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The Effect of Audiovisual Delays with Synchronous and Asynchronous Presentation on Stuttering Frequency

By

Hailey Krieger

A thesis

submitted in partial fulfillment

of the requirements for the degree of

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**Committee Approval**

To the Graduate Faculty:

The members of the committee appointed to examine the thesis of Hailey Krieger find it satisfactory and recommend that it be accepted.

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Daniel Hudock, PhD
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RE: Your application dated 12/4/2012 regarding study number 3827: Inhibition of stuttering via dyssynchronous speech signals

Dear Dr. Hudock:

Thank you for your response to requests from a prior review of your application for the new study listed above.

You are granted permission to conduct your study as most recently described effective immediately. The study is subject to continuing review on or before 12/5/2013, unless closed before that date.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

Submit progress reports on your project in six months. You should report how many subjects have participated in the project and verify that you are following the methods and procedures outlined in your approved protocol. Then, report to the Human Subjects Committee when your project has been completed. Reporting forms are available on-line.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Patricia Hunter (208-282-2179; fax 208-282-4529; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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**The Effect of Audiovisual Delays with Synchronous and Asynchronous Presentation on Stuttering Frequency**

**Thesis Abstract –Idaho State University (2014)**

When individuals who stutter are presented with auditory, visual or audiovisual speech feedback, their overt dysfluencies are reduced. Speech perception is a multimodal process that converges auditory and visual gestures. By presenting asynchronous auditory and visual information, or shifting the temporal components of these signals. This study aims to compare the effect of auditory only signals, visual only signals, synchronous audiovisual signals – with and without delay- and asynchronous audiovisual signals on stuttering frequency. Ten adults who stutter were presented seven conditions which consisted of a Baseline, Real time audiovisual feedback, 200ms DAF, 200ms DVF, DAF and DVF 200 ms delays, DAF 60 ms with DVF 200 ms delays, and DAF 200 ms with DVF 60 ms delay. Stuttering was significantly reduced during all feedback conditions relative to baseline, except the visual only condition. Findings that stuttering was significantly reduced during most feedback conditions supports previous literature.

## Chapter I

## Introduction & Literature Review

Stuttering is an involuntary communication disorder that overtly manifests itself as repetitions, prolongations, and fixations of syllables and words, and which disrupts the fluency of speech (Armson & Stuart, 1998). The severity of stuttering can range from mild to severe and is typically measured by the frequency of disruptions during oral readings and conversations (Riley, 2009). Interestingly, choral speech reduces stuttering 90% to 100% and causes speech to sound natural and effortless to produce (Cherry & Sayer, 1956; Kalinowski, Stuart, Rastatter, Snyder, & Dayalu, 2000; Silverman, 1996). Choral speech is when a person who stutters (PWS) produces speech while perceiving another speaker talking (Bowers, Saltuklaroglu, & Kalinowski, 2011). Choral speech is a form of "second speech signals," which are speech signals that are presented in conjunction with one's own speech. These signals can be presented through auditory and visual modalities.

Similar to choral speech, delayed auditory feedback (DAF) inhibits stuttering by 70%-80% (Andrews, Craig, Feyer, Hoddinott, & Neilson, 1983; Curlee & Perkins, 1973; Kalinowski et al., 1993; Kalinowski & Stuart, 1996; Saltuklaroglu et al., 2009). DAF presents speakers with their own voice at a slight delay. Choral speech can also be presented in the visual modality. Types of visual feedback used to reduce the frequency of stuttering include visual choral speech (VCS) and delayed visual feedback (DVF). VCS occurs when two people are speaking in near synchrony but one person is only mouthing the words the individual who stutters produces speech while the other person mouths similar utterances for the PWS to view during their ongoing speech production.

VCS decreases stuttering by approximately 80% (Kalinowski, et al., 2000). Saltuklaroglu et al. (2004) had participants read and memorize text then produce the 8-12 syllable length phrase while viewing a researcher miming the same utterance. This procedure was performed to determine the effect VCS has on stuttering. In addition to linguistically congruent text, researchers have investigated the effect visual choral speech had on the frequency of stuttering when the 'silently mouthed' material is linguistically different (Saltuklaroglu et al., 2004). It was found that stuttering is decreased by 71% when the visual speech signal is linguistically equivalent and only 35% when the visual signal is linguistically different (Saltuklaroglu et al., 2004).

An analog to DAF in the visual domain is delayed visual feedback (DVF), which is when the visual feedback of the speaker's mouth or face is delayed and presented back to them. Like DAF, DVF reduces the frequency of stuttering. Hudock et al. (2010) presented participants with five different visual feedback conditions. The visual feedback delays were 0 ms (simultaneous visual feedback "SVF"), 50 ms, 200ms, and 400ms. Results reveled that stuttering was inhibited up to 62% when presented with a delay over 0 ms and there was no significant difference between the different amounts of delay time. However, there was a difference between baseline to simultaneous and all delayed feedback conditions. Similarly, Snyder et al. (2009) investigated the effect of self-generated visual feedback that was synchronous and asynchronous. Participants recited memorized passages during three different conditions (baseline – no feedback, synchronous – watching their speech movements in a mirror, and asynchronous – watching their speech movements on a monitor that presented a slight delay). Stuttering was decreased significantly during both synchronous and asynchronous conditions.

As there are differential effects in stuttering from second speech signals that are presented via auditory, visual and audiovisual modalities simultaneously as compared to those presented with delays, it is relevant to explore the effect of other conditions that alters speech perception on stuttering frequency. One such condition is the McGurk effect that occurs when a listener watches a speaker's lips and tongue movements of one syllable, but hears a different syllable (McGurk & Macdonald 1976; Galantucci, et al., 2006). It results in the listener perceiving a completely different syllable than the one heard or seen from the speaker. This effect provides evidence that speech perception is a multimodal process integrating both visual and auditory information (Mai, 2009). An example of the McGurk effect is presenting the syllable "ba" auditorily and the syllable "ga" visually on audiovisual presentations, which causes the observer to perceive the syllable "da" (McGurk & Macdonald 1976).It has been found that certain syllables display the McGurk effect better than other consonant combinations. "ba/ga" syllable combination exhibited stronger effects than "pa/ka" combinations did (McGurk & Macdonald, 1976). Wright and Wareham (2005) researched the effectiveness of the McGurk effect when it is presented at the sentence level instead of only the syllable level. Participants were presented a video of a person mouthing "He's got your boot" while "He's gonna shoot" was presented auditorily, and asked to tell what they heard. Many participants reported hearing "He's got your shoe," demonstrating the McGurk effect at the sentence level. This study provides more flexibility to interpretations of the McGurk effect because sentences are more complex and used in our daily lives. For example, researchers presented synchronous and asynchronous audiovisual feedback to participants and when participants were presented audio before visual feedback the McGurk effect was still perceived even when the delay was 180ms. (Munhall, Gribble, Sacco, & Ward, 1996).

It is thought that the left superior temporal sulcus (STS) is the central location in the brain where audiovisual integration takes place during speech perception, indicating it as the place the McGurk effect happens (Nath & Beauchamp, 2011). Specifically, the STS is responsible for the visual representation of observed actions (Miall, 2003). It is estimated that 26% to 98% of the population experiences the McGurk effect; however that means that there are individuals who do not perceive the effect (Gentilucci & Cattaneo, 2005; McGurk & MacDonald, 1976). Nath and Beauchamp (2011) examined brain activity in individuals through an fMRI when they were presented stimuli that should induce the McGurk effect. They found that the STS had a stronger response to the audiovisual stimuli in those who perceived the McGurk illusion than those who did not perceive it. This demonstrates that non-McGurk perceivers may be ignoring the visual stimuli and focusing on the auditory cues presented.

The STS is associated with a neurological system called the Mirror Neuron System (MNS). The MNS is thought to be the neurophysiological basis for the link between perception and production of biologically salient goal directed objectives (e.g., speech, grasping or walking) (Rizzolatti & Arbib, 1998). Mirror neurons are a particular class of sensorimotor neurons that activate both when an action is performed and when observing a similar action (Rizzolatti & Craighero, 2004). This system is activated when perceiving audio or visual speech (Gallese & Goldman, 1998). Furthermore, researchers note neuromotor activity during various speech perception tasks, especially when the signal is degraded (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). MNS activate the premotor areas such as STS and Broca's area similarly during both perceiving the action and producing the same action (Rizzolatti & Craighero, 2004). Interestingly, premotor areas and the STS are thought to be integral in Max's Global Model of Sensorimotor Control, which incorporates both a feedforward control systems and a feedback control system that depends on the updating of the internal model system (Max, Guenther, Gracco, Ghosh, & Wallace, 2004).

In the directions into velocities of articulators (DIVA) Model of speech production one generates a predictive motor plan for the timing and sequencing of the articulators prior to speech production (Guenther, 1994). During and after these predictive command are executed the feedback system compares sensory (e.g., auditory and kinesthetic) information to the planned predictive model. Internal models must be updated and accurate because the neuromotor system in continually changing. If internal models are not being updated, it could make it impossible to create a motor plan and predict the sensory outcome of the planned movement resulting in dysfluent or incorrect production of speech. Max et al (2004), postulated explanations for the reduction in stuttering under auditory or visual feedback via the DIVA model. Max et al., (2004) explain these reductions as correcting for an overreliance on feedback control systems by altering feedback input. Similar to Max's hypothesis, models incorporating gestural theory, such as a weaker motor involvement and the MNS may explain reductions in stuttering from second speech signals utilizing similar processes. In other words, the comparator of feedforward and feedback processes described in the DIVA model, may be occurring in the STS as well as pools of sensorimotor neurons in the MNS.

Given that perception of auditory and visual ‘second speech signals’ reduces the frequency of stuttering and that perception of synchronous and asynchronous audiovisual feedback, as in the McGurk effect, alters speech perception, also neural processing and their locations for the McGurk effect overlaps with models of stuttering inhibition, the current study sought to explore the relationship of stuttering during the perception of audio, visual, and audiovisual synchronous and asynchronous feedback to infer about the hierarchy and location of inhibitory processing.

## Chapter II

## Methodology

*Participants*

Ten individuals with mild overt stuttering participated in the study. Participants were speakers of English and had no self-reported history of other speech, language, cognitive, reading, hearing or uncorrected visual deficits. Participants were recruited via word of mouth from the local stuttering support groups or referred by independent sources. Informed consent, approved by Idaho State University Human Subjects Committee, was obtained from each participant prior to the experiment.

*Conditions*

Each participant completed seven total conditions. All condition presentation sequences and passages were randomized using randomizer.org (Urbaniak & Plous, 2011). Participants were presented 8-12 syllable length utterances that were taken from a 300-syllable length passage. Passages were at the $3^{rd}$ and $4^{th}$ grade reading level and of similar linguistic complexity (Remedia, 2006). Participants memorized the passage of text and repeated the utterance into the camera, which was focused on the participant's whole face. The seven conditions were: 1) Baseline – no feedback, 2)Audiovisual feedback in real-time, 3) 200 millisecond (ms) DAF, 4) 200 ms DVF, 5) 200 ms audiovisual feedback with a synchronous delay, 6) 60 ms DAF with 200 ms DVF, and 7) 200 ms DAF with 60 ms DAF. 200 ms delay settings were chosen for auditory only, visual only and audiovisual synchronous conditions because 200 ms delays are midpoint in DAF (Dayalu, 2004; Kalinowski, Stuart, Sark, & Armson 1996) and DVF (Dayalu, 2004; Hudock, et al., 2010) studies examining stuttering inhibition across delay settings, and have not revealed significant differences between their respective DAF or DVF delay settings. DAF does significantly reduce stuttering to a greater extent than DVF (Dayalu, 2004), but no differences within DAF or DVF have been noted if there is a delay present. Additionally, the 200 ms delay setting allowed for a 140 ms temporal window for the auditory and visual signals during the asynchronous conditions, which is recommended when using sentence presentations for the McGurk Effect (Galantucci, et al., 2006).

*Procedure*

Participants were verbally briefed about experimental procedures then read and signed informed consent documents. Before participating, researchers demonstrated experimental procedures and the participant practiced until comfortable with all tasks (typically 2-3 phrases). Practice conditions were completed using nonexperimental text. Researcher presented participants 8-12 syllable length utterances that were displayed on a MacBook 13 in computer monitor via PowerPoint. Participants silently read and memorized text then viewed the monitor as they said the memorized passage. This was repeated for all seven conditions, even when no feedback was present, to maintain consistency of procedures. Participants performed two-minute spontaneous conversations with researchers between conditions to reduce any potential carryover effects.

*Stimuli*

The stimuli used in this study were 8-12 length utterances taken from 300 syllable length passages from 3$^{rd}$ to 4$^{th}$ grade reading level. All passages were of similar linguistic complexity. These passages were taken from Biographies: Skill-Based Story Cards (Remedia Publications, 2006). No utterances were used more than once in the study and all condition sequences were randomized. The stimuli were presented via PowerPoint from a laptop with a white background and black font.

*Instrumentation*

Participants repeated memorized text, 8-12 syllables in length, as they were audiovisually recorded by a HD H23 AIPTEX digital video camera. The text was presented to them via PowerPoint from a laptop positioned 24 inches adjacent to the participant. The video camera was placed 24 inches directly in front of the participants with an orientation of 0 azimuth. The stereo audio signal from the recorder was sent to the Harman/Kardon AVR3600 digital audiovisual processing unit to add delays. From the digital signal processor, a mono RCA cable transmitted the signal to a Samsung Sync Master p2770 monitor for audio output on the monitor's built in speakers. The video output from the camera inserted into a custom Allen Avionics visual delay unit for visual delay. The visual output was then displayed on the Samsung Sync Master p2770 monitor. As the audio signal was routed through the monitor's speakers, researchers covered the monitor during the audio-only condition. In the visual-only condition, researchers simply unplugged the audio RCA cable from the monitor. During the SVF condition, researchers switched the Harman/Kardon to bypass mode and plugged the video output from the camera directly into the monitor's RCA video input.

## Chapter III

## Results

Stuttering was defined as syllable repetitions, phoneme prolongations, and postural fixations (i.e., “silent blocks) (Armson & Stuart, 1998). The student researcher, second author, was trained to identify instances of stuttering by the first author, a certified speech-language pathologist and an Assistant Professor with an expertise in Fluency Disorders, who also analyzed a randomized 10% of the data for inter-rater reliability. Cohen’s Kappa (SPSS 21.0 for Mac) syllable-by-syllable agreement (Cohen & Cohen, 1983) revealed a *Kappa* value of 0.731. Values above 0.41 represent moderate agreement and values greater than 0.75 represent excellent agreement (Viera & Garrett, 2005). Researchers analyzed audiovisual recordings for frequency of stuttering episodes then calculated proportional values by dividing the number of stuttered syllables by 300 (i.e., syllable length per passage). For inferential analysis, stuttering episodes were transformed into arcsine units to reduce end point weighting of proportion values during inferential statistical analysis (Viera & Garrett, 2005).

A one-factor repeated measures analysis of variances (ANOVA; SPSS 21.0 for Mac) was conducted to examine the effect of condition on stuttering frequency. A significant main effect was revealed [$F(3.340, 30.064) = 4.736$, *Greenhouse-Geisser* $p = 0.006$, partial eta squared ($\eta_p^2$) = 0.345]. To examine the source of the main effect of condition, comparisons with least significance difference (LSD) post hoc adjustments were used. Researchers chose LSD adjustments due to the number of comparisons being made, sample size, and small effect size. Differences were revealed between the following: Baseline – no feedback to: all feedback conditions ($p < 0.05$) except 200ms

DVF ($p = 0.091$); Audiovisual feedback in real-time to200ms DAF ($p < 0.05$); 200ms DVF to 200ms DAF with 60ms DVF. It should also be noted that trends toward significance were revealed for Baseline- no feedback to  200ms DVF ($p = 0.091$), audiovisual feedback in real-time to 200ms DAF 60ms DVF ($p = 0.063$), 200ms  DAF to 200ms DVF ($p = 0.057$), 200ms DVF to 200ms audiovisual feedback with a synchronous delay and 200ms DVF ($p = 0.062$), and between asynchronous 1 (60 ms DAF with 200 ms DVF) and asynchronous 2 (200 ms DAF with 60 ms DAF) ($p = 0.098$).

## Chapter IV

## Discussion

This is the first study to compare auditory only and visual only feedback to audiovisual feedback with a synchronous and asynchronous presentations for stuttering inhibition. Stuttering frequency was significantly reduced during all conditions when compared to the baseline, except for DVF. Stuttering was reduced by 36% during DAF at 200ms, 15% with DVF at 200ms, 16% during audiovisual feedback in real-time, 41% 200ms DAF with 60ms DVF, 20% 60ms DAF with 200ms DVF and 34% 200ms audiovisual feedback with a synchronous delay. Current results support previous findings that stuttering is significantly reduced during the presentation of speech feedback (Andrews et al., 1983; Curlee & Perkins, 1973; Kalinowski et al., 1993; Kalinowski & Stuart, 1996; Saltuklaroglu et. al., 2009). However, contrary to previous literature, no differences were revealed for the DVF feedback condition, although there was a trend present. This is the first study examining stuttering inhibition using altered forms of speech feedback that reported such low effect sizes and small percent reductions in stuttering frequency. A possible explanation for these findings is that participants from the current study exhibited very mild overt stuttering as compared to previous studies. (Please see *Table 1* for the proportion of stuttering and standard errors by participant.) As indicated by the data presented in *Table 1*, participants from the current study were very mild in terms of overt stuttering. The current study reported 5.7% proportion of stuttering during baseline conditions, which is much less than Saltuklaroglu, et al., 2009 that reported 13% proportions of stuttering during baseline no feedback conditions.

Although the current study revealed much smaller percent reductions than previous studies, the trend of audio signals exhibiting a greater reduction than visual only signals, and delayed signals being more effective than signals presented in real-time remained. Stuttering was reduced from approximately 35 - 40% during conditions that had an auditory component with a delay. This is less than the 60-80% reductions commonly reported when participants verbally read text under altered auditory feedback (AAF) (Andrews et al., 1983; Curlee & Perkins, 1973; Kalinowski et al., 1993; Kalinowski & Stuart, 1996; Saltuklaroglu et al., 2009). Interestingly, the results are more comparable to percent reductions found during more hierarchically difficult communication situations, such as conversational samples (Armson, Kiefte, Mason, & Croos, 2006). As previously described, results from the current study did not reveal significant differences between DVF to baseline, although, a trend towards significance was revealed. This is the first study that did not report significant differences from visual only speech feedback to baseline conditions. This finding was unexpected and does not align with the literature. Reduction in stuttering during DVF of speech gestures ranges from approximately 30% (Dayalu, 2004) to 60% (Hudock, et al., 2010). In the current study DVF at 200ms decreased the frequency of stuttering by 15%, which was less than what was expected. Both Hudock et al., (2010) and Dayalu (2004) reported significant differences from DVF feedback conditions (i.e., 0 ms, 50 ms, 200 ms, and 400 ms delays) to baseline, and neither reported significant differences between the feedback conditions, if delayed (not real-time, 0 ms). However, there was a trend present in both DVF studies that longer delays reduced stuttering to greater extents. Findings in DAF also indicate no significant differences between delay settings, but tend to exhibit greater reductions with smaller (i.e., 50ms) rather than larger delay settings (Dayalu, 2004; Kalinowski & Stuart, 1996; Saltuklaroglu et. al., 2009). Similar to the current study, researchers revealed greater reductions in stuttering frequency if signals were delayed as compared to presented in real-time (Dayalu, 2004; Hudock, et al., 2010; Snyder, et al., 2009). In the current study, stuttering was reduced 16% during real-time audiovisual feedback as compared to approximately 40% during real-time visual only feedback in the previous studies (Dayalu, 2004; Hudock, et al., 2010).

Snyder, et al. (2009) examined the effect that synchronous and asynchronous visual speech feedback has on stuttering frequency. Snyder, et al. (2009) defined synchronous visual feedback as being produced when the participants focused on their own lips, mouth, and jaw while using a mirror. Asynchronous feedback was defined as being produced when participants were presented with a delayed video signal. However, the current study operationally defined synchronous audiovisual feedback as two signals presented at the same time. Asynchronous audiovisual feedback was defined as presenting audio feedback before the visual feedback, or in another condition presenting visual feedback before the auditory feedback. In the current study stuttering was reduced by 41% during the 200 ms audiovisual synchronous condition and only 20% during the auditory before visual condition (DAF 60 ms and DVF 200 ms) and 34% during the visual before auditory condition (DAF 200 ms and DVF 60 ms). There has been no previous research on the effects of synchronous and asynchronous audiovisual presentations on stuttering. Both audiovisual synchronous and asynchronous feedback inhibited stuttering, however the current study found 34% reduction when visual was presented before auditory signals which makes it approximately equally as effective as the synchronous condition. When auditory signals were presented before visual they only decreased stuttering by 20%, being represented of a disruption occurring during speech perception.

Results revealed no significant differences between synchronous or asynchronous audiovisual feedback, however stuttering was decreased to a greater extent when visual was presented before auditory feedback (200 ms DAF with 60 ms DVF). Van Wassenhove, Grant, and Poeppel (2007), reported that when auditory feedback is presented before visual feedback the integration of the McGurk effect decreases when compared to having the visual feedback presented before the auditory feedback increases the integration of the McGurk effect. The McGurk effect can be integrated within a temporal window of 200ms between the audio and visual feedback (van Wassenhow et al., 2007). Researchers have found that when a visual signal was presented within proximity of 200ms to the auditory signal the McGurk effect is the most effective (van Wassenhow et al., 2007). As speech perception relies on both auditory and visual feedback, the left superior temporal sulcus (STS) is a primary location in the brain where this multimodal audio and visual integration in the McGurk Effect is hypothesized to occur (Miall, 2003; Nath & Beauchamp, 2011). The brain processes auditory speech signals faster and more efficiently than visual only speech information (Hickok & Poeppel, 2007). This effect can be behaviorally represented in accuracy and reaction time of audio, visual and audiovisual studies of speech perception (Altieri & Hudock, 2014). Therefore when visual feedback was presented before auditory the processing time essentially approximated the signals, however when auditory feedback was presented before visual they became more distant. So one can likely conclude that due to temporal processing requirements of auditory and visual speech signals, the temporal window for the auditory before visual percept increased therefore reducing the effectiveness of the reduction in stuttering.

We will explain the findings from the current study by applying them to two models, first, the Gestural Model of Stuttering Inhibition (GMSI) (Hudock et al., 2010) and second, Max's Inverse Model of Sensorimotor Control (Max et al., 2004). Both of these models suggest that sensory feedback alters nerualmotor areas. The GMSI proposes that gestural cues are extracted from second speech signals simultaneously, which influences speech production by decreasing the frequency of stuttering (Hudock et al, 2010). This is based on neural motor areas being involved to varying degrees during speech perception (Nath & Beauchamp, 2011). Simply put, when humans perceive speech there is neural motor involvement by the brain processing the auditory and visual speech gestures similarly to how it plan to produce the same movements. Therefore perception is activating production mechanisms and inhibiting overt stuttering from occurring. The DIVA model is a model of speech production that involves a feed forward control and a feedback control (Guenther 1994; Tourville & Guenther 2011). Max et al., (2004) applied the DIVA model to stuttering, which they predict that speech production generates a predictive motor plan for the timing and sequencing of the articulators prior to speech production. During and after these predictive commands are executed the feedback system compares sensory (e.g., auditory and kinesthetic) information to the planned predictive model. Internal models must be updated and accurate because the neuromotor system in continually changing. If internal models are not updated, it could make it impossible to create a motor plan and predict the sensory outcome of the planned movement resulting in dysfluent or incorrect production of speech. Max et al. (2004) predicts that stuttering occurs due to an overreliance on feedback and therefore altering the feedback by improving predictions. Activation of auditory and visual cortices by auditory and visual feedback may improve the efficiency of feedback monitoring by improving the controller's predictions of the planned movements. Auditory signals reducing stuttering to a greater extent than visual signals can be explained because auditory signals contain gestural information from the vocal folds to the front of the lips with encoded information on placement, manner, voicing, fundamental and formant frequencies (Hudock et al., 2010; Rami, Kalinowski, Stuart & Rastatter, 2003), whereas, visual signals are a less precise system than auditory signals for speech perception. Visual signals are limited to gestural content of the lips, tongue, and jaw.

## Chapter V

## Clinical Implications

The effects revealed in the current study can be applied clinically by the use of feedback to reduce overt stuttering, such as using SpeechEasy devices (Kalinowski, Guntupalli, Stuart, & Saltuklaroglu, 2004), Casa Futura products (Kehoe, 2013) or different computer software programs or smartphone applications that provide altered feedback. This is a common effect during video conference calls, and programs such as Skype (Skype and/or Microsoft, 2013) and Google Chat (Google, 2014). Speech-Language Pathologists can utilize these effects and teach PWS to observe their own speech gestures during communication with these products and software. Additionally, such effects can be used during initial sessions when great increases in fluency are desired to build rapport or to teach strategies. Altered feedback provides the speaker a reduced sense tension and anxiety; therefore they may be better able to implement behavioral strategies with greater success.

## Chapter VI

## Conclusions

This study explored the relationship of stuttering during the perception of audio, visual, and audiovisual synchronous and asynchronous feedback to infer about the hierarchy and location of inhibitory processing. Stuttering was reduced during each feedback condition when compared to the baseline, other than DVF. Stuttering inhibition was also more powerful in delayed feedback conditions than real-time feedback. No significant differences were found between synchronous and asynchronous audiovisual feedback conditions which supports what is known about speech perception. This study demonstrated that asynchronous presentation of feedback, with visual leading before auditory feedback decreases the frequency of stuttering.  By presenting individuals who stutter with auditory feedback before visual feedback stuttering is inhibited by altering and disrupting their perception of speech. Clinical implications include using DAF programs and devices to decrease the frequency of stuttering. A consistent finding in the literature is that overt stuttering is inhibited during the perception of not only auditory but visual signals. The current study provides a comparison of the effectiveness of auditory and visual signals at the same delay. There are neural disruptions as indicated in the McGurk effect which reduces the effectiveness of these signals. This should be further examined with neural networking models or functional analysis with proper temporal and spatial resolution.

# Chapter VII

## Limitations

A limitation to this study is that the majority of the participants were mild overt individuals who stutter. Previous studies have found that altered feedback decreased stuttering to a greater extent when participants are moderate to severe individuals who stutter. There is a larger decrease in the percentage of stuttering in more severe populations than mild populations, because more stuttering occurs which causes a more notable difference (Watson & Alfonso, 1987).

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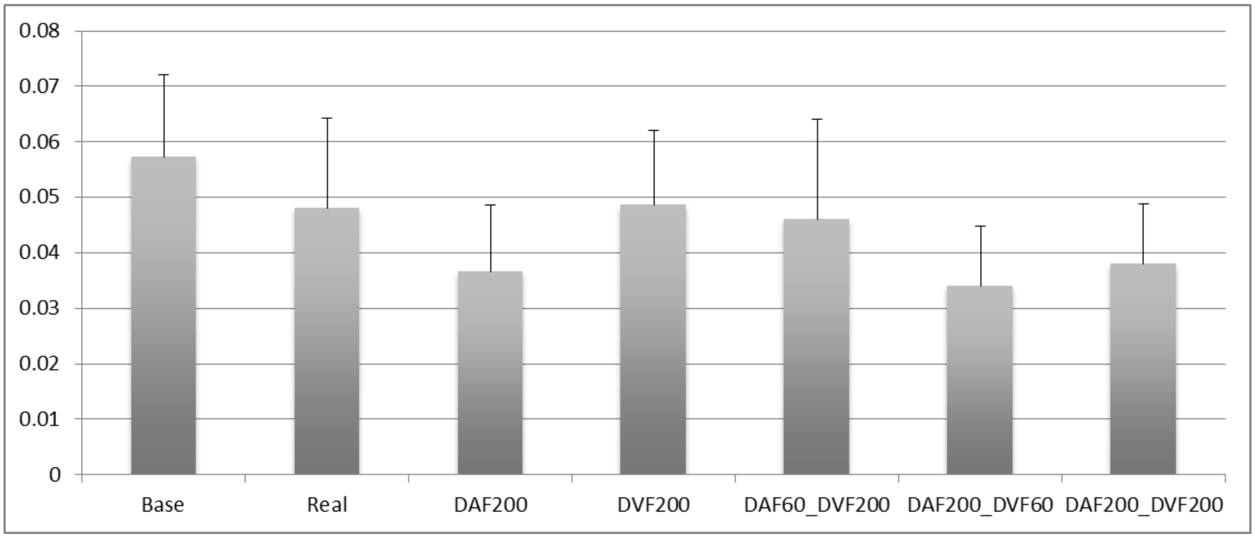
**APPENDIX A:**

*Table 1*

| Participant | Base | Real-time | DAF200 | DVF200 | DAF60_DVF200 | DAF200_DVF60 | DAF200_DVF200 |
|---|---|---|---|---|---|---|---|
| 1 | 0.037 | 0.020 | 0.013 | 0.020 | 0.017 | 0.003 | 0.007 |
| 2 | 0.020 | 0.020 | 0.010 | 0.023 | 0.013 | 0.017 | 0.020 |
| 3 | 0.060 | 0.033 | 0.037 | 0.080 | 0.047 | 0.060 | 0.063 |
| 4 | 0.027 | 0.023 | 0.017 | 0.023 | 0.017 | 0.010 | 0.017 |
| 5 | 0.137 | 0.127 | 0.087 | 0.137 | 0.080 | 0.060 | 0.083 |
| 6 | 0.033 | 0.017 | 0.010 | 0.017 | 0.010 | 0.000 | 0.030 |
| 7 | 0.150 | 0.160 | 0.120 | 0.103 | 0.197 | 0.110 | 0.107 |
| 8 | 0.043 | 0.037 | 0.047 | 0.023 | 0.033 | 0.037 | 0.027 |
| 9 | 0.027 | 0.017 | 0.010 | 0.023 | 0.020 | 0.013 | 0.010 |
| 10 | 0.040 | 0.027 | 0.017 | 0.037 | 0.027 | 0.030 | 0.017 |
| Mean | 0.057 | 0.048 | 0.037 | 0.049 | 0.046 | 0.034 | 0.038 |
| Std Err | 0.015 | 0.016 | 0.012 | 0.013 | 0.018 | 0.011 | 0.011 |

*Note:* Proportion of stuttering episodes by participant with means and standard errors.

*Graph 1*




*Note: Proportion of Mean and Standard Error per condition*