obtained during the prolonged condition when compared with the no-prolongation condition ($p = 0.008$). The difference between conditions was not significant for PWS ($p = 0.93$).

Discussion

Several relevant findings resulted from this study, despite its limitations. These findings provide some insight into the effects of prolongation and generate questions for future research.

Fluency

One purpose of this study was to determine whether or not a one-second sound prolongation at the beginning of a sentence has a measurable impact on speech fluency. Although it appeared that the technique did indeed induce fluency in the PWS, (the PWS had almost three times as much stuttering during the no-prolongation condition when compared with the prolonged condition), the effect did not reach statistical significance.

A number of factors must be taken into account when considering that statistical significance was not reached. First, the small number of participants made the requirements for reaching significance more rigorous than if a larger sample size had been available. This was especially true when running paired samples *t*-tests within each group that only contained five participants. Another factor that had an impact on the results of the study was the highly variable

severity of stuttering among the PWS, particularly during reading tasks. For instance, one participant had a %SS of 0.31 during the reading passage, which was less than the average %SS of the control group (0.5 %SS). This participant did not stutter on any of the 20 no-prolongation sentences, making it impossible to show any improvement in fluency during the prolonged condition. Finally, a factor that could also have had an effect on the outcome of this study was the variability in type of stuttering therapy and how recently this therapy was received. Time elapsed since completion of therapy ranged from over five years to currently in therapy at the time of the study. Three of the participants had experience with at least some form of prolonged speech therapy, and one of the participants used sound prolongations as a primary tool to manage his stuttering. This familiarity with the technique could have actually exaggerated the effect of sound prolongations during the experiment.

Other Effects on Speech

A second purpose of the study was to measure the temporal, acoustic, and kinematic changes that occurred during the stutter-free speech of PWS and controls as a result of the sound prolongation technique. Several relevant findings resulted from these analyses.

One result was that the sound prolongation technique did not significantly impact rate of speech for the remainder of the sentence. This finding is important for two reasons. First, a slower overall speaking rate would have made it difficult to interpret the rest of the findings because any differences in fluency, phonation, or kinematics could have been attributed to slowing down, rather than the technique itself. Second, the fact that speaking rate (other than the obvious slowing of the first sound) was not affected has implications for the clinical utility of the technique. It may be that a simple sound prolongation could lead to changes in speech and a reduction of stuttering without severely compromising speech naturalness.

Another significant finding was that the average length of phonated intervals increased significantly while participants used the prolongation technique. This phenomenon occurred in the non-prolonged portion of the sentences, in the absence of any changes in speaking rate, and excluding any sentences where disfluencies occurred. Given that Davidow et al. (2009) found similar changes in the duration of phonated intervals during well-established fluency-inducing conditions, this finding provides evidence that single sound prolongation has potential to be a fluency-inducing technique for PWS. Perhaps the most intriguing aspect of this finding was that the increase in the mean duration of phonated intervals occurred not only in the PWS but in the controls as well. This would suggest that the sound prolongation technique actually influenced speech motor control, leading to measurable acoustic changes in speech, as opposed to simply facilitating fluency, which in turn led to the acoustic changes.

One of the puzzling findings of this study was that upper- and lower-lip movements were significantly more negatively correlated (suggesting that they may have been more coordinated) during the prolonged condition, but only in the control group. This result is consistent with findings in a study by Dromey and Benson (2003) in which speakers were found to have stronger negative correlations between upper and lower lip displacements when speech tasks were paired with a challenging cognitive or linguistic task. It could be hypothesized that adding any sort of distracting task to speech production would decrease the neural resources dedicated to planning speech movements, resulting in reduced coordination. However, these findings contradict that assumption and require further research to fully understand.

Limitations

Because of constraints on funding, time, and availability, the number of participants was relatively low. This made it difficult to find meaningful significant effects using inferential

statistics and also led to a lack of stringent subject selection criteria. No participants were excluded from the study, regardless of the severity of their stuttering, whether or not they stuttered while reading, their native language (one participant spoke English as a second language), or their experience with prolonged speech or the prolongation technique. Each of these factors could have influenced the outcome of the study and could be controlled for in a study involving a larger participant pool.

The study was also limited by the setup of the experiment and the stimuli used. As explained in the methods section, a large number of tokens were excluded from the analysis because they contained disfluencies. This was necessary so that only equivalent samples were compared across conditions, but it also meant that group comparisons could not be made and sentences that were easier to say were more likely to be included in the analysis. Drawing conclusions based on the kinematic data was made difficult because of the stimulus sentences used for the study. In previous studies of lip coordination, speakers uttered phrases that contained many bilabial stops and low vowels, e.g., *buy Bobby a puppy*. Under these conditions, a strong coordination between the upper and lower lip during much of the utterance would be indicated by a correlation of -1.0. This is because the lips would be in the act of either opening or closing throughout much of the utterance. The sentences used for the present study, although purposefully constructed with more bilabial sounds than normal, contained many sounds and sound sequences for which the lips would not have a clear phase relationship. Accordingly, it was difficult to infer with confidence that more negative correlations equated to greater coordination of speech movements.

Finally, the fluency ratings and measurements in this study were made by one researcher with no attempt to establish inter-rater reliability. Given the sometimes subtle nature of stuttering

and the difficulty of precisely identifying and coding disfluencies, the validity of the fluency results could be questioned without some measure of inter-rater reliability. Future replications of this study could ensure that inter-rater reliability is established for perceptual measures of fluency.

Future Research

The present study served as an initial probe into the sound prolongation technique, and several questions remain to be answered by future research. A replication of this study with a greater number of participants would certainly help to clarify the current findings. Also, greater control over participant variables could help identify which PWS respond more to the prolongation technique (i.e., how severity, type of stuttering, etc., affect results). Another direction for future research is to determine which elements of the sound prolongation are actually causing changes in speech to occur. This could be accomplished by modifying the length and content of the prolongation. Investigating the perceived naturalness of speakers when using this technique would also be valuable and clinically relevant.

Conclusion

The quest to understand more about the conditions that lead to fluency in PWS continues to be essential to our understanding of the disorder and its treatment. Previous research in this area has yielded valuable insights into stuttering and led to the development of numerous treatment approaches. Despite its limitations, this study provides preliminary evidence of the effects of sentence-initial sound prolongation on fluent and non-fluent speech. These findings have important implications for the use of the prolongation technique in stuttering therapy. Further research would serve to clarify and expand the present results, uncovering additional

clues about the nature of fluency disorders and potentially adding another effective tool in the

effort to assist individuals whose lives are affected by stuttering.

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Davidow, J. H., Bothe, A. K., Andreatta, R. D., & Ye, J. (2009). Measurement of phonated intervals during four fluency-inducing conditions. *Journal of Speech, Language, and Hearing Research, 52*(1), 188-205. doi: 10.1044/1092-4388(2008/07-0040)

Goldiamond, I. (1965). Stuttering and fluency as manipulatable operant response classes. In L. Krasner & L. P. Ullman (Eds.), *Research in behavior modification* (pp. 106-156). New York, NY: Holt, Rinehart & Winston.

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Ingham, R. J., Martin, R. R., & Kuhl, P. (1974). Modification and control of rate of speaking by stutterers. *Journal of Speech and Hearing Research, 17*(3), 489-496. Retrieved from http://jslhr.asha.org/cgi/reprint/17/3/489

Ingham, R. J., Sato, W., Finn, P., & Belknap, H. (2001). The modification of speech naturalness during rhythmic stimulation treatment of stuttering. *Journal of Speech, Language, and Hearing Research, 44*(4), 841-852. doi: 10.1044/1092-4388(2001/066)

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Max, L., & Gracco, V. L. (2005). Coordination of oral and laryngeal movements in the perceptually fluent speech of adults who stutter. *Journal of Speech, Language, and Hearing Research, 48*(3), 524-542. doi: 10.1044/1092-4388(2005/036)

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Journal of Speech and Hearing Disorders, 55(3), 516-525. Retrieved from

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O'Brian, S., Onslow, M., Cream, A., & Packman, A. (2003). The Camperdown Program:

   Outcomes of a new prolonged-speech treatment model. *Journal of Speech, Language,*

   and Hearing Research, 46(4), 933-946. doi: 10.1044/1092-4388(2003/073)

Onslow, M., Costa, L., Andrews, C., Harrison, E., & Packman, A. (1996). Speech outcomes of a

   prolonged-speech treatment for stuttering. *Journal of Speech and Hearing Research,*

   39(4), 734-749. Retrieved from http://jslhr.asha.org/cgi/reprint/39/4/734

Onslow, M., Hayes, B., Hutchins, L., & Newman, D. (1992). Speech naturalness and prolonged-

   speech treatments for stuttering: Further variables and data. *Journal of Speech and*

   Hearing Research, 35(2), 274-282. Retrieved from

   http://jslhr.asha.org/cgi/reprint/35/2/274

Onslow, M., & O'Brian, S. (1998). Reliability of clinicians' judgments about prolonged-speech

   targets. *Journal of Speech, Language, and Hearing Research, 41*(5), 969-975. Retrieved

   from http://jslhr.asha.org/cgi/reprint/41/5/969

Packman, A., Onslow, M., & van Doorn, J. (1994). Prolonged speech and modification of

   stuttering: Perceptual, acoustic, and electroglottographic data. *Journal of Speech and*

   Hearing Research, 37(4), 724-737. Retrieved from

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Peters, H. F., & Boves, L. (1988). Coordination of aerodynamic and phonatory processes in

   fluent speech utterances of stutterers. *Journal of Speech and Hearing Research, 31*(3),

   352-361. Retrieved from http://jslhr.asha.org/cgi/reprint/31/3/352

Sheehan, J. G. (1974). Stuttering behavior: A phonetic analysis. *Journal of Communication*

    Disorders, 7(3), 193-212. doi: 10.1016/0021-9924(74)90031-8

Smith, A., Sadagopan, N., Walsh, B., & Weber-Fox, C. (2010). Increasing phonological

    complexity reveals heightened instability in inter-articulatory coordination in adults who

    stutter. *Journal of Fluency Disorders, 35*(1), 1-18. doi: 10.1016/j.jfludis.2009.12.001

Soderberg, G. A. (1967). Linguistic factors in stuttering. *Journal of Speech and Hearing*

    Research, 10(4), 801-810. Retrieved from http://jslhr.asha.org/cgi/reprint/10/4/801

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Appendix A

Annotated Bibliography

Andrews, G., Guitar, B. E., & Howie, P. (1980). Meta-analysis of the effects of stuttering treatment. *Journal of Speech and Hearing Disorders, 45*(3), 287-307. Retrieved from http://jshd.asha.org/cgi/reprint/45/3/287

This article was a meta-analysis of 42 stuttering treatment outcome studies from 1964-1980. The authors calculated effect size of treatment by dividing the difference between pre- and post-treatment measures by the standard deviation of the pretreatment scores. They determined that on average, the stuttering treatments that were analyzed showed a 1.3 standard deviation improvement from pre- to post-treatment measures. Treatments that used prolonged speech and gentle onset showed the greatest effect size (1.65 and 1.53, respectively). The authors concluded that stuttering therapy is effective and that prolonged speech and gentle onset appear to be most consistently effective in the short and long term.

Andrews, G., Howie, P.M., & Dozsa, M. (1982). Stuttering: Speech pattern characteristics under fluency-inducing conditions. *Journal of Speech and Hearing Research, 25*(2), 208-216. Retrieved from http://jslhr.asha.org/cgi/reprint/25/2/208

The authors of this study were trying to identify changes in speech pattern characteristics that were associated with reduced stuttering. Mean phonation duration, pause proportion, articulation rate, fluent speech rate, mean sentence length, and percentage of syllables stuttered were measured in the speech of three adult males who stuttered during six baseline conditions and 15 fluency-inducing conditions. They found that lengthened mean phonation and slowed fluent speech rate were both factors associated with increased fluency and that they were somewhat mutually exclusive. Only in the prolonged speech/delayed auditory feedback condition did the two factors co-occur. The authors interpreted these results as support for the use of prolonged speech and delayed auditory feedback in therapy because it was the only condition that affected both mean phonation duration and fluent speech rate. They also offered support for the hypothesis that fluency-inducing conditions function by providing increased effective planning time.

Barlow, S. M., Cole, K. J., & Abbs, J. H. (1983). A new head-mounted lip-jaw movement transduction system for the study of motor speech disorders. *Journal of Speech and Hearing Research, Vol.26*(2), 283-288. Retrieved from http://jslhr.asha.org/cgi/reprint/26/2/283

This article reported the development of a head-mounted strain gauge transducer for the purpose of tracking lip and jaw movements. Some of the advantages of this system are increased head mobility when compared with older methods, lightweight components, and low movement artifact. The system is mounted to the head at the zygomatic processes, the mastoid processes, and the cranial vertex. Strain gauge cantilevers are used

to transduce inferior/superior movements of the lips and jaw. The authors proposed that this new system would provide an unobtrusive method to investigate motor speech disorders.

Bloodstein, O. (1950). A rating scale study of conditions under which stuttering is reduced or absent. *Journal of Speech and Hearing Disorders, 15*(1), 29-36. Retrieved from http://jshd.asha.org/cgi/reprint/15/1/29

This study was a survey of 204 stutterers regarding the conditions under which their stuttering is reduced. Participants were asked to rate their amount of stuttering from 1 to 4 for a number of situations, to relate specific experiences when this occurred, and to provide any other conditions which they had found to reduce stuttering. This survey resulted in a list of 115 conditions under which fluency had been induced. Choral reading was the only condition on which 100 percent of the participants reported either hardly any stuttering or no stuttering at all. The author, based upon his reasoning, grouped the conditions into six categories according to similar underlying characteristics.

Bothe, A. K. (2002). Speech modification approaches to stuttering treatment in schools. *Seminars in Speech and Language, 23*(3), 181-186. Doi: 10.1055/s-2002-33751

This paper gives a brief overview of four speech modification approaches that are used to treat children in schools (prolonged speech, length of utterance, response-contingent, and mixed). The author reviewed several studies showing the effectiveness of these treatments with the school-age population. She then addressed some challenges that school clinicians encounter when trying to use speech modification strategies, including misinformation, criticism from those who support stuttering modification, and insufficient clinician-child time. The author provided support for speech modification strategies then suggested using structured homework assignments, intensive supplemental programs, or parental involvement to overcome the challenge of not having enough time.

Bothe, A. K., Davidow, J. H., Bramlett, R. E., & Ingham, R. J. (2006). Stuttering treatment research 1970-2005: I. Systematic review incorporating trial quality assessment of behavioral, cognitive, and related approaches. *American Journal of Speech-Language Pathology, 15*(4), 321-341. Doi: 10.1044/1058-0360(2006/031)

The authors reviewed162 stuttering treatment outcome articles published between 1970 and 2005. After being evaluated by their methodology and outcome, 39 articles met inclusion criteria for the systematic review. The authors found that response-contingent methodologies yielded the most positive results for young children who stutter, and that the combination of prolonged speech, self-management, response contingencies, and other infrastructural variables was the most successful treatment for adults. The authors asserted that self-management and naturalness training appeared to be critical aspects of any treatment involving prolonged speech.

Choo, A. L., Robb, M. P., Dalrymple-Alford, J. C., Huckabee, M., & O'Beirne, G. A. (2010). Different lip asymmetry in adults who stutter: Electromyographic evidence during speech and non-speech. *Folia Phoniatrica Et Logopaedica, 62*(3), 143-147. Doi: 10.1159/000287213

The authors of this study sought to determine if people who stutter exhibited abnormal neurological control of lip movements when compared with people who do not stutter. Electrodes measured activity of the orbicularis oris muscles during single-word production, oral reading, and a lip pursing task. Participants who stuttered showed significantly more activity in the lower left lip than the controls across all three conditions. Participants who stuttered also had less coordinated lip movements. The authors interpreted these findings to support the hypothesis that people who stutter show reversed cerebral lateralization for speech and non-speech oral tasks.

Cream, A., Onslow, M., Packman, A., & Llewellyn, G. (2003). Protection from harm: The experience of adults after therapy with prolonged-speech. *International Journal of Language & Communication Disorders, 38*(4), 379-395. Doi: 10.1080/13682820310001598166

This was a phenomenological study that looked at the experiences of those who had received prolonged speech treatment for stuttering. 34 interviews were conducted over a 2-year period with a total of 10 individuals who had undergone prolonged speech treatment. After analyzing the transcripts of these interviews, the authors identified 12 themes that appeared in the interviews. These themes revealed that the people in this study still experienced difficulties in their everyday lives due to their stuttering, and that prolonged speech techniques alone were not enough for them to effectively manage every communication situation. The authors concluded that treatment programs that use prolonged speech also need to assist individuals in figuring out how to implement prolonged speech into everyday situations and not just in controlled treatment environments.

Davidow, J. H., Bothe, A. K., Andreatta, R. D., & Ye, J. (2009). Measurement of phonated intervals during four fluency-inducing conditions. *Journal of Speech, Language, and Hearing Research, 52*(1), 188-205. Doi: 10.1044/1092-4388(2008/07-0040)

This study tested the hypothesis that the distribution of phonated intervals (particularly the reduction of short phonated intervals) would change during four of the most well-known fluency-inducing conditions: chorus reading, prolonged speech, singing, and rhythmic stimulation. 10 participants were recorded and observed during each of the fluency-inducing conditions, as well as control speaking conditions. The authors found a significant reduction in short phonated intervals that was associated with fluency gains during the experimental conditions. The authors used the evidence from this study to support the use of reducing short phonated intervals in the treatment of stuttering.

Goldiamond, I. (1965). Stuttering and fluency as manipulatable operant response classes. In L. Krasner & L. P. Ullman (Eds.), *Research in behavior modification* (pp. 106-156). New York, NY: Holt, Rinehart & Winston.

The author of this chapter reported work which he did with stutterers using delayed auditory feedback (DAF). Originally, the author was using DAF as an aversive stimulus to decrease stuttering through operant conditioning. He found unexpectedly, that under DAF, the participants began to speak fluently in a slow, prolonged manner. The author devised a stuttering therapy where participants read while under DAF while gradually increasing the speech rate and decreasing the delay time. This was done until the participants were speaking fluently without any DAF. The author labeled this new pattern of speaking as *prolonged speech*.

Gow, M. L., & Ingham, R. J. (1992). Modifying electroglottograph-identified intervals of phonation: The effect on stuttering. *Journal of Speech and Hearing Research, 35*(3), 495-511. Retrieved from http://jslhr.asha.org/cgi/reprint/35/3/495

This is a report of two single-subject experiments using the control of short phonated intervals as a means of reducing stuttering. The subjects were fitted with EGG neckbands and their phonated intervals were analyzed during the initial phase of the experiment. Each subject's range of phonated intervals was divided into decile ranges. The latter phases of the study involved having the subjects see if they could intentionally reduce or increase the number of phonated intervals within their lowest decile ranges and the effects that this manipulation had on fluency. Results showed that the subjects were able to reduce the number of phonated intervals within a 0-200 ms range and that this significantly reduced stuttering. These results were independent from speech rate, but the naturalness of speech was somewhat affected.

Griggs, S., & Still, A.W. (1979). An analysis of individual differences in words stuttered. *Journal of Speech and Hearing Research, 22*(3), 572-580. Retrieved from http://jslhr.asha.org/cgi/reprint/22/3/572

This study was aimed at finding the phonetic, syntactic, length, and positional properties of words that are stuttered. Six stutterers read at least 33 passages, 200 words in length. The authors subjectively identified moments of stuttering and analyzed the words on which these occurred. They found that stuttering occurred most often on words that began with consonants (although one subject showed a reversed pattern), longer words, and words at the beginning of the sentence.

Ingham, R. J., Kilgo, M., Ingham, J. C., Moglia, R., Belknap, H., & Sanchez, T. (2001). Evaluation of a stuttering treatment based on reduction of short phonation intervals. *Journal of Speech, Language, and Hearing Research, 44*(6), 1229-1244. Doi: 10.1044/1092-4388(2001/096)

This outcome study looked at the efficacy of a stuttering treatment program known as Modifying Phonation Intervals. This treatment program uses audiovisual feedback to

train people who stutter to reduce the number of short phonated intervals in their speech. Five subjects were evaluated for speech naturalness, speaking rate, and percent syllables stuttered, both in and out of the clinic on a variety of tasks. These evaluations were made throughout the treatment process and up to one year post-treatment. For all subjects, stuttering was virtually eliminated, speaking rate increased, and speech sounded natural both in and outside of the clinic. The authors suggested that further research is needed with a larger amount of subjects to fully investigate the benefits of this therapy approach.

Ingham, R. J., Martin, R. R., & Kuhl, P. (1974). Modification and control of rate of speaking by stutterers. *Journal of Speech and Hearing Research, 17*(3), 489-496. Retrieved from http://jslhr.asha.org/cgi/reprint/17/3/489

The authors of this study sought to find out how the manipulation of speaking rate affected stuttering frequency in three adult stutterers. The subjects were given visual feedback via a row of lights during spontaneous speaking sessions to help them either reduce or increase their rate of speech by 50%. Measures of stuttering frequency and percentage of words stuttered were taken during the procedure. Results showed that two of the three subjects appeared to have reduced percentages of words stuttered during the slower phase. The results were hard to interpret, however, because of the small number of subjects and the fact that no statistical analyses were performed.

Ingham, R. J., Sato, W., Finn, P., & Belknap, H. (2001). The modification of speech naturalness during rhythmic stimulation treatment of stuttering. *Journal of Speech, Language, and Hearing Research, 44*(4), 841-852. Doi: 10.1044/1092-4388(2001/066)

The authors of this study investigated the use of speech-naturalness ratings as feedback mechanism to increase naturalness of speech during rhythmic stimulation treatment for stuttering. Two female adolescents who stuttered underwent rhythmic stimulation treatment which involved learning to time speech to a metronome beat of either 90 or 180 beats per minute administered by earphones. At the same time, experimenters were listening to the sessions and providing naturalness feedback on a nine-point scale. Participants learned to gradually improve speech naturalness while maintaining gains in fluency. Eventually all stimuli and feedback were removed to see if the participants could maintain fluent, natural-sounding speech. The two participants in this study were able to significantly reduce their stuttering with speech naturalness that was equivalent to two age-matched controls.

Loucks, T. M. J., De Nil, L. F., & Sasisekaran, J. (2007). Jaw-phonatory coordination in chronic developmental stuttering. *Journal of Communication Disorders, 40*(3), 257-272. Doi: 10.1016/j.jcomdis.2006.06.016

The authors of this study tested the hypothesis that people who stutter may have a deficiency in sensorimotor integration, particularly a lack of oral/laryngeal coordination. Eleven men who stuttered and eleven male control participants were trained to complete a task which required them to phonate at a specific point during a jaw-opening exercise. Signals from a head-mounted strain gauge transducer and an EGG collar were displayed

on a computer monitor during training sessions, then the cues were removed for the experimental trials. Results showed that the adults who stuttered had higher movement error and greater variability in jaw-phonatory coordination. The authors interpreted this finding as evidence that people who stutter have an oral proprioceptive limitation.

Max, L., & Gracco, V. L. (2005). Coordination of oral and laryngeal movements in the perceptually fluent speech of adults who stutter. *Journal of Speech, Language, and Hearing Research, 48*(3), 524-542. Doi: 10.1044/1092-4388(2005/036)

This study compared oral/laryngeal coordination in the fluent speech of adults who stutter to the speech of nonstuttering adults. 10 stuttering participants and 10 controls were fitted with a head-mounted strain gauge transducer to measure lip movements and an EGG collar to measure phonation. The experimental task was a CV-CVC phrase by itself as well as embedded into longer sentences, with the medial consonant being a voice bilabial plosive. Analysis of the acoustic and kinematic data revealed that the two groups did not differ from each other with regard to the timing of oral and laryngeal movements, but that the experimental group had longer voice onset times, devoicing intervals, and times between initiation of labial closure and cessation of voicing. The authors interpreted these findings as evidence that people who stutter have difficulty initiating voicing rather than the coordination of articulation and phonation.

McClean, M. D., & Tasko, S. M. (2004). Correlation of orofacial speeds with voice acoustic measures in the fluent speech of persons who stutter. *Experimental Brain Research, 159*(3), 310-318. Doi: 10.1007/s00221-004-1952-8

The purpose of this study was to investigate the hypothesis that people who stutter have problems coordinating the different muscle systems involved in the production of fluent speech. 39 people who stutter and 43 controls were tested in this experiment. Using an electromagnetic movement analysis system, the experimenters tracked upper/lower lip, tongue, and jaw movement. A microphone transduced the audio signal as participants repeated the phrase "a bad daba" at habitual intensity as well as in soft and loud conditions. Analyses were performed to see how well the velocity of orofacial movements correlated with F0 and intensity measures, and how the correlations compared between groups. The authors found that correlations of lower lip and tongue speed to F0 and intensity were significantly lower for the people who stuttered than for the controls. These results were interpreted as evidence of weak connectivity in neural pathways linking the lower lip and tongue to the respiratory/laryngeal system.

Metz, D. E., Schiavetti, N., & Sacco, P. R. (1990). Acoustic and psychophysical dimensions of the perceived speech naturalness of nonstutterers and posttreatment stutterers. *The Journal of Speech and Hearing Disorders, 55*(3), 516-525. Retrieved from http://jshd.asha.org/cgi/reprint/55/3/516

The purposes of this study were to determine if speech naturalness is a parathetic or metathetic continuum, and to investigate the acoustic variables of speech that correlate with speech naturalness. 20 participants who had just completed a 5-week intensive

stuttering treatment program and 20 age- and gender-matched controls were recorded while telling a story about a picture and reading a paragraph. 30 listeners were asked to rate the naturalness of the speakers, half being instructed to use interval scaling and half being instructed to use direct magnitude estimation. By comparing the two methods of rating, the authors determined that speech naturalness is a metathetic continuum, meaning that it is a qualitative scale that can be divided into equal intervals. Analysis of the acoustic variables revealed that voice onset time and sentence duration most significantly correlated with and predicted speech naturalness.

O'Brian, S., Onslow, M., Cream, A., & Packman, A. (2003). The Camperdown Program: Outcomes of a new prolonged-speech treatment model. *Journal of Speech, Language, and Hearing Research, 46*(4), 933-946. Doi: 10.1044/1092-4388(2003/073)

This study reported on the aspects and outcomes of a prolonged-speech treatment called the Camperdown Program. This program was designed with features that were meant to improve upon aspects of traditional prolonged-speech programs that were deemed to be either problematic or unnecessary. First, the Camperdown Program used a video model of the prolonged-speech target rather than having clinicians provide the modeling. Second, the program did not provide programmed instruction, meaning that speech targets and rates were not defined, but clients were instructed to use whichever aspects of the speech pattern they found helpful. Third, stuttering severity was assessed using a Likert scale rather than having the clinician identify and count moments of stuttering. Dependent outcome variables included percent syllables stuttered, syllables per minute, speech naturalness, listener comfort, and self-report evaluations. Assessments were made at two weeks pretreatment, immediately after entry into the maintenance phase, six months after entry, and 12 months after entry. Of the 30 participants who began the program, only 16 remained for the final outcome data assessment. Results for the speech measures showed a significant reduction in stuttering rate to normal levels, accompanied by an increase in speaking rate. Results for speech naturalness and listener comfort were generally positive, but participants' speech was still significantly less natural than matched controls and listeners generally preferred listening to controls than to participants. Self-report data showed positive improvements from the treatment program, but participants reported more stuttering than the speech measures revealed.

Onslow, M., Costa, L., Andrews, C., Harrison, E., & Packman, A. (1996). Speech outcomes of a prolonged-speech treatment for stuttering. *Journal of Speech and Hearing Research, 39*(4), 734-749. Retrieved from http://jslhr.asha.org/cgi/reprint/39/4/734

The authors of this study reported on the outcomes of a prolonged-speech treatment program, using percent syllables stuttered, syllables per minute, and speech naturalness as dependent variables. These measures were assessed at several times during the treatment program, beginning at two months pretreatment, and ending three years post-treatment. Assessments included overt and covert measures both within and beyond the clinic. Of the 32 participants originally recruited for the study, outcome data were reported for only 18, and only 12 participants remained for the final assessment. Results showed significant reduction in stuttering while maintaining normal speaking rate. Participants exhibited

increased stuttering in the covert assessments when compared to the overt assessments. Naturalness ratings were made by the experimenter and were found to be within the range associated with speakers who do not stutter.

Onslow, M., Hayes, B., Hutchins, L., & Newman, D. (1992). Speech naturalness and prolonged-speech treatments for stuttering: Further variables and data. *Journal of Speech and Hearing Research, 35*(2), 274-282. Retrieved from http://jslhr.asha.org/cgi/reprint/35/2/274

The authors of this study looked at how the perception of speech naturalness is affected by speech mode, occasion of the speech sampling, and subject (control v. treated stutterer). Participants included seven clients of a residential treatment program and seven age-matched controls. 29 listeners made naturalness ratings based on a 9-point Likert scale. Results showed that the experimental subjects had significantly less natural speech than control subjects. Naturalness ratings did not differ significantly across times assessed (end establishment phase to discharge from the facility) or speaking task. A separate study revealed that participants with more severe stuttering pre-treatment, had significantly worse naturalness ratings post-treatment.

Onslow, M., & O'Brian, S. (1998). Reliability of clinicians' judgments about prolonged-speech targets. *Journal of Speech, Language, and Hearing Research, 41*(5), 969-975. Retrieved from http://jslhr.asha.org/cgi/reprint/41/5/969

The authors of this study questioned the reliability and usefulness of specific speech targets commonly used in prolonged-speech treatment approaches. These targets include gentle onsets, soft contacts, and continuous vocalization. Seven clinicians who were highly familiar with a particular prolonged-speech program were chosen to be judges in the experiment. They watched and listened to random 1-minute samples of clients in the prolonged speech program. Judges were asked to rate whether or not the speech targets were being used and how accurately they were being used. This was done two times, approximately two months apart. Results showed that intraclinician agreement was 94.7% for detecting the presence of the speech targets, and 80.4% for judging the accuracy. Interclinician agreement was 98.2% for the presence or absence of speech targets, and 55.6% for accuracy of the targets. The authors proposed that given the poor agreement on the accuracy of speech targets but the success of prolonged speech treatments, it is possible that such speech targets are not essential to the success of the treatment.

Packman, A., Onslow, M., & van Doorn, J. (1994). Prolonged speech and modification of stuttering: Perceptual, acoustic, and electroglottographic data. *Journal of Speech and Hearing Research, 37*(4), 724-737. Retrieved from http://jslhr.asha.org/cgi/reprint/37/4/724

This study examined the perceptual (stuttering and naturalness) and acoustic (vowel duration, intervocalic intervals, voiceless voice-onset times, and articulation rate) changes in the speech patterns of four subjects as they participated in a prolonged-speech

treatment program that did not provide programmed instruction on which aspects of the prolonged speech pattern to use. Rather, they were taught to mimic the pattern then allowed to use whichever features they found helpful. Significant stuttering reductions were observed in all four subjects. Acoustic findings varied from subject to subject, but a fairly consistent finding was that decreased stuttering was associated with reduced variability in vowel durations.

Peters, H. F., & Boves, L. (1988). Coordination of aerodynamic and phonatory processes in fluent speech utterances of stutterers. *Journal of Speech and Hearing Research, 31*(3), 352-361. Retrieved from http://jslhr.asha.org/cgi/reprint/31/3/352

This study examined the variables of subglottal pressure, voice onsets, shimmer, jitter, and acoustic durations during the speech of 10 stutterers and 7 control subjects. Participants were native Dutch speakers and the speaking task consisted of one-word utterances to be spoken as soon as they appeared on a TV screen. Analysis of the speech variables revealed that the people who stuttered had more variable patterns of subglottal pressure build-up and more abrupt vocal onsets than controls. Other results were not significant. The authors concluded that the fluent utterances of people who stutter are not homogenous and that the subsystems of respiration and phonation can behave largely independently from one another and from articulatory movements.

Sheehan, J. G. (1974). Stuttering behavior: A phonetic analysis. *Journal of Communication Disorders, 7*(3), 193-212. Doi: 10.1016/0021-9924(74)90031-8

The author of this study performed a phonetic analysis of the moments of stuttering. Phonograph recordings of 500 subjectively defined *stutterings* were made from the speech of 20 subjects. Prolongations were analyzed primarily in regard to length, and repetitions were analyzed in regard to number, rate, type, relevance to the word, position, and relation to the tonic phase. Results showed that all subjects had repetitions and prolongations. Prolongations lasted for a mean length of 0.87 seconds. The mean number of repetitions was 1.5. 96.2% of the moments of stuttering occurred in the initial position of the word.

Smith, A., Sadagopan, N., Walsh, B., & Weber-Fox, C. (2010). Increasing phonological complexity reveals heightened instability in inter-articulatory coordination in adults who stutter. *Journal of Fluency Disorders, 35*(1), 1-18. Doi: 10.1016/j.jfludis.2009.12.001

The purpose of this study was to examine the effects of increased phonological complexity on the inter-articulatory coordination of adults who stutter. The primary dependent variable for this experiment was upper/lower lip correlation, as recorded by an infrared motion tracking system. Participants included 17 adults who stuttered and 17 controls. The speech task consisted of the repetition of nonsense words that varied in length and complexity. The groups did not differ in their ability to correctly produce the nonsense words. The main findings from the kinematic analysis were that the stuttering group had higher lip aperture variability and also showed a marked practice effect from the first five productions to the last five productions.

Soderberg, G. A. (1967). Linguistic factors in stuttering. *Journal of Speech and Hearing Research, 10*(4), 801-810. Retrieved from http://jslhr.asha.org/cgi/reprint/10/4/801

This study looked at the occurrences of moments of stuttering in a reading passage in relation to the syntactic, semantic, and positional properties of the words on which they occurred. 10 adults who stuttered read a 141-word passage. Moments of stuttering were coded as either prolongations or repetitions. For clauses shorter than 7 words, stuttering most often occurred on the first word of the clause. Words at the beginnings of clauses were also more likely to contain a high amount of information. When analyzing for type of disfluency, it was found that prolongation was more likely to occur on lexical words and high information words, whereas repetition was more likely to occur on function words and low information words.

Appendix B

Sentences for experimental reading task:

Make mom's back patio bigger.

Many people buy water bottles.

Never wash whites with vivid colors.

Nice watches will cost big bucks.

Listen when my music begins.

Look for vipers in the pipes.

Red velvet cake makes me full.

Really big poppies are lovely.

Very fast mice could escape.

Vines were coming into the basement.

Ask for a free butter pecan scoop.

Amber whistled while mopping the floor.

Olives make a yummy topping.

On Wednesday my folks will visit.

Up by the mailbox is a puppy.

Ushers will be paid by the band.

It was a very fun party.

Issue more passports in the morning.

Enter by way of the front lobby.

Eggs were chosen for protein.

Appendix C

Consent to be a Research Subject

Introduction

This research study is being conducted by Darrell Matthews, a graduate student in communication disorders at BYU, and Christopher Dromey, a professor in the same department. The goal of the study is to determine the effect of a prolongation technique on speech. You were invited to participate either because you stutter, or because you have never stuttered and can participate in a control group.

Procedures

If you agree to participate in this research study, the following will occur:

- you will be asked to fill out a questionnaire containing basic information about you and any history of speech, language, or neurologic problems you may have had. (5 minutes)

- you will be asked to speak for three minutes about any of three topics which will be provided to you. (3 minutes)

- you will be asked to read a short passage. (1 minute)

- the researcher will teach you how to use a speech technique which involves prolonging certain sounds in your speech. (5 minutes)

- you will be asked to read several short statements, one at a time, using the prolongation technique when indicated. (5 minutes)

- occasionally you will be asked to speak for one minute about a topic which you will choose from several that will be provided to you. (10 minutes)

- during these speaking tasks, you will be fitted with a head-mounted device that measures the movement of your lips, and a device worn around the neck that measures the movement of your vocal folds. It will take about 10-15 minutes to set up and test this equipment once it is in place.

- the entire session will be audio-recorded in order to analyze how the technique affected your speech.

- the session will take place in a sound-treated booth in the researcher's laboratory at a time that is convenient for you.

- total time commitment will be 40-50 minutes.

Risks/Discomforts

There are minimal risks for participation in this study. You may, however, feel some mild discomfort when being recorded because small, lightweight levers will measure the movements of your lips and jaw. At any time you may choose to excuse yourself from the study.

Benefits
There will be no direct benefits to you. It is hoped, however, that through your participation researchers may learn about how a speech prolongation technique may be useful in providing speech therapy.

Confidentiality
The research data will be kept on a password-protected computer and only the researcher will have access to data that could identify you. A de-identified portion of the audio recording will be shared with a licensed speech-language pathologist to assist in the diagnosis of any speech/language disorders. At the conclusion of the study, all identifying information will be removed and the data will be kept in the researcher's locked office.

Compensation
You will receive a $10 BYU Creamery gift card for your participation; compensation will not be prorated.

Participation
Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely.

Questions about the Research
If you have questions regarding this study, you may contact Darrell Matthews at dsharpmatthews@msn.com or (801) 310-9172 for further information. Faculty mentor: Christopher Dromey (801) 422-6461 dromey@byu.edu

Questions about Your Rights as Research Participants
If you have questions regarding your rights as a research participant contact IRB Administrator at (801) 422-1461; A-285 ASB, Brigham Young University, Provo, UT 84602; irb@byu.edu.

Statement of Consent
I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Name (Printed): _____ Signature: _____ Date: _____