INHIBITION OF STUTTERING FROM SECOND SPEECH SIGNALS: AN EVALUATION OF TEMPORAL AND HIERARCHICAL ASPECTS

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Stuttering is an intermittent and involuntary speech disorder overtly characterized by syllable repetitions, phoneme prolongations and postural fixations that disrupt the natural flow of speech. Overt stuttering is reduced by 60-100% as the person who stutters produces speech while perceiving an ongoing second speech signal. The purpose of the current investigation was to further examine mechanisms of stuttering inhibition during perception of second speech signals. To do this the researcher conducted two experiments examining the level of inhibition during temporal-spatial alignment alterations and level of inhibition during hierarchically difficult scripted telephone conversations under combined altered auditory feedback signals.

The first study examined temporal-spatial alignments of speakers during choral and shadow speech. Choral speech is when two speakers talk in approximate simultaneity. This effect is believed to be the most powerful inhibitor of stuttering, reducing it 90-100%. A slightly less powerful inhibitor of stuttering is shadow speech, which is historically defined as the person who stutters lagging or shadowing behind a fluent speakers utterance. Reductions under shadow speech typically range from 80-90%. Interestingly, prior to the current investigation, empirical analysis of output from

people who stutter (PWS) when maintaining the lead speaker position during shadow speech, had yet to be evaluated. This temporal-spatial alignment most mimics delayed auditory feedback with a second speaker. Experiment I included four conditions: 1) choral speech, 2) shadow speech with the person who stutters maintaining the lead speaker position, 3) shadow speech with the person who stutters maintaining the lag speaker position, and 4) baseline. Nine participants who stutter verbally read 300 syllable passages while a second fluent speaker read the same passage and maintained close temporal-spatial alignments during choral conditions and three to four word separations during shadow speech conditions. Stuttering frequency was significantly reduced 95% during choral speech and approximately 80% during both shadow speech conditions. Results challenge notions put forth by previous hypotheses regarding reductions in stuttering during perception of second signals.

Experiment II examined stuttering inhibition during scripted telephone conversations under altered auditory feedback. As with the lag shadow speech condition, altered auditory feedback and more specifically delayed auditory feedback, presents a second speech signal along with ongoing speech. Delayed auditory feedback and frequency-altered feedback generate second speech signals from the speakers' initial speech productions. Reductions in stuttering frequency under altered auditory feedback typically range from 60-80%. These reductions occur during the presentation of one signal and one combination of signals across a variety of settings; specifically, telephone conversations, which are judged to be one of the most hierarchically difficult situations for people who stutter. The second experiment examined nine people who stutter during 15 scripted telephone conversations under baseline, one combination of DAF and FAF (*i.e.,* 50 ms delay and ½ octave shift up respectively; 1 COMBO), and two combinations of DAF and FAF (*i.e.,* 1 COMBO plus 200 ms delay and ½ shift down respectively; 2 COMBO). Stuttering was significantly inhibited during both altered feedback conditions (*i.e.,* 63% during 1 COMBO and 74% during 2 COMBO). Furthermore, significant reductions in stuttering frequency during the 2 COMBO conditions as compared to the 1 COMBO indicated that presentation of increased gestural information enhances the inhibitory effects.

Results from both studies challenge notions put forth by previous models of stuttering reduction during the perception of second signals. The findings that stuttering was reduced to similar extents during both lead and lag conditions in Experiment I and that more robust stuttering inhibition occurred during the COMBO II condition in Experiment II, challenge fundamental notions from previous reduction theories during the perception of second signals. Furthermore, these findings support the flexible and dynamic gestural percepts hypothesized in the Gestural Model of Stuttering Inhibition. It is likely that increased gestural information alters mirror neuron system activation patterns, which enables a more efficient and effective release of the central neural block that is stuttering, therefore increasing inhibitory effectiveness from the perception of second signals.

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LIST OF SYMBOLS AND ABBREVIATIONS

AAF	Altered auditory feedback
ANOVA	Analysis of variance
CWS	Children who stutter
DAF	Delayed auditory feedback
DVF	Delayed visual feedback
dB	Decibel
FAF	Frequency altered feedback
fMRI	Functional magnetic resonance imaging
GMSI	Gestural model for stuttering inhibition
IPL	Inferior parietal lobe
MEG	Magnetoencephalography
MEPs	Motor evoked potentials
ms	Milliseconds
NAF	Non-altered feedback
PWS	People who stutter
PET	Positron emission tomography
s	Seconds
SE	SpeechEasy
STS	Superior temporal sulcus
TMS	Transcranial magnetic stimulation
VCS	Visual choral speech

CHAPTER I

INTRODUCTION

Stuttering is an intermittent and involuntary speech disorder characterized by sound and word repetitions, phoneme prolongations and inaudible postural fixations that disrupt the natural flow of speech (Bloodstein & Bernstein-Ratner, 2007; Conture & Curlee, 2007; Peters & Guitar, 1991; Silverman, 2003; Van Riper, 1973; Wingate 1964). The presence of these overt characteristics is sufficient to diagnose a person with stuttering; however, the stuttering syndrome encompasses much more than just overt fluency counts (Saltuklaroglu & Kalinowski, 2005). Early in their lives, people who stutter (PWS) often encounter many adverse reactions to their stuttering, which leads them to develop life-long covert compensatory avoidance strategies and fatalistic self-perceptions regarding their stuttering and communication abilities. These negative self-perceptions are further intensified by cognitively strenuous therapeutic approaches that result in highly unnatural sounding speech. This creates a paradoxical duality with the syndrome. Clinicians reinforce the necessity for droned unnatural speech and suggest that it is more natural than overt stuttering; however, the PWS experiences more severe social penalties when employing the droned speech versus their own stuttering behaviors. Due to the lack of understanding and empathy for stuttering, many clinicians view the pathology only as overt conspicuous disruptions. Therefore, therapists often employ motor speech strategies to temporally expand syllabic productions. By voluntarily prolonging syllables, the occurrence and duration of residual stuttering is reduced; however, procedures incur negative stereotypes. The speech output becomes very unnatural sounding, appears effortful, and is often accompanied by high rates of relapse.

Although stuttering is resistant to long-term treatment, it is very amenable to short-term amelioration with natural sounding speech outcomes during the perception of second speech signals in conjunction with speech production. Often thought to be the gold standard of stuttering therapy, choral speech immediately inhibits stuttering 90-100% in most PWS. The choral speech phenomenon occurs when two speakers recite the same material in approximate unison. Under these and similar conditions, overt stuttering is drastically reduced without sacrificing speech naturalness. As it is improbable to have exogenous second speakers continuously accompany PWS, endogenous self-produced choral speech analogs can be manipulated and then perceived as endogenously produced and exogenously altered second speech signals. The speaker's own speech productions may be acquired by a microphone, electronically processed into altered forms and finally fed back to the speaker to inhibit their subsequent overt stuttering behaviors. By delaying or altering the frequency of the second speech signal, stuttering is typically inhibited 70-80%. Differential inhibitory outcomes across a variety of second signals offer insight into the nature of second signals and other underlying inhibitory systems.

The current investigation seeks to further explore the nature and inhibitory effect of second signals for stuttering inhibition. The literature review will begin by discussing the nature, development, and overall stuttering syndrome followed by hypothesized etiologies. In addition, how etiological paradigms influence therapeutic procedures while distorting cause and effect understandings will be addressed. The review will proceed with the nature and mechanisms of second speech signals for stuttering inhibition as related to typical models of speech perception and production. Based on the literature review, a series of studies are proposed to further explore the nature of second speech signals and their inhibitory effects on stuttering.

CHAPTER II

REVIEW OF THE LITERATURE

An Overview of Stuttering

Developmental stuttering typically emerges between the ages of two to six with an incidence of 5% across world populations affecting four times as many males as females (Bloodstein & Bernstein-Ratner, 2007; Silverman, 2003; Van Riper, 1982; Yairi & Ambrose, 1992). Of the 5% who exhibit developmental characteristics of stuttering approximately 80% will naturally recover. By age six, prevalence of the disorder decreases to approximately 1% and only has a three to one male to female ratio (Craig, Hancock, Tran, Craig & Peters, 2002; Yairi & Ambrose, 1992, 1999). Interestingly, these values have remained constant from the early 20^{th} century to present day (Finn, Ingham, Ambrose & Yairi, 1997; Yairi & Ambrose, 1992a; Yairi, Ambrose, Paden & Throneburg, 1996; Wingate, 2002). That is to say, regardless of the specific method of therapeutic intervention, if any, approximately 80% of children will spontaneously recover (Ambrose & Yairi, 1999; Craig & Calver, 1991; Yairi & Ambrose, 1992b). Yairi and Ambrose (1999) reported a peak recovery period from one to three years post onset of two to five year olds. Similar research supports their claim and reports that 75% of four year olds, 50% of six year olds, and 25% of ten-year-old individuals recover from stuttering by age 16 (Andrews, Craig, Feyer, *et al.*, 1983). Typically children who do not recover by that time will most likely stutter for the rest of their lives.

Stuttering is often initially exhibited as easy phrase or word repetitions that may even go unnoticed by the child (Van Riper, 1992). As stuttering becomes more incipient, prolongations and then postural fixations are manifested (Bloodstein & Bernstein-Ratner, 2007; Kalinowski & Saltuklaroglu, 2005; Silverman, 2003). The child then becomes more aware of their stuttering behaviors and may develop covert avoidance strategies and adverse emotionality toward their stuttering and communication ability. It is not uncommon that children as young as six years old can recognize their stuttering and will verbalize negative feelings about it.

This progression of developmental stuttering has been described and discretely categorized as stages (Bluemel, 1957), phases (Bloodstein, 1960a, 1960b; Peters & Guitar, 1991), and tracks (Van Riper, 1973). These hierarchical progressions share many similarities among the levels and suggest that an increase in level is generally related to increased stuttering severity. As the child exhibits more severe stuttering patterns they manifest syllabic repetitions then prolongations and finally postural fixations. In addition to different forms of overt stuttering, the individual expresses more negative perceptions about the pathology and may demonstrate increased secondary stuttering behaviors such as: excessive lip and facial tension, head jerking, eye blinking, hand clenching and other extremity or body movements (Bloodstein & Bernstein-Ratner, 2007; Van Riper, 1992). Secondary stuttering behaviors develop as a voluntary means to alleviate disfluent moments; however, these behaviors quickly become adopted as an almost involuntary anticipatory strategy to avoid stuttering. The final levels from most of the hierarchies advance the negative emotionality to severe covert aversion strategies in hopes of hiding the fact that they stutter at any cost. By not speaking, PWS maintain the façade of being normal.

Being able to describe and categorize characteristics and symptoms is the first step to understanding stuttering. The next step is searching for invariant cues, which are both necessary and sufficient to predict chronic versus developmental stuttering. This endeavor has proven to be complicated and has yet to provide sufficient evidence for accurate predictions. Familial incidence and genetics provides a logical starting point for the search. Andrews et al. (1983) reported that PWS were three times as likely to have a first order relative that stuttered as compared to families without stuttering. Sex-linked familial expression suggests that genetics may account for one component of predisposing factors. However, this relationship may be more complicated than initially thought. Evidence suggests that stuttering is not a simple sex-linked autosomal dominant or recessive monogenetic trait (Andrews & Harris, 1964; Drayna, Kilshaw & Kelly, 1999; Kidd, 1977; Kidd, Heimbuch & Records, 1981; Kidd, Kidd & Records, 1978; Meyer, 1945; Suresh, et al., 2006). More recent evidence indicates polygenetic expressions with possible environmental factors (Ambrose, Cox & Yairi, 1997; Ambrose, Yairi & Cox, 1993; Drayna & Kang, 2011; Kidd, Heimbuch & Records, 1982; Suresh, et al., 2006). In a recent study, Drayna and Kang (2011) were only able to use genetic markers in describing approximately 10% of the stuttering cases from their large sample. Due to the high complexity of stuttering, incidence rates and genetics, it appears that finding invariants using current investigative methods may not happen.

Other researchers have tried to distinguish between incipient developmental and chronic stuttering by examining linguistic and acoustical features of speech from fluent speakers and children who stutter (CWS) (Cooper, 1987; Van Riper, 1992). However, this line of research continues to yield inconsistent results. For example, researchers have noted differences in the average duration of repeated units in CWS as compared to their normally fluent peers (Adams, 1977; Adams & Ramig, 1980; Van Riper, 1982), while other have failed to find any acoustical differences (Zebrowski, Conture & Cudahy, 1985). The lack of differences has since been replicated numerous times (Yairi & Ambrose, 1999; Zebrowski, 1991; Zebrowski, 1994). Once again, it appears that the invariant cue for predicting chronic stuttering may not reside in speech acoustics (Yairi & Ambrose, 1999).

As there remain inconclusive findings for differential acoustic features as predictors, researchers also have investigated nonspeech factors. Conture and Kelly (1991) reported that CWS exhibit more nonspeech behaviors than children who do not stutter. They found that CWS could be classified on the frequency of these nonspeech behaviors alone. CWS averted eye gaze more frequently, demonstrated more extremity movements and had more object-based interactions than typically developing children. However, it seems unlikely that this model could be used as an a priori method to predict chronic stuttering due to extraneous influential effects that might be construed as causal factors.

With no clear prognostic factors evidenced, researchers continue to examine other aspects of the stuttering syndrome. One such area of interest is the development of covert avoidance strategies. It is not surprising that with acoustic disruptions, conspicuous visually aberrant secondary stuttering behaviors and increased nonspeech ancillary movements, PWS are often perceived differently from typical speakers. PWS are often stereotyped as being more introverted, shy, guarded and anxious than fluent speakers. These stereotypes are maintained across: college students (McKinnon, Hess & Landry, 1986); teachers and professors (Crowe & Walton, 1981; Dorsey & Guenther, 2000; Lass, et al., 1992; Yeakle & Cooper, 1986); special education teachers (Ruscello, Lass, Schmitt & Pannbacker, 1994); speech language pathologists (Cooper & Cooper, 1985, 1996; Doody, Kalinowski, Armson & Stuart, 1993; Lass, Ruscello, Pannbacker, Schmitt & Everly-Meyers, 1989; Woods & Williams, 1971; Yairi & Williams, 1970); vocational rehabilitation counselors (Hurst & Cooper, 1983b); employers of PWS (Hurst & Cooper, 1983a); peers of PWS (Dorsey & Guenther, 2000; St. Louis & Lass, 1981; White & Collins, 1984); members of rural communities who had close personal or familial contact with PWS (Doody, et al., 1993); and parents of PWS (Crowe & Cooper, 1977; Fowlie & Cooper, 1978; Woods & Williams, 1976). Somewhat ironically, the negative stereotype is even held by PWS themselves (Lass, Ruscello, Pannbacker & Schmitt, 1995; Kalinowski, Lerman & Watt, 1987). Simply put, fluent speakers and PWS alike seem to perceive PWS as being different than normally fluent speakers regarding general personality characteristics. These negative perceptions with other negative reactions can influence PWS to develop covert avoidance strategies. PWS often try to hide the fact that they stutter by circumlocuting, substituting words, or avoiding situations and interactions entirely. By not speaking, a PWS is perceived as being normal. These severe avoidance strategies are primarily developed to avoid the socially punitive penalties one incurs for stuttering.

As a way of empirically measuring these negative reactions people feel as they observer PWS speaking, researchers have focused on examining physiological reactions of listeners while observing stuttering. Guntupalli, Kalinowski, Nanjundeswaran, Saltuklaroglu, and Everhart (2006) reported that fluent speakers increased skin conductance and decreased average heart rates while observing stuttered speech samples as compared to fluent samples. These autonomic alterations indicate physiological arousal and uneasiness in participants. However, as participants were exposed to more 30-second audio-visual stuttered samples, levels of autonomic arousal decreased, although still remained elevated as compared to observation of fluent stimuli. These findings were replicated and highly correlated with self-reported feelings of increased tension, anxiety, and uneasiness in fluent speakers (Guntupalli, Everhart, Kalinowski, Nanjundeswaran & Saltuklaroglu, 2007). Surprisingly, despite life-long exposure to their own stuttering, PWS exhibit similar physiological arousal when observing stuttering in others (Zhang, Kalinowski, Saltuklaroglu & Hudock, 2010).

To examine conspicuous social penalties for stuttering that might aide in the development of covert avoidance strategies, researchers recently examined eye gaze behaviors of fluent speakers while observing stuttered and fluent speech samples (Bowers, Crawcour, Saltuklaroglu & Kalinowski, 2009; Hudock, Stuart, Saltuklaroglu, Zhang, Murray & Kalinowski, *submitted*). Listeners spent significantly less time observing eye regions of PWS as compared to fluent speakers and spent more time observing visually aberrant stuttering behaviors. It is generally accepted that eye gaze aversion indicates increased state anxiety and uneasiness in listeners (*for review see:* Hietanen, Leppanen, Peltola, Linna-Aho & Ruuhiala, 2008). This 30-50% eye gaze aversion is additionally important, as it is likely that PWS would observe these behaviors. By watching listeners avert eye contact to observe their visually conspicuous stuttering behaviors, PWS may be driven to avoid stuttering at any cost to avoid these looks and observations.

Other listener reactions that are more overt and easily recognizable exemplifying the need for PWS to develop covert avoidance strategies are verbal and nonverbal reactions, including: laughing (Guitar, 2005; Shapiro, 2011), various facial expressions that denote amusement, worry, annoyance, and or confusion (Kamhi, 2005; Klompas & Ross, 2004; Plexico, Manning & Levitt, 2009a; Plexico, Manning & Levitt, 2009b). It is not surprising then that negative listener reactions would lead to the development of covert avoidance strategies at an early age. By sacrificing some pragmatic social norms of maintained eye contact and willingness to communicate intended utterances, PWS perpetuate the fluent speaker illusion.

Word and situation avoidances can debilitate a person's confidence about communicating effectively and impede all aspects of their life. Simply put, stuttering is a very complex enigmatic pathology with no agreed upon etiology that severely impacts people's lives. This may occur to the extent that they may avoid social interactions altogether in hopes of being perceived as normal. The perception of normalcy is paramount for PWS. More severely impacted individuals would typically rather not talk than to sound unnatural and be perceived as being different (Kalinowski & Saltuklaroglu, 2005).

Searching for Invariance: How we Lost Our Way

Stuttering is a speech disorder, characterized by syllable and phrase repetitions, phoneme prolongations and postural fixations that disrupt the natural timing and flow of speech. Overt stuttering is an intermittent and involuntary pathology that ranges in severity, duration, and frequency of occurrence. Due to the fact that stuttering is a highly conspicuous disorder that leaves the individual cognitively intact, many theoreticians have postulated a variety of treatments and proposed etiologies. Stuttering characteristics are so highly recognizable that their historical depictions can be relatively easily interpreted and have been reported as early as 4,000 BCE in Chinese writings and on Mesopotamian clay tablets (Bloodstein & Bernstein-Ratner, 2007). The ancient Egyptians portrayed stuttering in hieroglyphics as a man on bended knees holding his throat and pointing vibrations of the earth (Silverman, 2003). The *Bible* describes God curing Moses of his stutter in order to do his will. Some of the earliest recorded theories of stuttering are physical in nature and came from great minds, such as Aristotle and Hippocrates during ancient Grecian periods. They believed stuttering was caused by an imbalance of the humors and should be treated by wetting the tongue with wine. However, for the sake of conciseness, the current review will only address more recent theories and therapies.

Proposed causes of stuttering have ranged the gamut of intervention from a deity, physical differences, learned responses, and psychological factors, all of which have been closely followed by various therapeutic strategies. For example, the forefather of the field of speech pathology, Lee Edward Travis, in the early 1900's prescribed casting the left dominant arm of PWS to regain proper cerebral dominance to the left 'speech' hemisphere (Van Riper, 1982). He believed that by immobilizing the left arm, the left more speech and language dominant hemisphere would regain control and stuttering would subside. However, this procedure proved not to be beneficial.

Two of his protégés and participants were some of the first students to graduate with their doctorates in speech pathology (Bloodstein & Bernstein-Ratner, 2007). Charles Van Riper is one of these students, who has had a profound impact on the field of stuttering, especially therapeutically. Throughout his tenure at Western Michigan University, he maintained his clinical passion for treating PWS by using psychological and motoric behavioral modification strategies. As with Travis, Van Riper initially believed the etiology of stuttering to be neurologically based with much psychological influence (Van Riper, 1982). Therefore, a major part of his therapy focused on mental hygiene and altering the way one perceives stuttering and communication. He thought that by desensitizing people to anxiety provoking situations, they would maintain a healthier mental model and be able to use motoric behavioral strategies easier.

These motoric strategies included voluntary stuttering and purposeful prolongations to alleviate the moment of stuttering. By teaching clients to stutter easier and use anticipatory prolongations to get out of blocks, he believed communication would be more natural.

Van Riper's contemporary and fellow student at the University of Iowa used similar motoric behavioral modification strategies to treat stuttering; however, he ascribed to a different etiology. In the 1930s, Wendell Johnson believed that stuttering was a learned developmental response to hyperprotective and worrisome mothers (Bloodstein & Bernstein-Ratner, 2007). He thought that recognition, perception, and labeling of stuttering caused the pathology to exacerbate from its natural developmental origins, and that treatment should focus on regressing stuttering episodes to their fundamental units of simple syllabic repetitions. Once children exhibited chronic stuttering, similar to Van Riper, Johnson's therapeutic strategies focused on fake stuttering, or negative practice, by producing easy syllabic repetitions.

As Freudian views became popular, the paradigm shifted to psychoanalytic perspectives. It was believed that stuttering was a neurosis compounded by tendencies to orally fixate. Even though Freud himself did not believe that stuttering was due to a neurosis, his protégées suggested that stuttering could only be treated by discovering and dealing with the catharsis (Silverman, 1996). Influenced by these perspectives, stuttering therapy was not as often treated by motoric behavioral strategies with underlying cognitive therapy, but focused on talk therapy in hopes of alleviating the cathartic event

(Brill, 1923; Coriat, 1931; Froeschel, 1934; Glauber, 1958). These approaches were amazingly unsuccessful, to the extent that researchers only claimed to have cured one out of 44 clients (Brill, 1923).

Joseph Sheehan maintained other psychological perspectives. He believed that stuttering was an approach-avoidance conflict and that if the desire to speak fluently were greater than the anxiety and fear of speaking, one would be fluent (Sheehan, 1970). If the fear were greater, the person would avoid talking altogether. However, if the fear of speaking and desire to speak were equal, stuttering would occur. He often used the analogy of a rat crossing an electrified mid-point in a cage to obtain hydration. If the rat desired water enough it would cross the mid point and receive a shock, whereas if the fear of the shock were too great it would avoid the water. Sheehan’s treatment approaches were based in learning theory and used response contingent paradigms. He also initiated group therapy for PWS, which focused on fear reduction via group discussions and voluntary stuttering. This cognitive therapy was similar to the improved mental hygiene procedures of Van Riper; however, he did not incorporate many of the motor aspects. With evermore social indoctrination of Skinnerism and learning theory, other response contingent stuttering therapies gained acclaim.

As audiotape recorders and other electronic instrumentation became more widely available, researchers switched from focusing on direct therapy and began the search for the invariant cue of stuttering. To begin the search, they started by examining the peripheral system of PWS. For example, Schwartz

(1974) hypothesized about laryngeal dysfunction, where the fear of stuttering would cause severe laryngeal adduction. This notion garnered support from fibroscopic evidence (Conture, McCall & Brewer, 1977) and direct electromyography (EMG) data (Freeman & Ushijima, 1978). Conture, et al. (1977) found that the vocal folds adducted prior to stuttering events; however, the researchers did not directly measure muscle activity. Freeman and Ushijima's (1978) data is a bit more complex. By using EMG data, they noted co-contraction of muscles of adduction and abduction during stuttering events in half of their participants (both fluent and nonfluent). These findings supported Wingate's (1974) vocalization hypothesis, however misinformed they may have been. Co-contraction did not occur during all stuttering events in all PWS, and more of these findings were also reported during the speech of fluent speakers. Similar effects were misinterpreted as causal agents such as: dyscoordinations reported in respiratory (Johnston, Watkin & Macklem, 1993; Schilling, 1960; Starbuck & Steer, 1954; Williams & Brutten, 1994) and articulatory systems (Alfonso, 1991; Caruso, Abs & Gracco, 1988; Caruso, Gracco & Abs, 1987; Zimmerman 1980 a, Zimmerman 1980 b, Zimmerman 1980 c). These findings represent differences found in PWS during both perceptually fluent and disfluent speech as well as differences between the fluent periods of PWS and fluent speech from typical speakers. Investigation of the fluent speech paradigm in stuttering has many inherent confounds (Armson & Kalinowski, 1994). Generally speaking, if speech is truly fluent, it cannot be compared to other fluent speech because it should be equivocal. Additionally, some of the confounding effects are history of therapy, stuttering severity, and sub-perceptual stuttering. Speech motor paradigms teach PWS to temporally expand their speech, which alters temporal and sequential properties of speech acoustics. If a PWS exhibits a more severe form of the pathology, their speech output is contaminated. Lastly, stuttering is not a series of dichotomous events, but occurs along a continuum, so stuttering occurs below the perceptual level. That being stated, only the moment of stuttering can accurately be examined. In addition, the above-mentioned studies found differences, whereas many studies do not reveal such differences (Watson & Alfonso, 1982; Watson & Alfonso, 1983; Watson & Alfonso, 1987), especially when controlling for therapy techniques (De Nil & Kroll, 2001; McClean, Kroll & Loftus, 1991; Metz, Sammar & Sacco, 1983; Sammar, Metz & Sacco, 1986). Simply put, articulatory sequences of PWS who have not attended speech therapy do not differ from fluent speakers and when fluent speakers produce speech using similar therapeutic techniques, they exhibit articulatory discoordinations that mimic post-treatment speech of PWS.

In addition to examining physiological measures, researchers began to examine speech acoustics of PWS and fluent speakers in the same fluent speech paradigm. As with the kinematic and physiological data, the acoustical data revealed controversial findings. Researchers reported that PWS exhibited longer syllable duration (Zimmerman, 1980b), slower voice initiation and termination times (Adams & Hayden, 1976), longer voice onset times (Agnello, 1975; Healey & Gutkin, 1984), longer segment durations (Colcord & Adams, 1979; Di Simoni, 1974; Starkweather & Myers, 1979), and decreased articulatory rate (Borden, 1983; Ramig, Krieger & Adams, 1982). Yet, there are studies that have not found acoustical differences (Alfonso, 1991; Max, Gracco & Caruso, 2004; Cullinan & Springer, 1980) and note large variabilities in some of the previous data (Gracco & Abbs, 1986; Caruso, Abbs, & Gracco, 1988). It appears that the confusion of cause and effect relationships persists in the speech motor paradigm. Therefore, research efforts turned to examining the sensory influence of second signals.

Researchers began to explore the acoustical characteristics of PWS while speaking under fluency enhancing conditions. Lee (1951) reported that an artificial stutter was created when fluent speakers listened to a slightly delayed version of their speech during speech production tasks. This delayed auditory feedback (DAF) was later tried with PWS and was found to greatly reduce stuttering frequency (Cherry & Sayers, 1956; Wingate, 1969). This reduction was immediate and produced natural effortless speech. In hopes of finding the invariant cue, researchers examined the acoustical characteristics of PWS when speaking with and without DAF compared to fluent speakers (Webster & Dorman, 1970; Webster & Lubker, 1968; Webster, Schumacher & Lubker, 1970). They noted temporal expansion of speech with decreased speaking rates. Later, researchers evaluated slowed, temporally expanded speech, without DAF. Similarly, acoustical characteristics were found. It was then believed that the invariant cue for stuttering reduction was reduced speech rate, not the DAF signal itself.

A new version of speech motor control therapy, fluency shaping therapy, developed due to these findings and from an attempt to correct what was believed to be a dyscoordinated speech production system. This therapeutic model was solely based in learning theory and hypothesized that a new more fluent speech motor form could be learned that would replace the old stuttered form. Similar to the prolongations used in Van Riper's stuttering modification therapies, fluency shaping teaches clients to begin temporally expanding speech productions. Fluency shaping has clients produce easy vocal onsets, use diaphragmatic breathing, light articulatory contacts, and continuous voicing to volitionally control their speech productions 100% of the time they speak. Fluency shaping therapies gained in popularity and became the mainstream therapy from the 1970's until the early 1990's.

There are many fundamentally flawed assumptions in this paradigm. First, the rate reduction hypothesis suggests that a reduced rate is both necessary and sufficient for fluent speech because PWS do not possess the inherent capacity to produce speech at a normal speech rate. However, researchers have demonstrated that speaking at normal and fast speech rates while under DAF is possible for PWS and they exhibit similar reductions in stuttering frequency at both rates (Kalinowski, Armson, Roland-Mieszkowski, Stuart & Gracco, 1993; Kalinowski & Stuart, 1996). Second, a discoordination of the speech production system is found in normally fluent speakers during rate reduction tasks. Third, if the speech of PWS under DAF were completely fluent, it should not be different from normally fluent speakers. Fourth, temporally expanded, or slowed speech, is just one continuous prolongation. Therefore, the PWS is constantly stuttering. Fifth, speech is not volitional and is not a learned or relearned process. Most importantly though, speech motor paradigms often confuse cause from effect during examination of peripheral mechanisms as previously indicated by the physiological, kinematic, and acoustical misinterpretations.

With the advancement of technology, researchers have turned away from examining peripheral systems and have started to examine neurophysiology. The current paradigmatic view on stuttering is that it has a neurophysiological origin. Although no one specific site is currently agreed upon, many researchers claim theories predicting deficit areas. Some of the consistent findings across neuroimaging studies that compare fluent speakers to PWS is general increased right hemisphere activations (Braun, et al., 1997; De Nil, et al., 1998; Fox, et al., 1996; 2000; Ingham, 2001). Interestingly, these findings are in congruence with Travis's 1931 cerebral dominance theory of right hemisphere laterality (Travis, 1978). However, the disorder appears to be much more complex than Travis's claim of simple laterality (Ingham, 2001). In addition to laterality differences, PWS typically exhibit higher levels of activation in motor and motor association areas such as the supplemental motor area (SMA), anterior insula (De Nil, et al., 1998; Fox, et al., 1996; 2000) and cingulate cortex (Braun, et al., 1997; De Nil, et al., 1998). Furthermore, a suppression of activity is noted in auditory cortices, as well as Broca's and Wernicke's areas during stuttering (Fox, et al., 1996; 2000). The suppression of these language and auditory areas during stuttering allows for a variety of interpretations. With no clear deficit-processing site located, the question of cause versus effect must be brought back into question. As with kinematic and articulatory fluent speech paradigms, causal agents cannot be determined from noted differences, especially when researchers have reported similar activations of typical speakers while imagined pseudostuttering (Ingham, 2003). Specifically, as fluent speakers and PWS alike imagine speaking fluently or imagine stuttering, they exhibit similar neural activity as production of that condition. Therefore, these findings bring into question the idea of effect as opposed to cause when examining differences noted during stuttering, or in PWS.

One of the biggest problems with the speech motor paradigm is the sacrifice PWS must make to reduce overt stuttering. By using these techniques and droning speech, one sounds and feels very unnatural. Even in fluent speakers, slowed speech rates increase voice onset times and are judged to be highly unnatural sounding (Metz, Schiavetti & Sacco, 1990), which coincidently enough are reported during post-intensive treatments for PWS (Martin, Haroldson & Triden, 1984; O'Brian, Onslow, Cream & Packman, 2003; Runyan & Adams, 1979). To exemplify this concept, researchers have not only looked at a treated group of PWS compared to typical speakers, but also added in a control group of PWS who did not, nor have never attended therapy (Metz, Schiavetti & Sacco, 1990). Acoustical characteristics of fluent speakers matched those who did not attend therapy and were judged to be more natural sounding than the speech of clients who attended the therapy. The paradox of speech motor paradigms is the more unnatural PWS sound, the greater the reduction in frequency and severity of overt stuttering; however, there is less likelihood that they will use the unnatural sounding techniques (Kalinowski & Saltuklaroglu, 2005). Furthermore, one cannot determine cause from effect using the speech motor or fluent speech paradigms as previously discussed (Armson & Kalinowski, 1994).

Due to the problems with accounting for anomalies and being unable to determine cause from effect, a new model of stuttering has been proposed. This model suggests that overt stuttering is not the problem, but is in fact the solution to another central neural block (Kalinowski & Dayalu, 2002; Kalinowski & Saltuklaroglu 2003a; Kalinowski & Saltuklaroglu 2003b; Kalinowski & Saltuklaroglu, 2005; Saltuklaroglu, Dayalu & Kalinowski, 2002). It hypothesizes that overt stuttering, especially repetitions and prolongations releases the central block and inhibits stuttering. The paradox is that, for centuries clinicians have been attempting to remove, hide or mask these stuttering behaviors and yet these same stuttering behaviors appear to be what the brain craves. Three assumptions must be maintained for this proposal. First, overt and covert stuttering are peripheral events from a central neural block. Second, if the neural block is inhibited, overt stuttering will subside. Third, overt stuttering is the solution to this problem instead of being the problem itself (Saltuklaroglu, 2004). This current view on stuttering is in contrast to other views on stuttering. It primarily differs in four points. First, it upholds the claim that stuttering is involuntary in nature and bringing it under complete volitional control is unreasonable. Second, stuttering is not a learned behavior that can be unlearned. Third, inhibiting stuttering or eliminating the primary characteristics of the pathology does not remove the pathology. Finally, stuttering is intermittent and involuntary; however, it can be temporally inhibited in the short term (Saltuklaroglu, 2004).

Stuttering Inhibition

Stuttering ranges in frequency and severity from situation to situation and often runs in cycles. PWS may be relatively fluent while speaking with friends and family members but may exhibit more severe stuttering during anxiety provoking situations of talking to people in authority or in front of audiences (Bloodstein & Bernstein-Ratner, 2007). Regardless of the specific situation or down phase in the cycle, there are fluency enhancing conditions that remain common among most PWS. These conditions can be primarily motor or sensory and tend to alleviate stuttering to varying degrees (Saltuklaroglu, 2004; Saltuklaroglu, et al., 2003). If stuttering is a central neural block, it is possible that these conditions act to release the block and inhibit stuttering. Motor related conditions occur as PWS alter the peripheral speech productions systems (i.e., kinematic, laryngeal, or respiratory). As previously stated, the more unnatural PWS sound when droning, the greater reduction in stuttering frequency that occurs. Motor related therapies were discussed in the previous section so they will no longer be a target of discussion. The current thesis revolves around alterations to the sensory system, the proceeding discussion will seek to describe the nature and reductions caused by these signals. Reduction in stuttering via sensory modalities occurs as externally produced signals are presented via auditory or visual modalities to the PWS during speech production (Saltuklaroglu, 2004).

Although the current study focuses on alterations to the sensory system, it is pertinent to comment that the motor system is affected by these changes. Therefore, one cannot solely alter the sensory system without influencing the motor system. These interconnected system alterations may only be recognizable at the neuronal level, but may differentially act on the same neural block (Saltuklaroglu, et al., 2003).

Inhibition of Stuttering via Exogenous Speech Signals

Choral speech. It is a well-documented fact that PWS can produce natural effortless speech while speaking in approximate unison with a second speaker (Bloodstein & Bernstein-Ratner, 2007; Kalinowski & Saltuklaroglu, 2005; Silverman, 2003; Van Riper, 1982). As PWS speak memorized passages or read prepared texts in conjunction with a second speaker, their stuttering is immediately inhibited from 90-100%. Although it is termed choral speech, it is not synchronous due to the fact that it is impossible for two speakers to speak in direct unison. Regardless of this temporal asynchrony choral speech is the gold standard for natural sounding fluent speech in PWS and requires little or no training (Adams & Ramig, 1980; Cherry & Sayers, 1956; Johnson & Rosen, 1937). An inherent limitation of this condition is that the linguistic material must be congruent to produce the optimal inhibitory effects. Due to this, most research investigating the choral speech effect has used prepared texts. Interestingly, if the choral speech signal is removed, stuttering reemerges almost instantly.

Although anecdotally noted for centuries, Johnson and Rosen (1937) were the first to confirm the choral speech effect via experimentation. They reported that when 18 PWS read the same prepared text in approximate unison with a fluent speaker or another PWS, overt stuttering was all but eliminated. Barber (1939) replicated the findings and reported that stuttering was reduced more when participants read the same passage as compared to reading different passages. A reduction in stuttering was also noted during conditions of sustained /a/ productions, production of nonsense syllables and presentation of mechanical noise. However, none of the conditions exhibited as intense of a reduction in stuttering as the choral congruent condition.

To better understand the choral speech effect, researchers had PWS speak in front of audiences while the second speaker remained in an adjacent room and had their voice projected via telephone (Eisenson & Wells, 1942; Patty & Knight, 1944). Eisenson and Wells (1942) noted a reemergence of stuttering and hypothesized it was due to the lack of communicative responsibility from the PWS. However, Patty and Knight (1944) reported similar reductions in stuttering frequency regardless if the second speaker was in an adjacent room speaking over a telephone or present in the room. These findings led researchers to investigate other possible fluency enhancing conditions. Bloodstein (1950) evaluated questionnaire responses from 204 PWS regarding fluency-enhancing conditions, including the choral speech effect. Of the respondents, 95% reported near elimination of their stuttering while speaking under the choral speech condition with congruent texts and only 13 reported similar reductions with different texts. These findings were experimentally tested by Cherry and Sayers (1956), who reported similar levels of stuttering reduction during congruent texts and even when the second speaker switched texts, but not when the speakers started out with different texts. They also reported a reduction in stuttering when the second speaker produced nonsense syllables and when audio recording were played in reverse. However, the amount of stuttering reduction was not reported for the later two conditions.

These and other choral speech permutations have more recently been investigated for the differential effects on the speech acoustics of PWS (Adams & Ramig, 1980; Andrews, et al., 1982; Ingham & Carroll, 1977; Ingham & Packman, 1979; Stager, Denman & Ludlow, 1997; Stager & Ludlow, 1998). During these investigations, researchers were driven by Wingate's vocalization hypothesis (Wingate, 1969, 1970). Wingate suggested that the reduction in stuttering under choral speech conditions was due to an altered motoric form of speech and not due to the second speech signal. Researchers did not find that an altered form of vocalization was necessary and sufficient for the reduction of stuttering under choral speech or similar conditions. Ingham and Packman (1979) noted that the ameliorative effects could be maintained at similar speech rates and that overt fluency was not contingent upon a slowed rate alone. These findings were replicated and expanded when researchers did not find differences in speech rate, articulation rate, or duration of phonation across various fluency enhancing conditions (Andrews, et al., 1982). In addition, speech acoustics from fluent portions of solo and choral speech of PWS could not be differentiated from PWS and fluent speakers (Ingham & Carroll, 1977).

As indicated above, there is a differential effect when the passages read are linguistically congruent versus incongruent. To further examine this effect, researchers presented stutter-filled and stutter-free with interrupted and continuous second signals to PWS (Kalinowski, Dayalu, et al., 2000). Participants read a 300 syllable passage while listening to a sustained /a/, /a-i-u/ loops, sustained /s/, or /s-ʃ-f/ loops. A significant 65-80% reduction in stuttering was noted across 10 PWS for all conditions with the greatest reductions occurring during perception of the vowels. This finding spawned a new direction of research by Kalinowski and colleagues to examine the invariant cues of second speech signals for stuttering inhibition. In order to explore the temporal constraints of the vocalic productions, Saltuklaroglu, et al. (2003) presented continuous /a/, /a/ with a one second interval, /a/ with a three second interval and an /a/ with a 5 second interval to 12 participants while reading a 300 syllable passage. All conditions significantly reduced stuttering frequency; however, the continuous and one second conditions were more effective than the three and five second conditions. Similarly, Dayalu, Kalinowski, Stuart, Saltuklaroglu and Rastatter (2011) reported that continuous presentation of /a/ was more effective at inhibiting stuttering than continuous presentation of /s/ or 1,000 Hertz tones. Further examination of the linguistic content of the second signal led researchers to present forward flowing and reversed stuttered and fluent speech samples to participants as they read 300 syllable passages (Kalinowski, Guntupalli &

Saltuklaroglu, 2004). Significant differences were reported across the four experimental conditions when compared to a control condition. The forward flowing samples and reversed stuttered sample reduced stuttering by approximately 60%, while the reversed fluent sample only reduced stuttering by 40%. These findings along with the preceding ones lend credence to the theory that a central mechanism is being acted upon by these exogenous, externally produced, second speech signals.

Previous theories regarding mechanisms of inhibition under choral speech have ranged from reduction of communication load, distraction, rhythm alterations, masking and altered vocalizations. Eisenson and Wells (1942) suggested that communicative pressures were reduced while speaking under choral speech with the second speaker present; however, it should not be so if the signal came from a telephone. This rational was disproved in Pattie and Knight's (1944) experiment as PWS obtained similar levels of stuttering reduction when the second speaker was present as when they were not. Years later the choral speech effect was attributed to distractions (Bloodstein, 1999). The distraction hypothesis came about from response contingent therapies that used auditory masking noise during fluent and disfluent periods of speech production (Webster & Lubker, 1968). However, the distraction hypothesis is based on a post-hoc interpretation, in which no a priori declaration can accurately be made or tested. In other words, a signal is only considered a distractor if there is a differential effect on stuttering frequency (Dayalu, 2004). Others have suggested that choral speech generates an external timing, or pacing rhythm (Armson &

Kiefte, 2008; Howell & Au-Yeung, 2002). This notion has been questioned several times due to the fact that the speakers do not train their timing during choral conditions and the signals are asynchronous. In addition, fluency remains if the second speaker changes passages during the reading and similar inhibitory effects are noted under sustained /a/, backwards and forward flowing stuttered speech (Dayalu, 2004; Glover, Kalinowski, Rastatter & Stuart, 1996; Kalinowski, et al., 1993; Kalinowski & Stuart, 1996; Macleod, Kalinowski, Stuart & Armson, 1995; Wingate, 1976). These findings all have different rates and no externally produced pacing effect. Yet other researchers have claimed that the second speech signal had a masking effect (Adams & Hutchinson, 1974; Andrews, et al., 1982). However, even at the most optimal, 90 decibel (dB) sound pressure level (SPL), stuttering is only reduced by 40%, whereas choral speech is typically at 60 dB hearing level and reduces stuttering by 80-100% depending on the congruency (Andrews, et al., 1982). Finally, Wingate's (1970) vocalization hypothesis suggests that PWS alter their speech production during choral speech. However, as previously stated, the majority of empirical evidence does not support this claim (Andrews, et al., 1982; Ingham & Carroll, 1977; Ingham & Packman, 1979; Stager, et al., 1977; Stager & Ludlow, 1998). In further refute of Wingate's claim, researchers reported that aerodynamic and acoustic differences were noted in both fluent speakers and PWS, therefore indicating a task effect instead of the proposed speaker effect (Metz, et al., 1990).

Due to the powerful and immediate inhibitory effects of choral speech, it is not surprising then that it has been used to induce fluency during neuroimaging studies (Fox, et al., 1996; Ingham, Fox, Ingham & Zamarripa, 2000; Wu, et al., 1995). Choral speech normalizes neurophysiological activations. However, it is difficult to determine cause from effect, similar to the fluent speech paradigm, especially due to the fact that normally fluent speakers and PWS exhibit similar neural activity during pseudostuttering, imagined stuttering, and fluent or imagined fluent conditions (Ingham, 2002). Simply put, although the choral speech effect demonstrates such dramatic and immediate effects on reducing stuttering, none of the previous theories account for all of the extraneous variables.

Shadow speech. Shadow speech is a permutation of choral speech, which does not have the second speaker as closely temporally aligned as in choral speech. Historically, the lead speaker position has been maintained by the fluent speaker and the PWS lags behind them, imitating the utterances of the fluent speaker. The first documented examination of shadow speech were Cherry, Sayers and Marland (1955) and Cherry and Sayers (1956), who examined many fluency enhancing conditions in addition to shadow speech. They reported that the reduction in stuttering frequency during shadow speech was comparable to reductions during choral speech. These findings have been adequately replicated and supported by various researchers (Andrews, et al., 1982; Healey & Howe, 1987; Wingate, 1981). Furthermore, similar paradigms have been used as components of therapeutic programs and have noted 70% reductions in stuttering frequency (Kelham & McHale, 1966; Kondas, 1967).

Shadow speech is typically tested during reading of prepared texts or during monologue productions from the fluent speaker that the PWS imitates. As the PWS closely follows the lead speaker they attempt to say the same utterances; however, even if they miss or add words, similar levels of stuttering inhibition as with choral speech are reported (Andrews, et al., 1982; Cherry & Sayers, 1956; Healey & Howe, 1987; Kelham & McHale, 1966; Kondas, 1967; Wingate, 1981). When using shadow speech during monologues, the PWS has a general idea about the content that is going to be said but has to guess at the specific semantics used. This process increases the cognitive demands on the PWS and yet dramatic stuttering inhibition is noted. This notion refutes some hypotheses regarding mechanisms of inhibition that claim PWS require reduced demands on the cognitive system for fluent speech. It also calls into question the idea of rhythmic necessity or pacing strategies due to the fact that no consistent rate or pacing occurs during shadow speech. To disrupt any possible pacing effect, researchers recently presented variable length phrases during active and passive shadowing (Saltuklaroglu & Kalinowski, 2011). Participants perceived and produced congruent and noncongruent syllabic repetitions prior to reading 7-12 syllable phrases. Results indicate 70% stuttering inhibition during active shadowing versus 56% during passive shadowing strategies as compared to baseline conditions.

The question of temporal positioning and alignment of the speakers during shadow speech has yet to be answered. If the PWS requires the input of an external timekeeper for fluency, there should be little to no reduction of stuttering if the PWS is in the lead speaker position. If the second speech signal is acting on the central neural block, stuttering should be inhibited to similar extents regardless of speaker positions, as long as the second speech signal is present and not too delayed. This is to say, if the PWS is in the lead speaker position, they should exhibit most of their stuttering behaviors prior to the onset of the second speaker: once the second speaker begins to lag behind the lead speaker, stuttering should be inhibited to similar extents.

Visual choral speech. Visual choral speech (VCS), similar to choral speech occurs when PWS watch a second speaker miming a prepared utterance in approximate unison with their speech production. This visual analog to choral speech inhibits stuttering from 70-80% (Kalinowski, Stuart, Rastatter, Snyder, & Dayalu, 2000). Ten participants memorized 5-10 syllable length utterances then verbalized them sequentially until the 300-syllable passage was produced. Baseline conditions had the participant produce the utterances at a normal loudness and rate, while experimental conditions had the participant produce the utterances as they watched a second speaker miming the same utterance. With no prior training the participants produced speech with 70-80% less stuttering and more natural sounding speech.

Similar to the linguistic congruency difference noted in choral speech, VCS results in a more severe differential effect. Saltuklaroglu, Dayalu, Kalinowski, Stuart, and Rastatter (2004) examined the effect of linguistically congruent versus linguistically noncongruent VCS on stuttering. Using similar methods and procedures from the previous study, researchers replicated the findings during linguistically congruent conditions; however, they noted only a 30% reduction in the incongruent condition compared to the 70% reduction during the congruent condition. Differential effects for linguistic content are similar during auditory choral speech, although not as severe (Barber, 1939; Cherry & Sayers, 1956; Dayalu, 2004; Kalinowski, Dayalu, et al., 2000). The severity of the differences may be in part due to the nature of the signals.

To further examine the auditory versus visual exogenous speech signals, researchers presented visual only and visual plus tonal conditions to PWS (Guntupalli, Nanjundeswaran, Kalinowski, & Dayalu, 2011). Stimuli were of a static image of a male speaker producing /a/ and a video of the same speaker producing /a-i-u/. Visual only conditions were compared to visual plus conditions, where 1,000 Hertz tones were presented in conjunction with the image and video. Participants watched videos during speech production of memorized texts. Results revealed an auditory effect and visual plus auditory effect but no effect of visual only. Auditory speech signals contain information with encoded gestures from the level of the larynx through the mouth. These gestures and perceived sounds provide information regarding articulatory placement, manner of the sound, and voicing along with the any contextual and gestural information, whereas the visual signal only provides gestural information from the exterior mouth (Hudock, Dayalu, Saltuklaroglu, Stuart, Zhang, & Kalinowski, 2011). By limiting the encoded gestural information one only perceives partial portions of the signal. However, the fact that stuttering was inhibited at all, suggests that visual gestures act on the same underlying mechanism as auditory choral speech. These findings dispute the claim that stuttering is a disorder caused by improper auditory feedback alone (Cherry & Sayers, 1956; Webster & Lubker, 1968; Yates, 1963).

Inhibition of Stuttering via Endogenously Initiated and Exogenously Altered Speech Signals

Endogenous signals are self-produced via auditory, visual or motor means. Similar to the temporally expanded speech in speech motor therapies, the signal is self-produced but becomes an altered form. It should be noted that any motor alteration to speech production via therapeutic intervention or not also affects sensory systems. Another example of a self-produced signal is VCS as the PWS talks in front of a mirror (Snyder, Hough, Blanchet, Ivy & Waddell, 2009).

As described in the previous section, exogenous signals are externally produced signals similar to the second speaker during choral speech or VCS. In addition, the externally produced signal may be prerecorded audio or visual second signals as in the forward flowing, reversed, continuous and interrupted stuttered and fluent experiments previously mentioned.

Endogenously initiated signals that are exogenously altered then fed back to the individual use the participants' own speech output to produce an altered form of the second signal. For example, a speakers' voice will be captured by a microphone fed into a digital signal processor where an altered form will be generated; then the altered form will be fed back to the individual via speakers.

This procedure provides the illusion of a second speaker without requiring the use of prepared texts or memorized material.

Delayed auditory feedback. Delayed auditory feedback (DAF) is an analog to choral speech where the speakers own speech output provides the initial signal for the second delayed speech signal. The second delayed signal can be set across a range of delays as determined by the settings on the digital signal processor. Similar to choral speech, stuttering is immediately inhibited with little or no training and natural effortless speech is produced by PWS. However, the reduction in stuttering frequency is not as extreme as it is in choral speech conditions. Stuttering is typically reduced by 70-80% when PWS verbally read under DAF, as compared to the nearly 100% noted during choral speech conditions.

DAF was initially examined in 1950's by Lee, who noticed that when fluent speakers spoke under DAF an artificial stutter was created (Lee, 1951). They began to exhibit syllable repetitions and hesitations as they spoke. Researchers claimed that the disrupted auditory system caused the normally fluent speakers to exhibit moments of stuttering (Fairbanks, 1955). Conversely, as PWS speak under DAF, their stuttering frequency is dramatically reduced (Andrews, et al., 1982; Cherry & Sayers, 1956; Kalinowski, et al., 1993; Kalinowski, et al., 1996; Soderberg, 1968; Soderberg, 1969; Webster, et al., 1970). Based on Lee's findings and the reduction of stuttering noted under DAF, researchers hypothesized that stuttering was due to a faulty auditory feedback system and that the DAF corrected the faulty mechanism in PWS and disrupted it in normally fluent speakers.

Faulty auditory feedback theories have some fundamental problems. First, syllable repetitions and hesitations noted in fluent speakers while speaking under DAF are dissimilar to the speech disruptions noted in PWS. PWS exhibit the majority of their stuttering behaviors on the initial syllable of the sentence (Saltuklaroglu, Kalinowski, Robbins, Crawcour, & Bowers, 2009), whereas fluent speakers talking under DAF exhibit stuttering events throughout the sentence (Stuart, Kalinowski, Rastatter, & Lynch, 2002). Second, fluent speakers only exhibit normal nonfluencies of repetitions and hesitations, whereas PWS produce syllable repetitions, phoneme prolongations and postural fixations which is a more halted form of speech production (Stuart, et al., 2002). Third, PWS and fluent speakers do not differ on their rate or accuracy of predicting or judging self-produced errors during speech production (Postma & Kolk, 1992). Fourth, the auditory system alone is too slow to disrupt or correct for feedback breakdowns influencing forward flowing speech (Borden, 1979; Kalinowski & Saltuklaroglu, 2005). Humans process their own auditory speech feedback at a 200-millisecond delay from their speech production. By the time the speech is processed, the speaker is 2-3 syllables ahead of the “disrupted” syllable. Furthermore, naïve listeners are able to accurately determine normal speakers from PWS per their disfluency regardless of DAF (Neelley, 1961).

Similar to theories on the reduction of stuttering from purely exogenous signals, researchers have used these claims to explain the effects of DAF. These theories include distraction hypotheses, introduction of timekeepers or rhythm, rate reduction hypotheses, and altered vocalizations, all of which have been previously discussed and refuted. As a brief recap, the distraction hypothesis is a post-hoc assignment that is an untestable hypothesis, which does not account for differential inhibitory effects. As the second speech signal is generated from and dependent on one's own rhythm pacing a reduction in stuttering is not due to implementation of an altered rhythm. Rate reduction hypotheses are disproven by the fact that PWS exhibit similar levels of stuttering reduction while speaking at normal and fast speech rates under DAF. Finally, Wingate's (1970; 1976) vocalization hypothesis was disproved due to the fact that either no differences were found in acoustical characteristics or differences that were found can be attributed to a treatment effect, as normally fluent speakers displayed similar differences (Andrews, et al., 1982).

Historically, DAF has been used in therapeutic settings to demonstrate the potential for fluency in PWS instead as a therapeutic device (Costello-Ingham, 1993; Goldiamond, 1963; Perkins, 1973a,b; Ryan & Van Kirk, 1974; Webster, et al., 1970). Most of these therapies had PWS talk under DAF at an extended temporal setting then reduced the delay as fluency was achieved. The optimal goal of these therapies was to retrain the speech production system of PWS to eventually not require the use of DAF. This concept has been discussed in a previous section and due to the fact that neither stuttering nor speech is a learned behavior, it cannot be unlearned and retrained. Modifying speech production requires constant cognitive maintenance and is never going to become a learned involuntary process. Furthermore, many researchers appear to ignore the fact that stuttering is immediately and dramatically reduced while PWS speak under DAF or analogous signals and that stuttering reemerges upon cancelation of the signal. This fundamental notion indicates an altered neural processing state due to the second speech signal itself and not a result of peripheral alterations.

To further investigate the nature of the DAF signal, researchers have examined delay settings and signal amplitude for their differential effects on stuttering frequency. Delay settings from 25 milliseconds to 500 milliseconds indicate that each PWS has an optimal delay setting; however, delay settings of 50 milliseconds tend to be the most optimal for a majority of people (Kalinowski, et al., 1993; Kalinowski, et al., 1996; Macleod, et al., 1995; Sparks, Grant, Millay, Walker-Batson & Hynan, 2002; Novak, 1978; Soderberg, 1969; Webster, et al., 1970). Findings regarding signal presentation amplitudes are more inconclusive and one must understand fundamental problems with these procedures prior to being presented with the findings. As speech acoustics are filled with varying durations of silence and different levels of amplitudes contingent upon the specific speech sounds produced, one cannot accurately measure the presentation amplitude during speech production. For example, during the verbalization of an utterance, the gaps between words are filled with silent periods and voiceless continuants such as /s/ are high frequency sounds with less amplitude as compared to vowels which exhibit louder amplitudes and more resonant characteristics. Measures of speech production amplitudes take an average from produced utterances, which include all silent periods, low amplitude speech sounds, as well as louder amplitude vowel productions. These methodological problems may account for the inconclusive results of some researchers reporting differences (Butler & Galloway, 1959; Soderberg, 1969) and others not finding differences between delay times and signal amplitudes (Gibney, 1973).

Frequency altered feedback. Similar to DAF, frequency altered feedback (FAF) is analogous to choral speech where the speakers own voice is used to generate the second speech signal via digital signal processing. FAF spectrally shifts the frequency characteristics of one's speech, either up or down in octave increments; then the signal is fed back to the speaker in almost real-time. As with DAF, FAF reduces stuttering frequency by 70-80% in PWS. Howell, El-Yaniv and Powell (1987) were the first group to report FAF's affect on stuttering frequency. They compared the effects of FAF, DAF, and masking auditory feedback (MAF) on stuttering frequency. FAF was produced at a half an octave shift down and DAF was set at 50 millisecond delay. Relative to baseline conditions, FAF produced the greatest level of stuttering reduction followed by DAF, then significantly lower was MAF. MAF was produced via the Edinburgh masker, which produced 70dB of white noise during speech production. Researchers attributed the effects of FAF to be due to altered vocalizations from the implementation of an external timekeeper. However, as previously stated, as the rhythm and pace is set at one's own rate and vocalization theories are not supported by empirical evidence, it is unlikely that this is the acted upon mechanism. It was not until researchers began to examine the nature of second speech signals that fundamental assumptions were challenged (Kalinowski, *et al.,* 1993).

To test the rate reduction hypothesis as well as demand and capacity models (Starkweather, 1997), Kalinowski, et al. (1993) had nine PWS read prepared 300 syllable passages at normal and fast speech rates while speaking under FAF (i.e., half and octave shift up), DAF, and MAF (i.e., 85 dB SPL). As with Howell, et al. (1987), it was found that stuttering frequency decreased under all altered auditory feedback (AAF) conditions and MAF was least effective. However, contrary to the previous findings, Kalinowski, et al. did not find differential effects between FAF and DAF. This was the first study to demonstrate that increased demands on the system of a fast speech rate, did not differentially affect stuttering frequency while speaking under AAF. Furthermore, these findings disprove rate reduction hypotheses for stuttering inhibition while speaking with AAF. These findings have been replicated in numerous studies (Hargrave, et al., 1994; Macleod, et al., 1995; Stuart & Kalinowski, 1996).

To further understand the nature of FAF, researchers examined various increments of octave shifts on the reduction of stuttering frequencies (Hargrave, et al., 1994). Participants verbally read 300 syllable length passages at fast and normal speech rates while speaking under four FAF conditions and one baseline condition. FAF conditions consisted of half an octave or a full octave shift up or down. All FAF conditions reduced stuttering to the same extent at both speech rates regardless of specific octave shifts. Stuart, et al., (1996) replicated these findings on 12 PWS with quarter and half octave shifts up and down. These findings add further impetus to refute rate reduction hypotheses. Interestingly, the whole octave shift down was unintelligible to the listener, and yet reduced stuttering to the same extent as the intelligible signals.

Researchers then began to examine other potential influential factors of the FAF signal. Stuart, et al. (1997) examined the effect of FAF presented monaurally to the right and left ears then binaurally. No differences were reported between the monaural presentations; however, a slight but significant difference was noted between the binaural condition and both monaural conditions. It was long thought that PWS do not stutter while they are speaking to themselves while alone and that increased audience sizes increase the severity of stuttering. To test the hypothesis that PWS do not do so while speaking to themselves, Kalinowski, Stuart, Wamsley, and Rastatter (1999) had PWS read prepared texts during known and unknown observation periods with and without FAF. Researchers conspicuously stopped an in view tape recorder and left the room after telling participants to practice reading the passage a number of times. However, an out of sight tape recorder remained on and recording during the trials. During baseline conditions, participants exhibited significantly more stuttering while the observer was present than when they were not. Stuttering frequency for FAF conditions interestingly did not differ between observer conditions. This demonstrates the observer effect on stuttering frequency and the robust effect of FAF on stuttering inhibition. Later, researchers examined the effect of audience size on stuttering frequency while speaking with FAF (Armson, Foote, Witt, Kalinowski, & Stuart, 1997). Nine PWS read passages to audiences of two, four and 15 unique members during baseline and FAF conditions. Contrary to previous findings of audience size, no differences were noted under FAF conditions. This indicates the robust effect of the second speech signal, as audience size has historically been used to induce more severe stuttering (Bloodstein & Bernstein-Ratner, 2007; Silverman, 2003).

FAF's affect on stuttering frequency during verbal reading of prepared texts is generally agreed upon; however, the findings for monologues and conversations are more controversial. Anecdotally, PWS report less struggle, avoidance, and tension with decreased stuttering severity and episodes while speaking with FAF (Kalinowski, Guntupalli, Stuart & Saltuklaroglu, 2004; Stuart, Kalinowski, Rastatter, Saltuklaroglu & Dayalu, 2004). Armson and Stuart (1998) examined 12 PWS in an ABA design, where they read then spoke using FAF for extended periods of time. Significant differences were noted between FAF and baseline conditions during the reading conditions; however, no differences were noted during the monologues. Findings that monologue presentations were not significantly different were supported by other researchers (Ingham, Moglia, Frank, Costello-Ingham, & Cordes, 1997; Natke, 2000). Ingham, et al., examined the affect of FAF on four PWS during reading and spontaneous speech conditions. However, Natke, (2000) reported significant differences of FAF during spontaneous speech samples. It is possible that avoidance behaviors are so ingrained in the stuttering syndrome that training may be required for maintenance during conversation samples.

Zimmerman, Kalinowski, Stuart, and Rastatter (1997) examined the effect of DAF and FAF compared to baseline conditions during scripted telephone conversations of nine PWS. Participants called local businesses and asked questions from a prepared 200-syllable script. Speaking on the telephone is one of the most feared situations for PWS and has been known to induce periods of severe stuttering (Bloodstein & Bernstein-Ratner, 2007; Brutten, 1975; Georgieva, 1994; Kalinowski & Saltuklaroglu, 2005; Leith & Timmons, 1983; Silverman, 1997, 2003; Van Riper, 1982). During the 15 scripted telephone calls, participants exhibited significant stuttering reductions under both DAF and FAF conditions. Researchers reported 55% reductions in stuttering frequency during DAF and 60% reductions during FAF that were not significantly different. These findings suggest that implementation of second speech signals in more natural environments aides in the speech naturalness and reduction of stuttering frequency, especially during more hierarchically complex situations. DAF and FAF also appear to exhibit equivalent effectiveness on stuttering frequency reduction.

To enhance the effect of second signals, researchers have investigated the effect of combined DAF and FAF signals. Macleod, et al. (1995) compared the effects of FAF, DAF, and a combination on the stuttering frequency of 10 PWS during verbal readings of prepared texts at normal and fast speech rates. All conditions significantly reduced stuttering to the same extent regardless of speech rate or form of AAF. To further investigate the signal propagation, researchers increased the complexity and demands of the situation. Recently, a therapeutic in the ear device called the SpeechEasy (SE) was invented and takes advantage of the combined DAF and FAF signals. Similar to DAF and FAF, the SE reduces stuttering by approximately 70-80% in PWS and can be worn like a hearing aid (Kalinowski, et al., 2004; Stuart, et al., 2004). This inconspicuous placement provides the benefits of the choral speech effect with natural functionality.

Researchers still claim that the effect from the FAF signal is due to a global speech rate change resulting from due to processing differences noted while using FAF (Howell & Sackin, 2002). However, Natke, Grosser, and Kalveram (2001) reported that there were no speech rate differences in PWS or typical speakers while speaking under FAF. Due to the findings that stuttering frequency and duration is reduced by AAF speech signals, it is likely that the perception of these signals is acting on a central inhibitory mechanism.

Effect of DAF and FAF on stuttering type and duration. As mentioned previously, stuttering severity is typically categorized by overt frequency of repetitions, prolongations, and postural fixations with occasional duration and social impact factors. Stuttering frequency is typically measured by percent syllables stuttered. As the duration of stuttering episodes is a difficult aspect to discretely categorize, the most commonly used temporal classification scheme is the longest stuttering episode produced or an average of the three longest stuttering episodes. However, some researchers have categorized and measured the duration and type of stuttering episodes (Hudock, et al., *unpublished work*; Kelly & Conture, 1992; Martin & Haroldson, 1979; Stuart, Frazier, Kalinowski & Vos, 2008;

Throneburg & Yairi, 1994, 2001; Yairi & Hall, 1993; Zebrowski & Conture, 1989; Zebrowski, 1991, 1994).

Prior to describing outcomes of these measures and how they are affected by the DAF and FAF signals, one must understand the assumptions and inherent problems with categorization schemes. Most models of speech perception use the syllable as the fundamental acoustical unit (Fowler, 2006; Galantucci, et al., 2006; Liberman & Mattingly, 1985; Massaro & Chen, 2008). The syllable is comprised of the consonants with the vowel. This combination is necessary due to the fact that the gestural information of the consonants is carried in the vowels. An example of this is coarticulation of adjacent consonants influencing the production and perception of the vowels. Simply put, this refers to consonants that appear prior to and after vowels alter the way the vowel is produced. Due to this and other factors, it is very difficult to determine the start and end points of specific syllabic structures.

In a continual effort to attempt to predict and classify children who stutter, researchers examined acoustical features of speech from 10 children who stutter compared to age and gender matched peers (Zebrowski, 1991). The only acoustical differences noted were the frequency of sound/syllable repetitions and audible prolongations. Duration of any speech feature did not differ between groups. These findings were replicated by Kelly and Conture (1992). Similar results were found in older children who stutter; however, the mean duration of disfluent episodes were increased from 500 millisecond found in Zebrowski (1991) to 650 milliseconds in Kelly and Conture (1992), to 700 milliseconds found in Zebrowski (1994). As the disfluent episode yielded such variable findings researchers began to explore the silent periods between the repeated units (Throneburg & Yairi, 1994, 2001; Yairi & Hall, 1993). Yairi and Hall (1993) did not find any significant differences between preschool children and age matched children who stutter, while Throneburg and Yairi (1994) reported shorter periods of silent intervals between repetition units and shorter durations of disfluent episodes for the children who stutter. However, the same researchers later failed to find evidence from a longitudinal study examining the same acoustical characteristics (Throneburg & Yairi, 2001). It appears unlikely that duration and type measures will be a valid predictor of chronic stuttering in CWS.

By examining the moment of stuttering during AAF one can better understand the whole picture of the inhibitory mechanism and residual stuttering. Martin and Haroldson (1979) were the first to examine duration variation of stuttering episodes during the presentation of DAF. Although their study examined five experimental conditions, they only reported average stuttering durations for the baseline and DAF conditions. During baseline conditions, PWS exhibited 1.37 second average stuttering durations, while during a 250 millisecond delay DAF condition participants only displayed 0.85 seconds average stuttering duration. These findings indicate that stuttering is not a dichotomous event as previously believed but occurs within a range and can be acted upon by inhibitory mechanisms to a similar extent. Similarly, Stuart, et al. (2008) reported that the average stuttering duration during baseline conditions was 0.995 seconds and the average stuttering duration under FAF was 0.786

seconds. Furthermore, that the duration per type during baseline conditions were 0.790 s, 0.935 s, and 1.259 s for prolongations, silent blocks and repetitions respectively. The average duration of stuttering episode during baseline conditions reported in Stuart, et al. was shorter than the average duration described in Martin and Haroldson (1979). In addition, the average stuttering duration under FAF was shorter than the reported duration of DAF. Recently, researchers compared reading and monologue samples during baseline, FAF and DAF conditions (Hudock, et al., *unpublished data*). Average stuttering durations during reading conditions were 1.178 s, 0.602 s, and 0.848 s for baseline, DAF, and FAF respectively. Furthermore, the duration per type of disfluency during baseline conditions were 1.525 s, 1.045 s, and 1.145 s for repetitions, prolongations, and silent blocks. The duration per type of disfluency during DAF conditions were 0.688 s, 0.593 s, and 0.458 s and FAF conditions were 0.833 s, 0.820s, and 0.855 s for repetitions, prolongations, and silent blocks respectively. Average stuttering durations for monologue conditions were 1.471 s, 0.989 s, and 0.998 s for baseline, DAF and FAF respectively. Furthermore, the duration per type of disfluency during baseline conditions were 1.378 s, 1.602 s, and 1.713 s for repetitions, prolongations and silent blocks. The duration per type of disfluency during DAF conditions were 0.900 s, 0.870 s, and 1.092 s and FAF conditions were 0.776 s, 0.989 s, and 1.016 s for repetitions, prolongations and silent blocks respectively. These data indicate a differential reduction of duration per type of disfluency and may give insight into the central inhibitory mechanism. Furthermore, the differences noted between reading and monologue samples suggest different requirements on the production systems. It is likely that these differential reductions are similar to ones noted while listening to reverse stuttered speech, stuttered filled speech and syllabic repetitions (Kalinowski, et al., 2000; Kalinowski, et al., 2004; Saltuklaroglu, et al., 2003). This is to say that, different types of disfluencies exhibit different disruptions and that repetitions and prolongations that maintain audible speech production inhibit stuttering more than postural fixations when speech is halted and no signal is produced. As speech is halted no speech signal is being sent. These findings also suggest that therapeutic devices may inhibit stuttering differently depending on the type of stuttering that the PWS exhibits. These findings provide further evidence to the nature of second speech signals. As there is no sound production at the beginning of utterances or during silent periods, behavioral techniques of prolongation should be taught prior to speech initiation and intermittently throughout the intended utterance.

Delayed visual feedback. Similar to VCS, delayed visual feedback (DVF) uses the visual speech gestures of a speaker to act as the second speech signal and inhibit stuttering. As the PWS speaks, their visual gestures are recorded by a camera sent to a video signal processor which delays the video a predetermined amount; then, the video is displayed on a screen for the participant to watch as they speak the memorized utterances. To examine this phenomenon empirically, one must control for text and content. Most research studies examining DVF have the participants silently read and memorize prepared utterances of 8-11 syllables in length, then say them as they are viewing their visual gestures on a monitor.

Recently, researchers examined simultaneous visual feedback (SVF) and DVF for stuttering inhibition (Dayalu, 2004; Hudock, Dayalu, Saltuklaroglu, Stuart, Zhang & Kalinowski, 2011; Snyder, Hough, Blanchet, Ivy & Waddell, 2009). Dayalu (2004) compared the inhibitory effect of DAF to DVF on nine PWS. He used a baseline condition compared to delay settings of 0 ms, 50 ms, 250 ms, and 400 ms. Stuttering was significantly reduced across all feedback conditions although the auditory system provided more effective inhibition than the visual system. During simultaneous feedback (i.e., both auditory and visual), stuttering was inhibited 40%. While during the auditory delay conditions, stuttering was reduced 70-80%, and visual delay conditions reduced stuttering 50-60%. Similarly, Snyder, et al. (2009) reported that PWS reduced stuttering by 60% during SVF and was reduced to 80% during DVF. However, Hudock, et al. (2011) reported similar findings as Dayalu (2004). In addition, Hudock et al. (2011) reported similar levels of stuttering inhibition at normal and fast speech rates. As with the previous study, stuttering was inhibited during all conditions and no inhibitory differences were reported between the speech rates for each of the four delay settings. Although differential inhibitory effects are noted between modalities, it is plausible that the same inhibitory mechanism is being acted upon.

Reduction of Stuttering from Nonspeech Signals

Over the years many researchers have examined fluency-enhancing conditions for PWS. For example, Bloodstein (1949) documented 100 conditions from questionnaire responses of PWS that described stuttering reduction due to specific situations or conditions. Some of these described alterations to the sensory or motor systems are similar to placing an object in ones mouth to alter speech production. This procedure was documented by Demosthenes during Ancient Grecian periods (Bloodstein & Bernstein-Ratner, 2007). It is said that this great orator spoke with pebbles in his mouth as he walked down the beach to cure his stuttering. Speaking with pebbles in his mouth would have altered his motoric productions and sensory feedback during speech production. By altering the way one speaks, overt stuttering is typically reduced for the short-term. It is also poignant to note that the description suggests that he walked by the sea during these times. This is important due to the white noise effect of the ocean waves. Researchers have anecdotally reported the suppression of stuttering while speaking adjacent to waterfalls, waves, hearing the beating of barney drums or hearing loud amplitudes of white noise (Bloodstein & Bernstein-Ratner, 2007). In this example, it is likely that the sounds of the waves crashing would have acted as an auditory masking signal.

The sensory or motor implementation of altered forms influences stuttering frequency. By presenting auditory, visual or tactical signals during speech production, PWS exhibit reduced stuttering. However, this reduction in stuttering does not occur to the extent it does during the perception of second speech signals. Theories regarding the effect of second nonspeech signals on the reduction of stuttering have ranged from distraction hypotheses, altered feedback loops and implementation of external time keepers. These theories have been previously discussed and disputed during the perception of second speech signals. Depending on the nonspeech signal used one might explain signal components by these various theories; however, as a whole no one of these theories accounts for the differential effects of second speech signals compared to nonspeech signals.

Rhythmic Signals

It is a generally agreed upon fact that if a PWS speaks in sync with a metronome their stuttering will be alleviated (Bloodstein & Bernstein-Ratner, 2007; Kalinowski & Saltuklaroglu, 2005; Silverman, 2003). This knowledge has been used to develop therapeutic programs that teach PWS to swing their arms or tap their fingers to a rhythm while they talk (Barber, 1939; Johnson & Rosen, 1937). However, due to the unnatural conspicuous nature of the produced behaviors these therapies are not practical. Later research found that speaking with an asynchronous metronome was less effective than a synchronous one (Fransella, 1967; Meyer & Mair, 1963). Interestingly, speech rate was also examined. Fransella and Beech (1965) reported that PWS could speak at slow, normal and fast speech rates while speaking in rhythm with a metronome. It is surprising that this finding did not dissuade researchers from still claiming that the reduction in stuttering frequency noticed during the metronome effect was due to a slowed speech rate, as it likely is.

Other researchers have used these timing procedures in hearing aid style devices that PWS have worn (Azrin, Jones & Flye, 1968; Brady, 1969; Donovan, 1971; Meyer & Mair, 1963; Wohl, 1968). Speech produced in time with metronomes sounds very unnatural and is not likely to be used in more naturalistic settings. As with other theories about second signals, researchers believed that the metronome effect was a training tool and not an altering signal. They could not see that the rhythmic speech was altering speech production during the time the signal was presented only and that it was not training the PWS to realign their timing mechanism. It was believed in DAF and metronome speech that the timing systems of PWS would realign upon extended presentation to the metronome and that the signal could eventually be removed and fluent speech would remain. However, researchers overlooked the impact of the signal itself and focused on how the signal affected the speech production system.

Masking Signals

Masked auditory feedback (MAF) is produced by presenting white noise to speakers during speech production. The MAF signal is typically produced at loud amplitudes (i.e., approximately 90 dB SPL) and demonstrates differential effects on stuttering frequencies (Adams & Hutchinson, 1974; Andrews, et al., 1982; Brayton & Conture, 1978; Cherry & Sayers, 1956; Conture, 1974; Kalinowski, et al., 1993; Martin & Harloldson, 1979; Webster & Dorman, 1970; Yairi, 1976). Most studies report some beneficial effect during MAF (Adams & Hutchinson, 1974; Andrews, et al., 1982; Brayton & Conture, 1978; Cherry & Sayers, 1956;

Conture, 1974; Kalinowski, et al., 1993; Martin & Harloldson, 1979; Webster & Dorman, 1970; Yairi, 1976). However, some studies have not reported such differences (Hutchinson & Norris, 1977; Mallard & Webb, 1980). Most studies that evaluate MAF use verbal reading procedures to control for linguistic complexity and avoidance strategies. Of these, Cherry and Sayers (1956) were some of the first to examine stuttering frequency using MAF in a controlled setting. They examined 56 participants during conditions of choral speech, shadow speech, and auditory masking among others. Results demonstrated a dramatic reduction in stuttering frequency during all of the speech conditions and most of the nonspeech conditions; however, the speech conditions inhibited stuttering to a greater extent. Findings that stuttering frequency is immediately reduced have been replicated in spontaneous speech tasks (Dewar, Dewar & Anthony, 1976; Ingham, Southwood & Horsburgh, 1981; Martin & Haroldson, 1979). Yet again, some researchers have failed to find differences during spontaneous speech (Hutchinson & Norris, 1977; Mallard & Webb, 1980).

The effects of MAF are quite variable and depend on various factors. It was initially reported that MAF was more effective when presented at low frequencies (i.e., under 500 Hz) (Cherry & Sayers, 1956). However, these findings have yet to be reproduced (Conture, 1974; May & Haywood, 1968). In addition, it appears that MAF presented binaurally versus monaurally decreases stuttering frequency to a greater extent (Yairi, 1976). Researchers hypothesized that the greater extent the auditory feedback system was disrupted the more stuttering would be inhibited (Adams & Hutchinson, 1974; Cherry & Sayers, 1956; Stromsta, 1986). To test this, researchers evaluated stuttering frequency at different levels of MAF amplitude (Johnson, 1955; Maraist & Hutton, 1957). Researchers initially evaluated participants binaurally at 25 dB SPL and 90 dB SPL and noted a greater reduction in stuttering at the higher amplitude (Johnson, 1955). Later, Maraist and Hutton (1957) examined stuttering frequency at 30, 50, 70, and 90 dB SPL and noticed an inverse relationship between stuttering frequency and level of MAF. The louder the MAF the greater extent the stuttering was reduced. Replicating the previous findings, they did not report significant differences in stuttering frequency under 50 dB SPL. These findings support the auditory system disruption hypothesis; however, findings that stuttering is still significantly reduced when MAF is presented monaurally discredit this theory (Barr & Carmel, 1969; Yairi, 1976). When MAF is presented monaurally, PWS can hear their auditory feedback clearly in their nonoccluded ear, suggesting that reductions are not due to PWS not being able to hear themselves.

The above findings were published at the time learning theory and Skinnerism were at their peak, so it is not surprising that people hypothesized that MAF was acting as a form of punishment for an unwanted behavior (Cherry & Sayers, 1956; Webster & Dorman, 1970). It was believed if the signal was continuously present, stuttering should be alleviated to the greatest extent. Murray (1969) empirically supported this hypothesis; however, his finding was not replicated, as others reported similar reductions regardless if MAF was presented during phonations, silences or continuously (Sutton & Chase, 1961; Webster & Dorman, 1970). Based on these findings, it is logical to believe that

MAF is not acting as a punishment signal due to the fact that even when not associated or timed with the stuttering behaviors it still reduces stuttering.

Wingate's (1970) vocalization hypothesis reemerged as a theory for MAF. As people are presented with loud amplitude of noise, they produce speech at higher volumes. This is called the Lombard effect. MAF is no different; as PWS are presented with 90 dB white noise, their speech productions become louder (Adams & Hutchinson, 1974; Conture, 1974; Dewar, et al., 1976; Mallard & Webb, 1980; Yairi, 1976). If this increase in speech amplitude were the invariant cure, PWS should be as fluent when producing loud speech amplitudes without MAF. This does not occur; PWS exhibit a greater reduction under MAF as compared to just reading passages at loud amplitudes (Conture, 1974; Mallard & Webb, 1980; Yairi, 1976). Furthermore, similar levels of reduction are noted when normal speech amplitude is maintained (Cherry & Sayer, 1956; Dewar, et al., 1976). It is true that speaking under MAF does alter speech production; however, due to the fact that even when these variations are controlled for, differences in stuttering reduction exist, thus disproving an altered vocalization hypothesis.

Researchers also attribute the reduction under MAF to be due to a novel distraction hypothesis. However, as previously stated, these theories are post-hoc assignments and do not account for the differential effects between the second signals, especially second speech signals. If this reduction were due to novel sensation of a distraction, there should be a signal adaptation after prolonged exposure. Due to the fact that scientists developed and sold MAF feedback devices for decades, this is not plausible. In addition, Dewar, et al. (1979) longitudinally tested the Edinburgh Masker and reported similar stuttering reductions across time.

Miscellaneous Signals

Other of Bloodstein's (1949) 100 fluency enhancing conditions include auditory, visual and tactile modalities. However, most of the empirical research on these miscellaneous conditions and signals have been performed to prove distraction hypotheses. Coincidently, in trying to prove their theory, most have provided evidence to the contrary. Similar to DAF, researchers examined the effect of auditory reverberation on stuttering frequency (Adamczyk & Kuniszyk-Jozkowiak, 1987; Adamczyk, Kuniszyk-Jozkowiak, & Smolka, 1979; Adamczyk, Sadowska, Kuniszyk-Jozkowiak, 1975; Kuniszyk-Jozkowiak, Smolka & Adamczyk, 1997). Reverberation provides an echo like sound that is delayed behind the speaker's speech production. As with DAF stuttering frequency was significantly reduced in all auditory feedback conditions. Stuttering was reduced by 60-80%, similar to DAF.

To examine if the reduction in stuttering was simply due to auditory phenomenon, researchers examined the visual modality. Attempting to provide evidence for a distraction hypothesis, researchers examined stuttering frequency during intermittent luminescence not related to stuttering episodes (Mallard & Webb, 1980). There was no difference between the baseline and light flashing randomly conditions. Next, to determine if the effect was caused by increasing attention to stuttering, researchers had participants depress a key every time they stuttered, that turned on a light bulb (Hanson, 1978; Siegel & Hanson, 1972). This case study did not report mean differences between the conditions for the two participants. Finally, researchers examined visual luminescence related to speech production amplitudes (Kuniszyk-Jozkowiak, et al., 1996; Kuniszyk-Jozkowiak, et al., 1997). They had PWS speak as a variable light would intensify and decrease with their relative speech amplitude. A significant but small effect was reported for the reduction of stuttering associated with visual reverberation.

To further explore the distraction hypothesis, researchers examined the tactile modality (Kuniszyk-Jozkowiak, Smolka, & Adamczyk, 1996; Kuniszyk-Jozkowiak, Smolka, & Adamczyk, 1997). Similarly, the reverberation of the tactile probes were relatively matched to the speakers speech amplitudes. Stuttering frequency was significantly decreased during vibrotactile reverberation conditions. However, the greatest reduction in stuttering frequency was noted during auditory reverberation conditions alone as compared to any combination or single visual or tactile condition. More recently, researchers evaluated digital vibrotactile influence on stuttering frequency (Snyder, Blanchet, Waddel & Ivy, 2009). Specifically, participants placed their hands exteriorly to their larynx and moved it during speech production. Once again, a small but significant difference was noted during experimental conditions.

The above findings suggest that alterations to sensory and or motor systems may influence stuttering; however, due to the findings that auditory feedback provided the most powerful inhibitor of stuttering, it is unlikely that these findings were due to a distraction or stuttering awareness effect. The reductions noted during other conditions were minimal at best and do not account for the dramatic reduction in stuttering frequency by second speech signals.

Differences Between Second Signals

There are many differences in the reduction of stuttering between second signals. It is beneficial to have a relative scale to compare these differences. Choral speech is the gold standard for the reduction of stuttering. This reduces overt stuttering 90-100%, requires no or minimal training, and produces natural effortless speech. However, it is not plausible to have an individual speaking with a PWS throughout their lifetime. As with choral speech, shadow speech provides natural effortless speech with little or no training and reduces stuttering by 80-100%. These and other exogenous speech signals provide a continuous presentation of the speech signal and are not dependent on one's own speech output. That being said, other exogenously generated speech signals reduce stuttering by 70-80%. These signals can be forward flowing fluent, forward flowing stuttered, or reversed stuttered, temporally expanded, temporally reduced to some extent, syllabic repetitions or continuous vocalic productions (Kalinowski & Saltklaroglu, 2005). However, if the second speech signal is linguistically different from the produced utterance, less reduction in stuttering is reported. In addition, signals that are more speech like and provide more gestural information inhibit stuttering to a greater extent. For example, perception of a continuous or intermittent /a/ inhibited stuttering more than continuous or intermittent perception of /s/.

Typically the next signals that reduce stuttering to the greatest extent are endogenous-exogenous signals that use one's own speech output to produce the second signal. These second speech signals typically inhibit stuttering from 60-80% depending on the type of signal it is. Specific differences between DAF and FAF are controversial. Some studies claim that FAF provides more of a robust inhibitory effect (Howell, et al., 1987), others claim that DAF does (Andrews, et al., 1982; Natke, 2002), and yet others claim no difference between DAF and FAF (Kalinowski, et al., 1993; Macleaod, et al., 1995). Furthermore, the effects of AAF are highly variable among PWS and some researchers have failed to find differences during monologue samples and more natural communication settings (Ingham, Moglia, Frank, Ingham & Cordes, 1997; Stuart, et al., 1998).

Visual perception of speech gestures that are linguistically congruent provide the next level of inhibition. By perceiving a second speaker miming similar gestural content, stuttering is reduced by approximately 80%. However, as with choral speech, if the content is linguistically different stuttering is only inhibited by approximately 40%. DVF of one's own speech gestures inhibits stuttering by approximately 60% averaged across delay settings, while SVF decreases the stuttering inhibition to only 40%.

Nonspeech second signals that are matched to relative speech amplitudes and are either continuously produced or contingent upon stuttering demonstrate a 20-40% reduction in stuttering. This level of reduction occurs in the auditory, visual and tactile modalities. In addition, the findings that second nonspeech signals are effective at reducing stuttering are quite controversial (Kalinowski &

Saltuklaroglu, 2005). As stuttering and more so the reduction of stuttering is so variable, only signals with large effect sizes can be valid measures of the underlying mechanism.

More congruent speech like signals that decrease the dependency on one's own speech for second signal production offer a more robust inhibitory effect. Furthermore, it is plausible that due to similar effects a common inhibitory mechanism is responsible for these reductions. As these effects occur cross modally and to a greater extent during whole or partial speech perception or during motoric prolongations, it is likely that this inhibitory mechanism is highly related to the speech perception and production system.

Speech Naturalness

Most behavioral speech motor therapies for PWS target the reduction of primary overt stuttering symptoms. By reducing the frequency of repetitions, prolongations and postural fixations, clinicians believe that they will ultimately eliminate the involuntary nature of the pathology by teaching a new form of speech. In addition to the vast cognitive effort these procedures require the residual speech sounds very unnatural and droned (Franken, Boves, Peters & Webster, 1992; Ingham, Gow & Costello, 1985; Kalinowski, Nobel, Armson & Stuart, 1994; Runyan & Adams, 1979). Most therapeutic programs teach PWS to temporally expand speech, therefore reducing the speech rate and further decreasing the speech naturalness (Kalinowski & Saltuklaroglu, 2005). These motoric modifications range from easy onsets, light contact, constant voicing, purposeful prolongations, and voluntary repetitions among many others.

Therefore, the goal of any therapeutic repertoire should be to increase speech naturalness while decreasing overt stuttering behaviors and emotional reactivity to stuttering. This is further exemplified by the fact that stuttered speech is perceived to be more natural sounding that “fluent” speech post intensive therapy programs (Stuart & Kalinowski, 2004).

Speech that is produced under AAF is judged to be more natural sounding and effortless. Martin, et al. (1984) were the first to examine listeners' perceptions of the speech naturalness of PWS and fluent speakers during baseline and DAF conditions. Participants judged fluent speakers to be more natural regardless of the feedback condition. Both feedback conditions for PWS were judged equally unnatural, likely due to the stuttering and slowed speech-rate from the 250 ms delay. Contrary to these findings, researchers reported that clinicians judged speech production under FAF to be more natural than baseline conditions (White, et al., 1995). Ingham, et al. (1997) further evaluated speech naturalness during oral reading and spontaneous speech under FAF. One of the two clinical researchers reported speech naturalness differences, while the other did not. This suggests that speech naturalness findings are highly variable. However, to investigate the speech naturalness of PWS across therapies instead of against fluent speakers, researchers compared the speech of 10 PWS prior to and post intensive therapy and with AAF (Stuart & Kalinowski, 2004). Results indicated that speech prior to intensive therapy was judged more natural and AAF was judged more natural than baseline conditions. In addition, participants rated speech under FAF to be more natural than speech under DAF. Similarly, speech was perceived to be more natural under AAF than during baseline conditions (Kalinowski, et al., 2004). Most importantly, if AAF is used over an extended period of time (i.e., one year as compared to four months), speech is perceived to be more natural (Stuart, et al., 2006).

Motor Theory of Speech Perception

Stuttering inhibition during the perception of second signals is immediate, requires no training or motoric alterations, and produces effortless natural sounding speech (Kalinowski & Saltuklaroglu, 2005). The most robust effects of stuttering inhibition are reported when perceiving second speech signals that are linguistically congruent. These high, 80-100%, levels of stuttering inhibition occur during perception of both auditory and visual second speech signals. This suggests that there is a common cross modal inhibitory mechanism that is preferential to speech signals rather than nonspeech signals (Kalinowski, et al., 2002). It is plausible that a central involuntary block is overridden and released as the perceived speech signals generally match expected productions (Guntupalli, 2006; Kalinowski & Dayalu, 2002; Kalinowski & Saltuklaroglu, 2003). The Motor Theory of Speech Perception provides the best support for this conceptual framework (Liberman & Mattingly, 1985, 1989).

In 1944, Alvin Liberman and Frank Cooper were commissioned to invent a reading machine so blinded veterans had access to the printed word (Liberman, 1993). They initially tried to produce audible tones for each orthographic character. Participants were only able to understand eight words a minute with much required repetition. They began to examine the syllable as the fundamental unit of speech; however, this proved difficult due to the fact that vowels are not categorically perceived. As described earlier, vowels carry the consonant information and are influenced by coarticulation. Even with these variable productions, the intended message can still be accurately and instantly perceived by someone who shares the same gestural code (Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967). These notions are empirically supported by studies demonstrating that perception of a phoneme can be altered via context (Cooper, Liberman & Borst, 1950, 1951). This is to say the perception of a vowel or whole word can change depending on the final consonant. Specific acoustical percepts have yet to be found and if some cues are missing the gestural system can compensate for these missing components (Dorman, Raphael & Liberman, 1979). Participants accurately judged monosyllable words when the final phoneme had been removed. By perceiving the gestural trajectory that occurs during coarticulation, participants understood the intended final gesture. This notion was exemplified by the findings of Remez, Rubin, Pisoni and Carrell (1981) who demonstrated that sinusoidal speech analogs could be perceived. This sine wave speech synthesis had pure-tones placed at the mean vocalic formants and removed all consonant energy bands. Furthermore, combinations of the formant analogs were still perceived for their intended messages.

Liberman and colleagues described the fundamental unit of speech as the phonetic gesture (Fowler, 2006; Galantucci, et al., 2006; Liberman, 1998; Liberman, et al., 1967; Liberman & Mattingly, 1985, 1989; Liberman & Whalen, 2000; Massaro & Chen, 2008). Phonetic gestures are hypothesized to be neural representations of articulatory productions that can be immediately perceived for their production properties (Fowler, 1986; Knight & Studdert-Kennedy, 2000). Specifically, they proposed that humans perceive speech as the motoric gestures it would take to produce the same syllable. They hypothesize that due to gestural perception, speech is automatically perceived and does not require cognitive decoding. If a cognitive decoding phase were required, it would be analogous to learning to speak a foreign language. The speaker would have to translate each syllable as one might make word or phrase translations.

This theory is pertinent for a number of reasons. First, it explains humans' ability to understand multimodal speech production via auditory and visual representations (Liberman & Whalen, 2000). Second, it intrinsically links the speech perception and production systems into two sides of the same coin (Liberman & Whalen, 2000). Previous theories of speech perception have suggested a direct phonetic correlation where sounds can accurately be perceived for their intended message (Fant, 1962). However, this does describe the difficulty of combining words when their individual phonemes are produced (Repp, Milburn & Ashkenas, 1983) or the coarticulation that only gives meaning to forward flowing utterances (Knight & Studdert-Kennedy, 2000). This concept is best represented by the McGurk effect (McGurk & McDonald, 1976). Researchers presented auditory /ba/ /ba/ /ba/ stimulus that was matched up with visual presentations of /be/, /ve/, /□/. Participants perceived /da/ and /ga/ due to the neural convergence of the percepts (Liberman, 1979). When perceiving visual only speech in context, humans can still understand the intended messages (Knight & Studdert-Kennedy, 2000). Further observation of visual only speech activates auditory speech perception areas (Nishitani & Hari, 2002).

The existence of these phonetic gestures and gestural perception in general is supported by the findings of stuttering inhibition. As stuttering is immediately inhibited by the perception or production of simple syllabic repetitions and prolongations to the perception of auditory and visual speech gestures, it is likely that the inhibitory effect is tapping into this speech perception/production mechanism. Until recently the major problem with their theory was that no neurophysiological evidence existed to support their claims. However, the recent discovery of mirror neurons accounts for the majority of the underlying assumptions in the revised motor theory (Rizzolatti & Arbib, 1998).

Mirror Neurons

Mirror neurons (MN) appear as if they provide the perception and production link described in the Motor Theory. A research group in Para, Italy initially discovered the basis for MN in 1988. They noticed that single neurons in the premotor cortex (F5) of Macaque monkeys fired similarly when viewing a graspable object as they did when grasping the object (Rizzolatti, Camarda, Fogassi, Gentilucci, Luppino & Matelli, 1988). They coined these neurons canonical neurons. Further investigation in this region led researchers to discover MN (di Pellegrino, Fadiga, Fogassi, Gallese & Rizzolatti, 1992; Gallese, Fadiga, Fogassi & Rizzolatti, 1996; Rizzolatti, Fadiga, Gallese & Fogassi, 1996). They noticed that single neurons in the F5 region (i.e., premotor cortex) of Macaques monkeys fired during perception of researchers grasping for objects and they fired during the monkeys producing the same action. These findings link the perception and production systems to the neuronal level. Prior to this finding, it was believed that there were sensory neurons and motor neurons but not neurons that fired during both perception and production. The interesting finding of MN is that they did not fire during the perception of graspable objects like the canonical neurons, but fired during goal directed objectives performed by the hand. Furthermore, MN do not fire during non object action (i.e., hand movements alone). Later research indicates that MN in this area are preferential to visually presented stimuli regardless of distance and that similar firing patterns are even noted during production in a dark room (Rizzolatti & Arbib, 1998; Rizzolatti & Craighero, 2004). Specific MN also exhibit preference for precision versus general grasping behaviors (Gallese, et al., 1996). This is to say some neurons code for the general goal directed intent, while others code for the specific action or recognition.

As the phonetic gestural module is postulated in the Motor Theory, it is hypothesized that these action recognition MN code for performed actions (Gallese, et al., 1996; Rizzolatti & Arbib, 1998; Rizzolatti, et al., 1996). This is to say that the neurons code for how they would produce a perceived action and may contain a motoric module for these perceived actions. As one watches another produce a goal directed objective they learn how to imitate the production. So the basis of the MN system is imitation. By learning through imitation the concept of self and others during these productions is realized. As the sender produces a goal directed objective, the receiver is relatively performing similar actions as far as neural activity is concerned.

To this point, many interpretations may account for neural activation patterns; however, a more fully recognized action understanding system was realized by separating the modalities and presenting hidden action events. Kohler, Keysers, Umit'a, Fogassi, Gallese and Rizzolatti (2002) demonstrated that MN also fired during auditory perception of a goal directed objective and during hidden presentations of action events. Monkeys were presented with audiovisual, visual only and audio only goal directed objectives. For example, a researcher ripping ordinary paper, wet paper, and the sound of paper being ripped. It was found that 15% of the MN still fired during audio only perception of the sound. Furthermore, when monkeys were presented with the same audiovisual and visual only procedures behind a screen 50% of the MN fired. These findings suggest that the MN system is multimodal and exhibits preference to the intentions of goal directed objectives. Similar activations occurred when outcomes were known, which demonstrates the nature of the mirror neurons activating for actions and intentions.

Interestingly, MN also have been described in the inferior parietal lobe (IPL) (i.e., area 7b) (Fogassi, Gallese, Fadiga & Rizzolatti, 1998; Gallese, Keysers & Rizzolatti, 2004). These neurons exhibit similar firing patterns as the ones in the premotor cortex, in that about half fired during action observation and approximately 70% fired during production of the same behavior. The IPL is located posteriorly and adjacent to the premotor cortex and medial to the superior temporal sulcus (STS) and premotor cortex. The STS is known to be highly involved with processing visual information. Although it is yet unknown if the STS has MN, all three regions are highly connected and processing similar visual action recognition, albeit at different levels (Okada & Hickok, 2009).

MN provides the perception and production link described in the Motor Theory. In addition, the fact that they fire during goal directed action intentions of visual and auditory stimuli of general representations provides a good rationale for speech perception systems in human.

Mirror Neuron Systems

As it would be highly unethical to perform single neuron studies on humans, researchers are limited to describing mirror neuron systems (MNS) using function imaging and pseudoablation studies (Nishitani & Hari, 2000, 2002; Fadiga, Craighero, Buccino & Rizzolatti, 2002). Initially, researchers used transcranial magnetic stimulation (TMS) to measure motor evoked potentials (MEPs) from muscles of participants' left motor cortex (Fadiga, Fogassi, Pavesi & Rizzolatti, 1995). By stimulating the left motor cortex, muscles of the right hands and arms were activated. Participants were then presented goal directed and nongoal directed hand and arm sequences as MEPs were measured. Researchers noted increased muscle activity of the participants' hand and arm during observation of others movements, therefore supporting the perception and production link found in Macaques. An interesting finding from this study is that unlike in the monkey activation patterns were noted during nongoal directed movements as well as goal directed ones; however, they were activated to a lesser extent (Corballis, 2010).

To further evaluate this action recognition system in humans, researchers used positron emission tomography (PET) during observation and execution of goal directed and nongoal directed behaviors (Grafton, Arbib, Fadiga & Rizzolatti, 1996; Decety, et al., 1997; Iacoboni, Woods, Brass, Bekkering, Mazziotta & Rizzolatti, 1999). Researchers reported activation in the left frontal gyrus (i.e., Broca's area which is homologs to the F5 region in Macaques) during the observation of meaningful goal directed behaviors but not during nonmeaningful movements. However, activity was reported in the posterior parietal lobe during the meaningless gestures. These observations suggest two major hypotheses. First, the posterior parietal lobe likely has mirror capabilities and second, that Broca's area, known for speech production in humans, also codes for hand movements. Similar studies that examined imitation and observation of finger tapping sequences report similar results (Iacoboni, et al., 1999; Nashitani & Hari, 2000; Skipper, Goldin-Meadow, Nusbaum & Small, 2007). Researchers noted activations of the left Broca's area, right parietal lobe, right operculum during production tasks and only activation of the left Broca's area and right parietal lobe during observation. The notion that Broca's area is coded for hand movements can best be demonstrated by the findings of Heiser, Iacoboni, Maeda, Marcus and Mazziotta (2003). They showed that continual disruption of Broca's area using repetitive TMS impaired participants' ability to imitate finger-tapping sequences.

To examine if other systems than the hand met the criteria for goal directed objectives, researchers also evaluated mouth and foot areas (Buccino, et al., 2001). Participants were presented with actions made by the hand, foot, and mouth either toward an object or without an object present. Results indicated activation of both sections (i.e., the lower segment of the precentral gyrus and the pars operculum) of Broca's area bilaterally during the observation of a mouth biting an apple. During the same condition bilateral activation of both parts of the IPL (rostral and caudal segments) were activated bilaterally. Interestingly, the nonobject stimuli only activated premotor areas without activating the more intention driven IPL. These studies show that the MNS is goal directed and occurs during more than just hand related behaviors. Furthermore, it appears that the MNS is a complex interrelated system that affects all lobes of the brain.

The MNS is of great evolution importance due to action understanding and learning through imitation (Arbib, 2010; Corballis, 2010). It is not known if other primates have developed these capabilities to the extent of humans, but humans can effortlessly learn through imitation. For example, babies can deduce what shape block fits into what hole from observation, but monkeys have to learn from experimentation to use a stick to get ants out of an anthill and would not deduce this from observation (Rizzolatti, Fogassi & Gallese, 2001). Learning through observed imitation has been shown with functional magnetic resonance imaging (fMRI) (Iacoboni, et al., 1999; Koski, et al., 2002) and magnetoencephalography (MEG) (Nishitani & Hair, 2000). Due to the temporal resolution of MEG, researchers concluded that cortical activation progressed from the occipital cortex, superior temporal region, inferior parietal lobe, Broca's area and then finally to the premotor cortex during perception of lip forms and facial grimaces. They noted that only Broca's area and the motor cortex were activated during production of these postures.

The intentional basis of the MNS is exemplified in the findings that MNS activate during the perception of still images after goal directed events (Aziz-Zadeh & Ivry, 2009). Researchers showed human participants pictures of pre and post events, for example a clean set table and a messy table. Participants MNS areas exhibited increased activation during the post-event but not during the pre-event. Similar to the canonical neurons these findings suggest a neural basis for action intentions.

The aforementioned findings suggest that the MNS adequately provides evidence for the learning through imitation system for goal directed behaviors. As speech and language are developmental processes from an innate system it seems likely that the MNS would be an active component of this process.

Mirror Neuron Systems and Language

All communication requires the understanding of a common code. Speech and language in humans is no different. The Motor Theory of Speech Perception (Liberman & Mattingly, 1987) suggests that in humans, this code is gestural in nature. This is to say that during speech perception of a common gestural system, humans perceive neural representations of how the motoric forms would be produced. The perception of this phonetic module is direct and does not require decoding. Discovery of the MNS provided a neurophysiological basis for these prior assumptions (Rizzolatti & Arbib, 1998). This dual observation and activation system enables direct understanding between senders and receivers intentions. Prior to development of a language system a species must exhibit an action recognition system (Arbib, 2010; Corballis, 2010).

Humans demonstrate the most efficient capacity to learn from imitation. This claim is supported by functional imaging studies, which demonstrate activation of MNS areas during the observation of general or specific motor intentions (Aziz-Zadeh & Ivry, 2009; Iacoboni, et al., 1999). These activation patterns are different from our primate relatives that only demonstrate activation during the observation of goal directed objects with an object. Humans exhibit activity during the observation of goal directed intentions with and without object relevance. This allows for a more general intentional understanding of produced gestures. Homologues to the F5 region in Macaques, Broca's area in humans provides a general system of interpretation for motor intentions (Arbib, 2010). Broca's area codes gestures and intention for hands, facial postures, and articulators. Neural activation during the observation of others performing motor behaviors is found at the neuromuscular level in humans (Fadiga, et al., 1995). Specifically, by observing others talk our muscles of articulation increase activity. However, overt imitation is inhibited along the neural pathway (Baldissera, Cavallari, Craighero & Fadiga, 2001). It is likely that speech developed as manual gestures and general vocalizations, then adapted for motoric positioning, which became action recognition of motor intentions (Arbib, 2010; Corballis, 2010).

Speech and language acquisition is a developmental process that occurs from birth throughout the early years of life. It is likely that the MNS develops in a similar way. During the first few months of life, children can track lip movements (Meltzoff & Moore, 1977) and imitate vocalizations from most cultures (Kuhl & Meltzoff, 1996). Furthermore, during vocal development babies imitate vocalizations of caregivers typically starting at the highly encoded audio-visually presented sounds /m/ and /b/ then progressing down the vocal tract. Infants develop a complete gestural repertoire from this reflexive imitative process (Kalinowski & Saltuklaroglu, 2003). In a recent fMRI study, researchers demonstrated that infants 3 months old exhibited similar neural activations as adults during the presentation of forward flowing and reversed speech (Dehaene-Lambertz, Dehaene & Hertz-Pannier, 2002). This is interpreted as a precursor to language processes. Interestingly, Piaget's (1963) sensorimotor stage that describes vocal and manual imitative behaviors coincides with MNS development (Kalinowski & Slatuklaroglu, 2003). This is approximately the same age that stuttering is initially observed and, as the imitative behaviors decrease stuttering typically is classified as a chronic pathology and develops more complex symptomatology. If a child never developed beyond the imitative stage, it is likely that stuttering would never persist.

Mirror Neuron Systems and Stuttering Inhibition

Learning is hypothesized to be a primarily imitative process. This life long propensity begins at infancy and lasts throughout adulthood. As children produce more linguistically complex structures, imitation decreases. Stuttering typically develops as the imitative reliance subsides. Developmental phases of stuttering generally co-occur with the remission of Piaget's (1963) sensory motor stage (Kalinowski & Saltuklaroglu, 2003). It might not be a coincidence that imitative behaviors such as choral speech are the most effective and efficient inhibitor of stuttering. Engagement of the MNS during auditory and visual perception of second speech signals or self-produced stuttering behaviors may release a central neural block, therefore inhibiting overt stuttering (Kalinowski & Saltuklaroglu, 2003; 2005). Choral speech and its analogs are likely a form a direct neural imitation that engages phonetic modules during speech perception and production. Findings that stuttering is inhibited during audiovisual, audio only, and visual only second speech signals support the notion that speech is gestural in nature. In addition, findings that simple syllabic repetitions inhibit stuttering provides support to the notion of the general framework and temporal flexibility described within speech perception and the MNS.

Recently, a Gestural Model of Stuttering Inhibition (GMSI) has been proposed with a basis in the MNS (Hudock, et al., 2011). This model is the only model that adequately accounts for differential reductions of stuttering from second speech signals across the auditory and visual modalities and normal and fast speech rates (Kalinowski & Dayalu, 2002; Kalinowski & Saltuklaroglu, 2003a; Kalinowski & Saltuklaroglu, 2003b; Kalinowski & Saltuklaroglu, 2005). This model proposes that second speech signals tap into the gestural system of speech perception and production proposed by the Motor Theory of Speech Perception (Liberman & Mattingly, 1985, Liberman & Whalen, 2000; Studdert-Kennedy, et al., 1970). Simply put, PWS automatically decode speech gestures from auditory or visual speech signals by motorically rehearsing it at a neuromuscular and neurological basis. This real-time suppressed production inhibits stuttering in a forward flowing fashion. This is to say that the central neural block might be reduced or released prior to the stuttering event however will not completely alleviate the moment of stuttering once the neuro-oscillations have begun. By simultaneously perceiving the signal during production, a common inhibitory system is engaged. The MNS provides the neurophysiological basis for this link between observation and execution (Kalinowski & Saltuklaroglu, 2003, 2005). The GMSI is based on assumptions from the Motor Theory of Speech Perception and neurophysiological findings of the MNS. These notions of perception and production are linked in an intricate fashion via a common gestural code; it is also possible to extract and extrapolate missing, incomplete, or limited gestural content in the second speech signal. This interaction between the incoming speech gestures and the ongoing speech production acting via the MNS is believed to be an important component in stuttering reduction.

Summary and Rationale

With no foreseen cure for stuttering on the horizon, one should take the practical approach and examine methods to effectively and efficiently reduce overt symptomatology while treating the syndrome. Past methods for treating stuttering have been proven ineffective in the long-term due to the amount of effort and the minimal benefit gained from unnatural speech outcomes. Relapse rates from upwards of 90% can partially be blamed on how clinicians have viewed and treated the syndrome over decades. Overt stuttering has historically been viewed as the problem and that implementation of behavioral speech motor paradigms should eliminate the disorder if techniques are properly and often used. More so, the client has continually been blamed for not being able to control their involuntary disorder with the cognitively strenuous and artificial speech motor strategies.

It is a primary tenant of the current thesis, that PWS should not be blamed for an inability to control their involuntary pathology. Furthermore, the author’s view of stuttering is that it is caused by a central involuntary block and that overt manifestations are proximal effects from a distal agent. This central block can be released and inhibited during motor or sensory alterations. However, due to the inefficiency and ineffectiveness of most speech motor strategies, treatment should focus on more efficient and effective methods. A more efficient means of treating stuttering is implementing second speech signals during speech production. The perception of second speech signals has been shown to immediately inhibit stuttering from 60-100% and produces natural sounding effortless speech.

Stuttering inhibition during the perception of second speech signals is fundamentally based on the choral speech effect. Choral speech is when a second speaker speaks in approximate unison with a PWS. The resultant outcome is that stuttering is immediately and dramatically inhibited. Choral speech is thought to be the gold standard for stuttering therapy by immediately reducing overt features by 90-100% and producing natural effortless speech. A derivation of choral speech is shadow speech. Shadow speech has historically been defined and examined as a fluent speaker in the lead speaker position with the PWS in the lag speaker position. As with choral speech, stuttering is inhibited from 90-100% during shadow speech conditions. These findings contradict some demand and capacity models for stuttering. Demand and capacity theories suggest that stuttering holds an inverse relationship to cognitive and linguistic demands placed on the system due to the limited capacities of PWS (Starkweather, 1997). Under the historical alignment of shadow speech the PWS has increased demands and increased fluency. Increased demands are from maintaining the lead speaker's speech rate, temporal alignment, and guessing at the linguistic productions if not evaluated with prepared texts. Further demands would be placed on the PWS if they were in the lead speaker position. However, the temporal alignment of the speakers has yet to be evaluated.

The purpose of the current series of studies was to further examine the nature and mechanisms of stuttering inhibition during the perception of second speech signals. The first experiment examined stuttering inhibition as a factor of speaker position. The four conditions consisted of the PWS speaking alone (i.e., baseline), the PWS in the lead speaker position with a fluent speaker in the lag position, a fluent speaker in the lead speaker position with the PWS in the lag position, and choral speech where the speakers maintain close temporal proximity during the condition. To control for linguistic complexity and possible avoidance behaviors participants recited the same 300 syllable prepared text per condition. Passages and condition presentation were randomized. To control for speaker effects, the same fluent speaker was trained, then used during all participants. In addition the PWS and fluent speaker practiced speaker positions prior to recordings.

DAF and FAF are choral and shadow speech analogs. As it is not plausible or likely to have a second speaker with the PWS at all points during communication, DAF and FAF provide a viable natural means of dramatic stuttering inhibition by using one's own speech output to generate a second speech signal. These forms of AAF inhibit stuttering by 80% across situations and speech rates. Furthermore, the majority of studies report that stuttering inhibition does not significantly differ from FAF, DAF or a combination of FAF and DAF. Researchers have extensively examined the type, modality, and proportion of delay among second speech signals; however, researchers have yet to fully examine the amount of gestural information necessary and sufficient for practical stuttering inhibition during hierarchically more complex situations. Only a handful of studies have examined stuttering inhibition during more complex situations such as speaking on the telephone. One such study compared stuttering frequency during scripted telephone conversations using DAF or FAF to baseline conditions (Zimmerman, et al., 1997). The effect of multiple AAF signals during scripted telephone conversations has not been tested. Therefore, the second experiment examined the inhibitory effect of one combined DAF and FAF signal to two combined DAF and FAF signals at different delays and frequency shifts during scripted telephone conversations. Three conditions consisted of a baseline condition with no altered feedback (NAF), one combined DAF and FAF signal, and two different delayed and frequency altered feedbacks. Participants called five categories of businesses per condition for a total produced syllable count of 300 per condition. Conditions and scripts were randomized.

Experimental Questions

Presenting second speech signals is one of the most powerful stuttering inhibitors known and produces natural sounding effortless speech in PWS. However, aspects of temporal alignments for second speech signals have yet to be fully examined. In addition, the use of one DAF and FAF combination versus multiple DAF and FAF combinations during hierarchically complex speaking situations has yet to be tested. The present study proposed two experiments to further investigate the nature of second speech signals for stuttering inhibition. The first experiment examined stuttering inhibition during three experimental conditions compared to a baseline condition. Temporal alignment of speaker positions during shadow speech has never been examined. Experimental conditions consist of choral speech, the PWS in the lead speaker position with a fluent speaker in the lag speaker position, and a fluent speaker in the lead speaker position with the PWS in the lag speaker position. The following questions were proposed for the first experiment:

1) Is stuttering frequency significantly reduced during choral speech?
2) Is stuttering frequency significantly reduced with the PWS in the lead speaker position and a fluent speaker in the lag speaker position?
3) Is stuttering frequency significantly reduced with a fluent speaker in the lead speaker position and the PWS in the lag speaker position?

4) When the PWS is in the lead speaker position, is stuttering frequency significantly different from choral speech conditions?
5) When the PWS is in the lag speaker position, is stuttering frequency significantly different from choral speech conditions?
6) Does stuttering frequency significantly differ when the PWS is in the lead speaker condition as compared to the lag position?

The second experiment proposed examining stuttering frequency during baseline conditions (i.e., NAF), one combination of DAF and FAF and two combinations of FAF and DAF signals with different frequency shifts and delays during scripted telephone conversations. Minimal studies have examined stuttering inhibition during hierarchically complex situations such as scripted telephone conversations and no other study has examined stuttering frequency during the perception of multiple DAF and FAF signals. The following questions were proposed for the second experiment:

1) Does stuttering frequency significantly decrease under one combination of DAF and FAF relative to NAF during scripted telephone conversations?
2) Does stuttering frequency significantly decrease under two combinations of DAF and FAF relative to NAF during scripted telephone conversations?
3) Does stuttering frequency significantly differ from one combination of DAF and FAF compared to two combinations of DAF and FAF during scripted telephone conversations?

CHAPTER III

EXPERIMENT I

Introductory Statement

Choral speech is the gold standard for reductions of stuttering. Choral speech is when two speakers produce the same utterance in an approximate simultaneity, which typically reduces stuttering by 90-100%. Shadow speech is a derivation of choral speech that has the PWS lag behind a fluent speaker while they recite linguistically similar material with a slight spatial-temporal delay. However, the effect of speaker position on stuttering frequency has yet to be examined. The purpose of the current experiment is to better understand temporal alignments of second speech signals and their effect on stuttering inhibition.

Methods

Participants

Eleven native English speaking adults who stutter including nine males and two females with a mean age of 30.2 years (*SE* = 4.9, range 18 – 72), and no self-reported history of concomitant speech, language, cognitive, uncorrected visual or hearing deficits participated in the study. Participants met inclusionary criteria of 5% or more stuttering during informal assessment of spontaneous speech. Prior to experimental procedures, informed consent (approved by the University and Medical Center Institutional Review Board, East Carolina University) was obtained from all participants (*see Appendix C*).

Instrumentation and Stimuli

Texts consisted of four nonstandardized passages from fifth to seventh grade reading levels, as determined by the Flesch-Kincaid reading scale (Flesch, 1974) (as reported in Saltuklaroglu, 2004). Passages have been used in previous studies (Hudock, et al., 2011; Kalinowski, et al., 1993, Kalinowski & Stuart, 1996; Stuart & Kalinowski, 1996) and are linguistically similar. Participants were recorded using an iPhone 4 digital camcorder with 720p resolution that was statically positioned approximately 24 inches with a 0 degree azimuth from participants.

Normally fluent female communication sciences and disorders students, with no speech, language, reading, hearing or visual deficits performed the role of the second speaker. Prior to experimental conditions the same researcher trained fluent speakers using developed standard protocols. Fluent speakers maintained approximately three to four word distances from the participant during lead and lag conditions and a close temporal proximity during choral conditions. Fluent speakers adjusted their speech rates and alignments to accommodate the participants'. If stuttering occurred during verbal readings the fluent speaker repeated the proximal three to four word phrase maintaining similar temporal alignments. Once participants reinitiated fluent productions, the second speaker continued reading to maintain proper distances and alignments. All texts and condition sequences were randomized using a numbering system for each on www.randomizer.org.

Procedures

All participants and fluent speakers signed informed consent documents prior to study initiation. During conditions, participants were requested not to use any fluency enhancing strategies. Participants were seated directly adjacent to the left side of the fluent speaker during all conditions. The fluent speaker and participants practiced maintaining proper speaker positions and spatiotemporal alignments prior to recordings for a maximum of two minutes; however, this typically lasted two to three sentences with novel text. Once the fluent speaker and participant understood and accurately demonstrated procedures the camera was set up and novel texts were distributed. Participants maintained two-minute spontaneous speech conversations between all conditions in order to reduce any possible carryover effects.

Table 1

Raw and Mean Participant Descriptive Data with Standard Errors for Experiment I

Participant	Gender	Age	Baseline	Lag	Lead	Choral
1	M	23	33	11	10	3
2	M	30	6	1	5	1
3	M	19	45	7	4	2
4	M	32	15	2	2	1
5	M	72	9	1	0	0
6	F	31	9	0	0	0
7*	M	20	123	38	190	5
8	M	21	13	2	1	1
9	F	18	33	7	7	2
10	M	22	38	4	6	0
11	M	34	35	9	15	1
Means**	NA	30.2	23.6	4.4	5.0	1.1
Standard Errors**		4.9	4.6	1.2	1.5	1.2

Note. Choral = choral speech, Lead = PWS maintaining the lead speaker position, Lag = PWS maintaining the lag speaker position, and Baseline = PWS speaking alone.
* Participant 7 was not included in the analysis as they were deemed an outlier.
** Means and standard errors do not include data from participant 7.

Results

A trained researcher calculated stuttered syllables for each condition during audiovisual analysis of recordings. Stuttering was defined as part-word repetitions, phoneme prolongations, and postural fixations. Intra-rater and inter-rater reliabilities were obtained from a randomized 10% of the data. A certified speech-language pathologist trained in stuttering evaluation performed the inter-rater reliability using Cohen's *kappa* syllable-by-syllable agreements (Cohen, 1960; Fleiss *et al.,* 2003). Kappa values for intra-rater analysis were 0.825 and were 0.716 for inter-rater. Values above 0.750 represent excellent agreement.

Prior to statistical analysis participants' proportional times were transformed into arcsine units, as is common practice when dealing with proportional values during inferential analysis (Fleiss, 1981). Data from one participant was discarded as they were deemed an outlier (*i.e., participant 7 as displayed in table 1*). This was due to the participant's high degree of stuttering and abnormal results during experimental conditions. A two-factor linear mixed model repeated measures analysis of variance (ANOVA; SPSS Inc., SPSS 19.0 for Mac) was undertaken to examine the effect of condition and script on stuttering frequency. A significant main effect for condition was revealed [$F(3,9) = 50.812$, $p = 0.000$, $\square_{p}^{2} = 0.376$). To examine the source of the main effect of condition post hoc least significant difference (LSD) were undertaken. Differences were revealed between NAF relative to all conditions ($p < 0.001$) and choral conditions relative to both lead and lag conditions ($p < 0.012$). No differences were revealed between lead and lag conditions ($p > 0.05$). Further, there was no main effect for script ($p > 0.05$) or interaction effects ($p > 0.05$). Participants total and mean stuttering frequencies with standard errors are reported in *table 2*. Average stuttering frequencies with standard errors are represented in *figure 1*.

Table 2

Means and Standard Errors for Total Frequency of Stuttering as a Function of Condition in Experiment I

Condition	Mean	Standard Error
Baseline	23.6	4.9
Lag	4.4	1.2
Lead	5.0	1.5
Choral	1.1	0.3

Note. Choral = choral speech, Lead = PWS maintaining the lead speaker position, Lag = PWS maintaining the lag speaker position, and Baseline = PWS speaking alone.

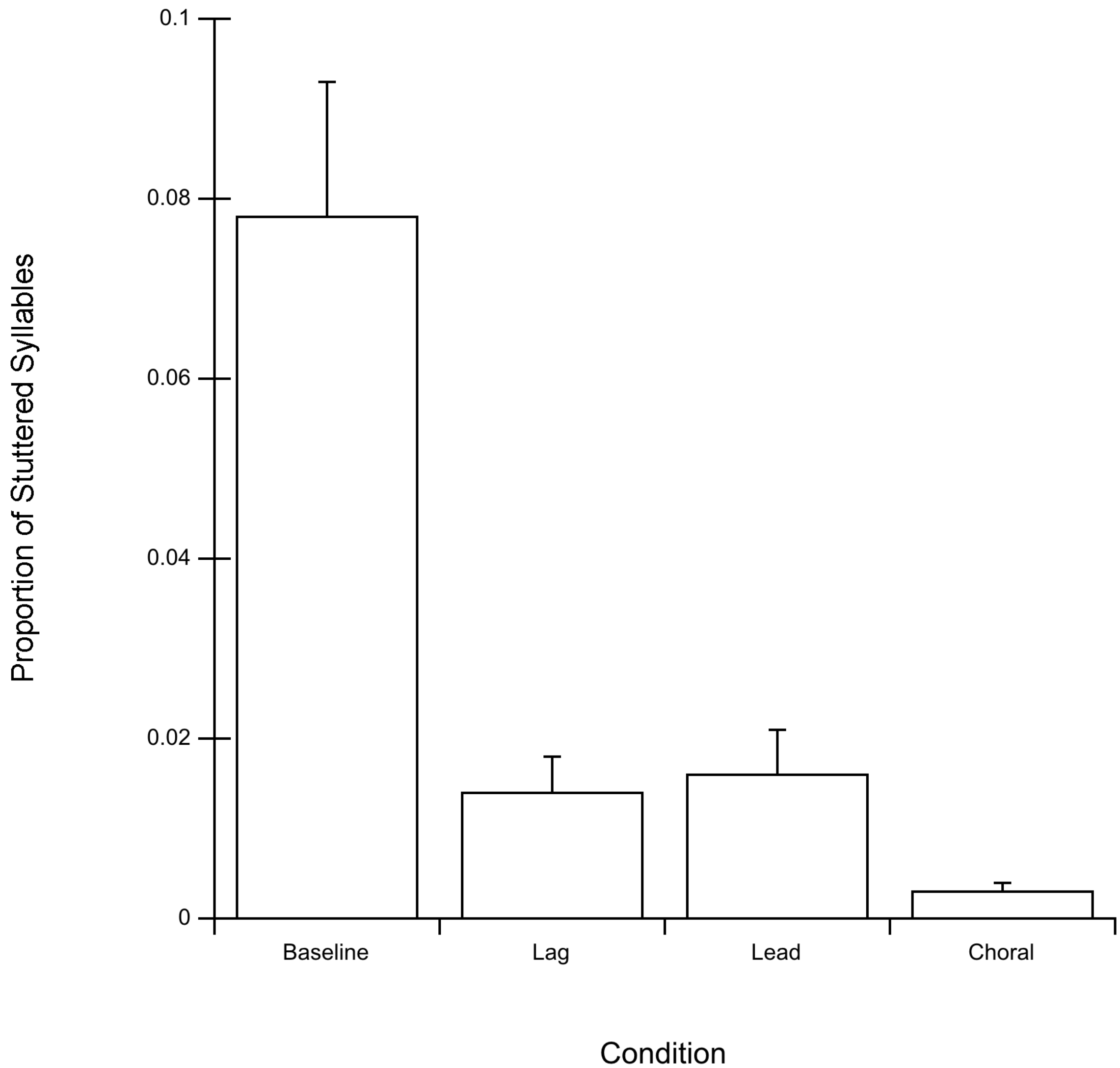

Figure 1. Mean proportions and standard errors of stuttering frequency as a function of condition. Choral = choral speech, Lead = PWS maintaining the lead speaker position, Lag = PWS maintaining the lag speaker position, and Baseline = PWS speaking alone. Error bars represent plus one standard error of the mean.

Discussion

The current study revealed three pertinent findings. First, stuttering was immediately and dramatically inhibited during all experimental conditions relative to baseline. Second, choral speech offered a more robust inhibition of stuttering and practically eliminated the overt presence for all participants. Third, there were no significant differences in stuttering frequency between lead and lag speaker conditions. Findings that stuttering frequencies were significantly reduced during choral speech and lag speaker conditions support decades of research (Bloodstein & Bernstein-Ratner, 2008; Cherry & Sayers, 1956; Eisenson & Wells, 1942; Johnson & Rosen, 1937; Patty & Knight, 1944; Van Riper, 1971). A unique finding revealed in the current study was the level of stuttering inhibition noted when PWS maintain lead speaker positions. Relative to baseline conditions stuttering frequencies were reduced 95% during choral speech and approximately 80% during both lead and lag speaker conditions. To the best knowledge of this researcher, the current study is the first to empirically examine stuttering inhibition during shadow speech with the PWS maintaining the lead speaker position.

Overt stuttering is often described as a neuromuscular deficit with timing and sequencing muscles of speech production. Interestingly, stuttering is immediately and dramatically inhibited during the perception of second speech signals without training or effort and creates natural sounding fluent speech (Adams & Ramig, 1980; Bloodstein & Bernstein-Ratner, 2008; Cherry & Sayers, 1956; Johnson & Rosen, 1937). These reductions in stuttering demonstrate sensory influences on production systems. Being that stuttering is all but eliminated in choral speech and drastically reduced under shadow speech hypotheses have been made that perceiving second speech signals alters timing and sequencing patterns of production processes. Researchers often speculate about specific causal mechanisms of these fluency-enhancing conditions. Some of the most common theories are that second signals produce external pacing or rhythm generators that temporally align speech patterns of PWS to those of second signals (Armson & Keifte, 2008; Howel, *et al.,* 2005).

Findings from the current study lend themselves to theoretical implications refuting some hypothesized claims. For example, stuttering frequency was reduced to similar extents in both lead and lag shadow speech conditions. As PWS generated initial pacing and rhythm during lead speaker conditions, it is not possible for these contingencies to be reliant on the second speakers' productions. Furthermore, fluent speakers adjusted their rate and spatiotemporal proximity to participants. This procedure makes PWS responsible for generating pacing and rhythm during productions. Even during choral speech temporal alignments between speakers vary and are never truly synchronous. During oral readings two speakers may frequently alter speaker positions by speeding up, slowing down or emphasizing different word and sentence components in a constant dynamic fluctuation. Regardless of the fact that speaker positions and spatiotemporal alignments are seldom maintained throughout readings, choral speech is still the gold standard for stuttering inhibition by reducing disfluencies from 90-100% (Bloodstein & Bernstein-Ratner, 2008).

A second set of general hypotheses claim that perceiving second signals reduces the cognitive load on the individual who stutters therefore enabling extra allocation to speech production processes, therefore increasing fluency. Demand and capacity models suggest that increased demands, such as heightened anxiety, increased linguistic complexity or faster speech-rates negatively impact stuttering frequency by exceeding the inherent fluent speech capacities of PWS (Starkweather, 1997). According to these models regardless of second signals, PWS should not be able to speak fluently at a fast rate or while they have increased demands placed on them. Contrary to these notions, PWS can speak at normal and fast speech rates and yet maintain similar levels of stuttering inhibition during the perception of second speech signals (Hudock *et al.,* 2011; Kalinowski, *et al.,* 1993; Stuart and Kalinowski, 1996). In addition, many participants in the current study self-reported how difficult it was to maintain their own speech productions while not being influenced by the second speaker. Attempting to block out the second speaker's productions, probably increased cognitive demands for the participants; however, stuttering was still reduced 80-95%. It was previously hypothesized that speaking demands are alleviated during choral and shadow speech because the reliance for fluency dissipated across two speakers (Eisenson & Wells, 1942; Howell*, et al.,* 2005; Perkins, 2002; Patty & Knight, 1944; Starkweather, 1997). As PWS relied on second speakers for rhythm and pacing generation their cognitive allocations for speech production expanded. During shadow speech the lead speaker position was thought to require additional cognitive demands for setting pace, rate and rhythm and initially generating linguistic content (Starkweather, 1997). Reductions in stuttering during shadow speech while PWS maintain lag positions was claimed to be due to the participant mimicking the produced content of the lead speaker (Adams & Ramig, 1980; Cherry & Sayers, 1956; Johnson & Rosen, 1937). Findings that participants self-reported difficulty with attending to their own utterance productions and similar stuttering inhibitions during lead and lag speaker conditions, challenge the aforementioned claims.

The Gestural Model of Stuttering Inhibition (Hudock, *et al.,* 2011; Kalinowski & Saltuklaroglu, 2002; Kalinowski & Saltuklaroglu, 2005) accounts for limitations with previously discussed theories as well as findings of similar stuttering inhibition during lead and lag speaker conditions. Prior to describing the model, one must understand fundamental tenants of the theory that are based on notions from the Motor Theory of Speech Perception (Liberman and Mattingly 1985, Liberman and Whalen 2000; Studdert-Kennedy *et al*. 1970). First, speech is perceived as a series of articulatory gestures instead of specific acoustic cues. These gestures are neural imprints of phonetic motor modules of articulatory sequences required to produce specific syllables. In other words, this theory suggests that humans perceive speech as the motor sequences it would take to produce it, instead of the acoustic features that are heard. Second, perception of these gestural motor representations shares a common mechanism for perception and production; this is theorized to the extent that perception and production are two sides of the same coin. Recently, the mirror neuron system was discovered, which offers support for these tenants of the motor theory

(Rizzolatti & Arbib 1998). As mentioned, mirror neurons are collections of single neurons that fire both during the perception and production of biologically salient goal directed objectives (Gallese, *et al.,* 1996; Rizzolatti, *et al.*, 1996). Furthermore, mirror neuron systems code for auditory, visual, auditory, and visual, and imagined goal directed intentions (Kohler, *et al.,* 2002). Specifically, when humans perceive speech, the receivers' neural activation patterns are similar to the production patterns of the sender. This occurs almost to the extent as if the receiver were producing the articulatory gestures themselves.

The Gestural Model of Stuttering Inhibition (GMSI) suggests that stuttering occurs as a central neural block; by perceiving second speech signals PWS immediately engage their mirror neuron systems, therefore inhibiting stuttering. It is likely that similar levels of stuttering inhibition were noted during lead and lag speaker conditions, due to the flexibility of the dynamic gestural perception system. For example, this flexible and dynamic system inhibits stuttering 40-60% when PWS view visual only speech gestures (Dayalu, 2004; Hudock, *et al*., 2011; Saltuklaroglu, *et al.,* 2000; Snyder, *et al.,* 2009) and 70-80% during AAF (Kalinowski, et al., 1993; Guntupalli, *et al.,* 2005; Saltuklaroglu, *et al*., 2005; Stuart & Kalinowski, 1996). More robust inhibition of stuttering is often noted when second speakers produce the second signals as compared to second signal production being contingent upon one's own speech (*e.g.,* DAF and FAF). The exogenous signal is not reliant on production capabilities of the PWS and can act in a forward flowing manner, regardless of the PWS speech disruptions. An interesting anecdotal finding from the current study to support the idea of stuttering inhibition rather than simply a reduction in stuttering occurred when participants were stuttering and the second speaker began to speak during an ongoing stuttering episode. Presentation of the second signal did not stop the static oscillation but instead, typically inhibited stuttering on the following words.

Conclusions

In conclusion, stuttering was significantly reduced during all three experimental conditions and was inhibited to the greatest extent during choral speech (*i.e.,* 95%). No differences between levels of stuttering inhibition were noted between lead and lag speaker conditions (*i.e.,* 79% and 81% respectively). Similar stuttering frequencies during lead and lag conditions refute notions proposed by proponents of external timekeeper models and demand and capacity models for stuttering reduction during the perception of second signals. That is, the lead speaker position required generation of self-produced rhythm and pace, as well as increasing cognitive demands by linguistic formulation tasks. Regardless of these increased demands, PWS maintained equivalent stuttering inhibition during both lead and lag speaker conditions. Finally, the Gestural Model of Stuttering Inhibition can be used to explain findings of the current study.

CHAPTER IV

EXPERIMENT II

Introductory Statement

The most powerful inhibitor of stuttering known is choral speech. When two speakers speak in approximate unison stuttering is inhibited by 90-100%. DAF and FAF are analogs of choral speech that use one's own speech output to generate second speech signals from digital signal processors. These forms of AAF have been shown to inhibit stuttering by 70-80% regardless of single signal presentation or a combination of DAF and FAF signals. Only a handful of studies have examined stuttering inhibition during hierarchically complex situations such as scripted telephone conversations and no studies have examined the effect of multiple combinations of DAF and FAF signals for stuttering inhibition. The current study examined stuttering inhibition during one combination and two combinations of DAF and FAF during scripted telephone conversations.

Method

Participants

Nine native English speaking adults who stutter including eight males and one female with a mean age of 35.1 years (*SE* = 5.3, range 21 – 72) with no self-reported history of concomitant speech, language, cognitive, uncorrected visual or hearing deficits participated in the study. Participants met inclusionary criteria of greater than 5% stuttering during informal assessment of spontaneous speech. Prior to experimental procedures, informed consent (approved by the

University and Medical Center Institutional Review Board, East Carolina University) was obtained from all participants (*see Appendix F*).

Instrumentation and Stimuli

Scripted telephone conversations for types of businesses were retrieved via Zimmerman, *et al*., (1997) (*i.e., see Appendix G*). Some scripts were altered in order to increase social relevance for 2012. Presentation sequences and telephone scripts were randomized by assigning individual numerical values to each then randomly generating number sequences using www.randomizer.org. Participants spoke into a Sennheiser HMD 281 Pro 64 Ohm monaural headset with a unidirectional dynamic microphone (frequency ranges 500Hz – 20,000 Hz) positioned one-inch directly in front of their mouths. Downstream audio was received by a Radial JS-3 XLR splitter that delivered the threw-put, unamplified, stereo signal via XLR to 3.5mm cable into an iMac 10.1 Intel Duo Core computer, which used Audacity 1.3.14 Beta software to capture the signal at 44.1K Hz. The Radial JS-3 delivered two amplified stereo signals into a Mackie Micro Series 1202 12-channel mixer via XLR connections.

Two lineout stereo signals went from the mixer into two separate left mono RCA inputs in Yamaha DSP-1 digital signal processors (DSP). The first DSP generated a second signal with a 50ms delay and positive half-octave shift up. The second DSP generated a second signal with a 200ms delay and negative half-octave shift down. Mono unbalanced signals from the two DSPs were then fed into a Rolls Mix Max RM81 mixer via line inputs. The mixed signal was then sent to a Rolls RA68b headphone-amplifying mixer where the line stereo plug for the Sennheiser headset was insert. Frequency ranges for the broadcast quality headset were 20 – 20,000 Hz.

Specific delay and frequency settings were chosen due to prior examination (Dayalu, 2004; Hargrave, *et al*., 1995; Macleod, *et al.,* 1994; Stuart, *et al*., 1997), while signals were markedly different, yet individually perceptible by participants. Hargrave, *et al.* reported equivocal reductions in stuttering frequency between half and one octave positive and negative frequency shifts during reading conditions. Similarly, under DAF, Dayalu, *et al.,* reported equivocal reductions in stuttering frequency between 50, 200 and 400ms delay conditions. The level of stuttering inhibition noted in Dayalu, *et al.,* is similar to levels noted during 25, 50 and 75ms delay conditions (Kalinowski and Stuart, 1996). Macleod, *et al.,* reported equivocal reductions in stuttering frequency when comparing DAF with a 50ms delay, FAF minus one-half octave shift and a combination of these two signals. Finally, similar reductions have been noted with binaural and monaural signal presentations (Stuart, *et al*., 1997). The preceding studies all report approximately 70-80% reductions in stuttering frequency during oral reading conditions. Furthermore, general experimental designs for the current study were similar to Zimmerman, *et al.* (1997) who used feedback conditions of 50ms DAF, one-half octave negative shift down FAF and baseline nonaltered feedback conditions during scripted telephone conversations. These procedures allowed researchers to capture the unaltered downstream audio from the participants without recording the speaker on the other end of the phone.

Procedures

The researcher verbally briefed participants prior to signing informed consent documents. Participants were requested not to use any fluency enhancing strategies and to talk in their natural way of speaking during all conditions. Prior to altered feedback conditions, researchers adjusted headphone volumes to the participants designated most comfortable listening level while perceiving both combinations of signals at approximately the same loudness. Participants then called 15 local businesses (*i.e.,* five per each of the three feedback conditions) requesting information and items. In order to reduce any possible carryover effects researchers had participants produce two-minute spontaneous conversation samples without auditory feedback between the three feedback conditions.

Results

Prior to analyzing stuttering frequencies, the researcher orthographically transcribed participants' audio-recorded telephone conversations to obtain total syllable production counts, since conversations slightly varied. The researcher then analyzed conversations for stuttered syllables and calculated proportional values for each condition by dividing the number of stuttered syllables by the total spoken syllables per condition. Stuttering was defined as part-word repetitions, phoneme prolongations, and postural fixations. Intra-rater and inter-rater reliabilities were obtained from a randomized 10% of the data. A certified speech-language pathologist trained in stuttering evaluation performed the inter-rater reliability using Cohen's *kappa* syllable-by-syllable agreements (Cohen, 1960;

Fleiss *et al.,* 2003). Kappa values for intra-rater analysis were 0.874 and were 0.537 for inter-rater. Values above 0.500 represent strong agreement and values greater than 0.750 represent excellent agreement.

Prior to inferential statistical analysis participants' proportion of stuttering values were transformed into arcsine units. This procedure reduces endpoint weighting of proportional data sets (Fleiss, 1981). A two-factor linear mixed model repeated measures analysis of variance (ANOVA; SPSS Inc., SPSS 19.0 for Mac) was conducted to examine the effect of condition and script on stuttering frequency. A significant main effect for condition was revealed [$F(2,90) = 59.698$, $p = 0.000$, $\square_{p}^{2} = 0.570$). To examine the source of the main effect post hoc least significant difference (LSD) were conducted. Differences were revealed between NAF relative to all conditions ($p < 0.001$) and between one combination of DAF and FAF and two combinations of DAF and FAF signals ($p < 0.05$). Significantly less stuttering frequency was noted in both altered feedback conditions during the scripted telephone conversations relative to nonaltered feedback. Furthermore, significantly less stuttering occurred under two combinations of DAF and FAF than one combination. Proportions of stuttering per participant by condition are displayed in *table 3* and *figure 2*. No main effects for script or interactions were revealed ($p > .05$).

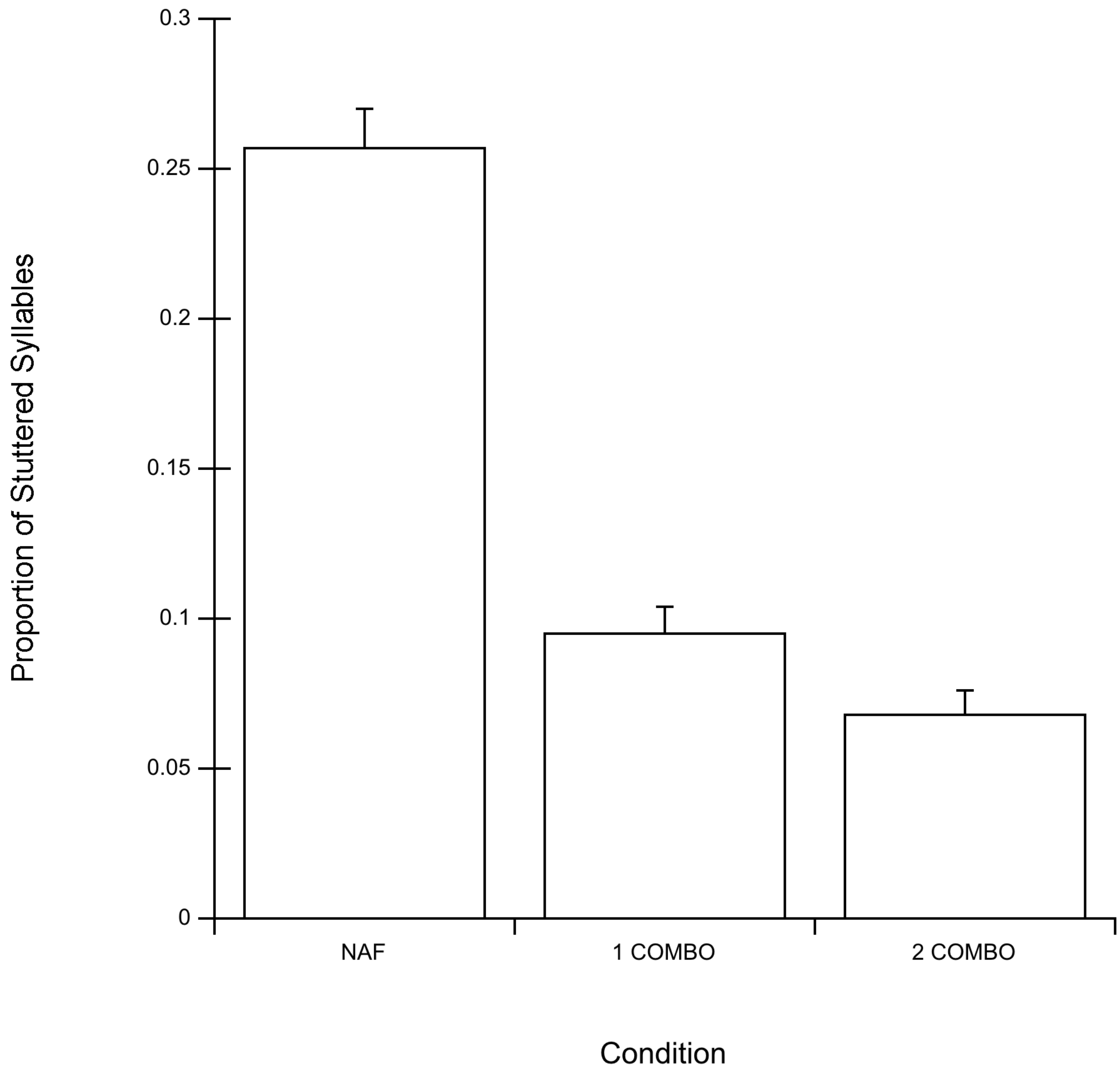

Figure 2. Mean proportions and standard errors of stuttering frequency as a function of AAF condition. NAF = no altered feedback, 1 COMBO = combination of DAF (50ms delay) and FAF (1/2 octave shift up), 2 COMBO = combination of 1 COMBO signal, DAF (200ms delay), and FAF (1/2 octave shift down). Error bars represent plus one standard error of the mean.

Table 3

Raw Data with Mean and Standard Errors for Total Spoken and Total Stuttered Syllables as a Function of AAF Condition

	NAF		1 COMBO		2 COMBO	
Participant	Spoken Syllables	Stuttered Syllables	Spoken Syllables	Stuttered Syllables	Spoken Syllables	Stuttered Syllables
1	233	41	231	10	351	19
2	222	32	221	12	232	4
3	422	125	243	37	279	39
4	218	67	255	33	255	33
5	248	82	236	39	206	20
6	236	54	251	17	246	13
7	264	84	292	36	363	29
8	188	33	155	5	166	1
9	352	104	508	39	407	15
Means	264.7	69.1	265.8	25.3	278.3	19.2
Standard Errors	24.8	10.8	32.6	4.7	26.5	4.2

Note. NAF= no altered feedback, 1 COMBO = combination of DAF (50ms delay) and FAF (1/2 octave shift up), 2 COMBO = combination of 1 COMBO signal, DAF (200ms delay), and FAF (1/2 octave shift down).

Discussion

For PWS, the telephone is often described as one of their most feared and avoided situations (Brutten, 1975; Georgieva, 1994; Leith & Timmons, 1983). Stuttering frequency has even been shown to increase during this hierarchically difficult situation relative to conversations held within clinical settings (Ladoucer, *et al*., 1982). To date however, only a limited number of studies have examined stuttering frequency during telephone conversations. The majority of these used clinicians, researchers, briefed listeners or family members during timed conversational exchanges (Andrews & Craig, 1982; Bloom & Silverman, 1973; Craig, *et al*., 1996; Martin & Haroldson, 1982; Stager, *et al.,* 1995). The procedures can be classified by three factors: 1) conversation initiator (*i.e.,* PWS or a researcher), 2) listeners' familiarity with stuttering and 3) conversation content (*i.e.,* scripted or unscripted conversations). For example, to evaluate stuttering across different communication situations, researchers may call clients (Andrews & Criag, 1982) or have clients call family members or staff from clinical settings (Bloom & Silverman, 1973; Craig, *et al.,* 1996; Martin & Haroldson, 1982; Stager, *et al.,* 1995). However, using these methods to evaluate true fluency levels during hierarchically complex tasks may be confounded; if receivers are familiar with stuttering they do not portray typical responses during exchanges. In addition, the participant is aware of the increased level of comfort in the supported situation and therefore their true levels of stuttering are not accurately represented. These procedures are further confounded by not having participants use scripted texts. Some of the most frequently employed compensatory strategies by PWS are circumlocutions and substitutions (Bloodstein & Bernstein-Ratner, 2008; Kalinowski & Saltuklaroglu, 2005). These procedures often occur to the extent of being almost reflexively produced to avoid anticipated difficult words. By changing words or word orders, PWS provide the illusion of being more fluent than they actually are. Few studies have PWS call unfamiliar listeners (Guitar, 1975; Zimmerman*, et al.,* 1997) and to the best knowledge of the researcher, only two have used scripts during any conversation (Stager, *et al.;* Zimmerman, *et al.*). The use of scripted conversations with unfamiliar naïve listeners as in Zimmerman, *et al.* is likely the most accurate portrayal of a participant stuttering while in a natural environment. Furthermore, this procedure likely elicits the most accurate representation of participant stuttering while truly assessing intervention effectiveness.

In the current study, stuttering frequency was significantly reduced during both altered feedback conditions relative to baseline. It was reduced 63% under one combination of DAF (*i.e.,* 50ms delay) and FAF (*i.e.,* plus one-half octave shift up) (1 COMBO) and was reduced 74% during two combinations of DAF and FAF (*i.e.,* 1 COMBO plus DAF – 200ms delay and FAF – one-half octave shift down) (2 COMBO). Findings support prior research results of decreased stuttering during telephone conversations under altered feedback conditions (Adamczyk, 1963; Zimmerman, *et al.,* 1997). For example, Zimmerman, *et al.,* reported 55% and 60% reduction in stuttering frequency for FAF and DAF respectively. Interestingly, the 1 COMBO and 2 COMBO conditions inhibited stuttering to greater extents than single DAF or FAF signal conditions reported in

Zimmerman, *et al.* Lastly, the 2 COMBO condition was significantly more effective at inhibiting stuttering than the 1 COMBO condition.

DAF and FAF rely on the participants' speech production to generate second altered signals. A microphone encodes the initial signal, and then it is processed by a DSP that generates a second signal that is fed back to the individual. For this reason there is no second signal present during speech initiations. Recently, Saltuklaroglu, *et al.,* (2009) reported that 90% of stuttering episodes occur in the course of speech initiation during NAF and AAF conditions; however, no stuttering transpired as the participant initiated speech with an ongoing speech signal. As participants read single phrases, stuttering frequency was reduced by approximately 70% during AAF conditions. AAF affects more than just the ongoing speech and may act to inhibit future stuttering events from occurring due to the levels of stuttering inhibition reported in initial syllable positions under AAF. Specifically, frequency of stuttering was reduced in all syllable positions under AAF, even though the second signal was not present during initiations. In the current study as with the above study, AAF may have provided a future inhibition of stuttering episodes. This concept may help to explain the differences revealed between the 1 COMBO and 2 COMBO conditions. The presentation of more gestural information may enhance future inhibition effectiveness. Providing increased amounts of speech gestures during the 2 COMBO condition increased the level of inhibition and indicates a scale of inhibition depending on the amount of gestural information. This provides support for the gestural system maintaining an intricate component of the inhibitory process.

Differing levels of stuttering inhibition are reported during the perception of continuous intermittent syllable productions (Saltuklaroglu, *et al.,* 2003), forward flowing and reversed fluent and stuttered speech (Kalinowski, *et al.,* 2004) temporally compressed or expanded speech (Guntupalli, *et al.,* 2005), sinusoidal speech synthesis (Saltuklaroglu & Kalinowski, 2006), visual only speech gestures (Saltuklaroglu, *et al.,* 2004) and visual feedback (Dayalu, 2004; Hudock, *et al*., 2011; Snyder, *et al*., 2009). Evidence of a dual modality perception system along with the flexibility for perceiving dynamic speech like gestures while inhibiting stuttering is fundamentally supported with notions put forth by the Motor Theory of Speech Perception (Liberman and Mattingly 1985, Liberman and Whalen 2000; Studdert-Kennedy *et al*. 1970) and the Gestural Model of Stuttering Inhibition (GMSI) (Hudock *et al.,* 2011; Kalinowski & Saltuklaroglu, 2002; Kalinowski & Saltuklaroglu, 2005; Saltuklaroglu & Kalinowski, 2002).

Tenants for the GMSI are based on notions from the motor theory. First, speech is perceived as a series of actualized articulatory gestural trajectories. Specifically, higher order primates do not decode the acoustic features of speech, but rather perceive how they would produce the perceived syllables. Second, that perception and production are fundamentally connected. This notion is supported with the recent discovery of mirror neurons (Gallese, *et al.,* 1996; Rizzolatti, *et al.*, 1996). Mirror systems are comprised of dual modality neuronal clusters that fire during both visual and auditory perception and motor production of biologically salient goal directed objectives (Rizzolatti & Arbib, 1998). In other words, groups of single neurons fire during encoding and decoding of grasping, locomotion and speech. By perceiving these objectives and intentions humans simultaneously map how they would produce the same event.

The GMSI hypothesizes that perception of these speech gestures engages mirror neuron systems and inhibits a central neural block that occurs during stuttering, therefore alleviating stuttering symptomatology. As previously stated, stuttering is inhibited from 40 – 100% when producing speech under altered feedback. Perception of visual only speech gestures typically inhibits stuttering from 40 - 60%, whereas altered auditory feedback exhibits 70 – 100% reductions (Kalinowski & Saltuklaroglu, 2005). Findings that AAF inhibits stuttering and that the 2 COMBO signal produced more robust stuttering inhibition than the 1 COMBO signal supports claims of the GMSI, primarily that stuttering and stuttering inhibition during perception of second signals occurs along a continuum that is contingent upon the amount of type of gestural information.

Conclusions

Stuttering frequency was significantly reduced approximately 70% under AAF during scripted telephone conversations with naïve listeners. In addition, two combinations of DAF and FAF offer a more robust inhibition of stuttering than one combination. These levels of stuttering inhibition reported during this hierarchically intense feared communication situation indicate the robust effect of second speech signal perception during speech productions for PWS. Findings from the current study support claims of the GMSI.

CHAPTER V

GENERAL DISCUSSION

Three common findings appear from the current series of studies. First, as PWS perceive second speech signals during simultaneous speech production tasks their stuttering is immediately and dramatically inhibited. Second, decreased stuttering frequencies were revealed during conditions that increased demands on participants, therefore refuting prior second signal hypotheses of stuttering reduction. Third, varying amounts of stuttering inhibition per condition support claims made by the GMSI.

Choral speech is the gold standard for fluency enhancements among PWS, inhibiting stuttering from 90 – 100% (Bloodstein & Bernstein-Ratner, 2008). Findings from the first study support these results by revealing 95% inhibition of stuttering during oral reading under choral speech conditions. The resultant speech becomes natural sounding and effortless to produce (Bloodstein & Bernstein-Ratner, 2008; Cherry & Sayers, 1956). Speakers in choral speech conditions attempt to maintain synchrony of productions, although seldom achieve this goal. There is a constant fluctuation between the speakers' lead and lag position alignments and speech rates. Regardless of this consistent asynchrony of the signals and altered rhythms or pacing, which are produced by the speakers, robust effects are reported. A slightly less powerful but similar condition that inhibits stuttering is shadow speech. Stuttering is typically reduced from 80 – 90% during shadow speech conditions (Bloodstein & Bernstein-Ratner, 2008; Cherry & Sayers, 1956). Results from the first study support these findings noting an 80% reduction in stuttering frequency during the lag speaker conditions.

Interestingly, to the best knowledge of the researcher Experiment I is the first study to examine the PWS maintaining the lead speaker position in shadow speech. This condition best simulates DAF with a second speaker instead of the second signal generation being reliant on the participants own speech output. Similar levels of inhibition during lead speaker conditions as compared to previous AAF literature were found in Experiment I. Specially, DAF (Kalinowski, *et al.,* 1993; Kalinowski & Stuart, 1996), FAF (Hargrave, *et al.,* 1994; Kalinowski, *et al.,* 1993; Stuart, *et al.,* 1996), and combined DAF and FAF (Macleod, *et al.,* 1995) reduce stuttering 60-80% during similar oral readings. In the second experiment, stuttering was inhibited 63% under the 1 COMBO condition and 74% under the 2 COMBO condition during the scripted telephone conversations. Although oral reading and scripted telephone conversations are markedly and hierarchically different perceiving second speech signals in both studies acted to immediately and dramatically inhibit stuttering.

Second, results from both studies refute notions put forth by previous second signal hypotheses for stuttering reductions, mainly pacing/rhythm (Armson & Keifte, 2006; Howell, *et al.,* 2005) and demand and capacity models (Starkweather, 1997). Pacing and rhythm theories claim that perception of second signals implements external pacing or rhythm generators that properly aligns temporal speech sequences in PWS. Two findings from the first study provide evidence against these claims. Stuttering was reduced to similar extents during both shadow speech conditions (*i.e.,* lead and lag speaker positions). If a reduction in stuttering during second signal presentations is contingent on the second speakers' pace or rhythm there should not be a reduction in stuttering under the lead speaker condition. This was not the case. As PWS maintained lead speaker positions, they determined pace and rhythm of productions while maintaining 80% reductions in stuttering frequency. These levels of stuttering inhibition were equivalent to lag speaker conditions. Furthermore, fluent speakers were trained to adjust their pace, rate, and spatiotemporal proximity to the participant. During shadow speech conditions, the spatiotemporal distance maintained between speakers was three to four words. The spatiotemporal distance between speakers during speech productions makes it unlikely that similar inflection and pacing patterns frequently occurred. Maintaining a perfect synchrony of pace and rhythm between two speakers is difficult to achieve. Even during choral speech, a synchrony cannot be maintained and is seldom truly obtained. Speakers' lead and lag alignments constantly fluctuate as each continually alters their rate, rhythm and pacing to align with the other.

Similar interpretations can be made from the results of the second study. Although there was not a second speaker and the second signal maintained constant distances from the initial productions, signals were self-produced at the speakers own pace and rhythm. In AAF, perception of second signals happens after productions have occurred, therefore it is impossible for second signals to generate external pacing's or rhythms prior to productions. Perception of second speech signals may alter speech productions but do not implement external pacing or rhythms. Specifically, previous research has demonstrated relationships between length of delay settings in DAF and reduced speech rates (Stuart, Kalinowski, Rastatter & Lynch, 2002). Typically, longer DAF delays cause decreased speech production rates. Furthermore, similar levels of stuttering inhibition are noted at normal and fast speech rates under altered feedback conditions (Hargrave, *et al.,* 1994; Hudock, *et al.,* 2011; Kalinowski, *et al.,* 1993; Kalinowski & Stuart, 1996; Macleod, *et al.,* 1995). If perceiving one second signal or second signal combination (*i.e.,* DAF and FAF as in 1 COMBO) produces external pacing or rhythms, then perceiving two combinations (*i.e.,* 2 COMBO) should disrupt the system and less reduction in stuttering should be noted due to the conflicting signals. This was not the case. Perception of multiple combinations of DAF and FAF increased inhibitory effectiveness.

Common findings between the two studies challenge notions purported by the demand and capacity model (Starkweather, 1997). This model hypothesizes that stuttering occurs when inherent capacities are overloaded by implementation of exceeding demands on the system. Modeling the brain and more so speech production systems in a binary computer based analogy may in itself be problematic, as neural functioning is far from completely understood; it is not likely as simplistic as binary computer based processing. Regardless of theoretical framework limitations, findings from the current studies provide concrete evidence against this model. Participants in the first study consistently self-reported their difficulty with maintaining oral reading of their passage, due to disruptions of hearing the second speaker during lead and lag conditions. Adding attentional requirements on participants likely increased cognitive demands, yet resulted in robust stuttering inhibition. Maintaining lead speaker positions and therefore determining pace and rhythm along with initial productions of linguistic content increases the demands; however, stuttering frequency did not differ from less demanding lag speaker conditions.

Similarly, conditions of scripted telephone conversations with naïve listeners implemented increased demands relative to hierarchical judgments and yet robust stuttering inhibition was reported. The telephone is consistently judged as the most anxiety provoking and most avoided situation among PWS (Brutten, 1975; Bloodstein, 1949; Bloodstein & Bernstein-Ratner, 2008). Results that stuttering was inhibited approximately 70% during this highly anxiety provoking condition indicates the powerful effects of perceiving second speech signals. Furthermore, results demonstrated that increasing demands are not mutually exclusive from decreasing stuttering. Perceiving second signals while producing speech in itself increases demands on the system. People often self-report distractibility and an inability to properly attend while speaking under altered feedback conditions; however, stuttering is immediately and dramatically inhibited 60-80% (Stuart, Kalinowski, Rastatter, Saltuklaroglu & Dayalu, 2004). Participants' self-reported similar accounts of distractibility during the second experiment, especially during the 2 COMBO condition where 74% stuttering inhibition was noted. Results that the more demanding 2 COMBO condition inhibited stuttering to greater extents than the 1 COMBO condition challenges fundamental claims by demand and capacity model during second signal perception.

The third common finding between the studies is that results support the GMSI (Hudock, *et al.,* 2011; Kalinowski & Saltuklaroglu, 2002; Kalinowski & Saltuklaroglu, 2005). Fundamental concepts for the GMSI are based on the Motor Theory of Speech Perception (Liberman & Mattingly, 1985). First, speech is perceived as a series of motoric representations for syllable productions, instead of the acoustic features of speech. As higher-level primates perceive speech via auditory, visual, or a combination of auditory and visual modalities they actually perceive articulatory trajectories required when producing syllabic structures (Liberman & Whalen, 2000). Second, that perception and production are fundamentally linked to the extent of being two sides of the same coin. These claims were recently empirically supported via neurophysiological research from a discovery of mirror neurons that found single neuron coding for both perception and production of biologically salient goal directed objectives (*i.e.,* eating, grasping, vocalizations and locomotion) (Gallese, *et al.*, 1996; Rizzolatti, *et al.,* 1996). In addition, it was later found that mirror neurons code for auditory, visual and combinations of auditory and visual motoric gestural intentions (Kohler, *et al.,* 2002). These single neuron studies in macaque monkeys provide initial evidence for mirror systems in humans; however, it is unethical to perform such research on human participants. To support these concepts in human models, researchers examined neural functioning. Similar neuronal clustering and coding effects are represented in TMS (Fadiga, *et al.,* 1995), PET (Grafton, *et al.,* 1996;

Decety*, et al.,* 1997; Iacobini, *et al.,* 1999), fMRI (Iacobini, *et al.,* 1999; Koski, *et al.,* 2002) and MEG (Nishitani & Hair, 2000) studies. If speech is perceived as a series of motoric gestural representations and this perception engages mirror systems, it is possible that this mechanism is at least partially responsible for stuttering inhibition.

The GMSI does not ascribe a specific causal or functional locus for stuttering, but instead describes it as occurring within the central nervous system as a neural block (Kalinowski & Saltuklaroglu, 2003; 2005). This central neural block may be comprised of individual or multiple system breakdowns or insufficiencies, but likely consists of the same disruption pattern. Although stuttering is overtly represented and categorized as syllable repetitions, phoneme prolongations and postural fixations, among many other sub classifications, it is likely centrally represented by a single central disruption. Furthermore, acoustical production characteristic requirements and treatment effects that alter conscious control of speech production influence those types of overt representations (Armson & Kalinowski, 1994). In other words, specific types of behavioral management strategies influence the stuttering to be more like the treatments. If clients are taught prolongation strategies they will begin to exhibit more prolongation disruptions instead of their typical types of stuttering. The model hypotheses that stuttering can be actively or passively inhibited via engagement of mirror neuron systems to release the central neural block. Active engagement of the mirror system occurs during altered gestural productions. An example of these procedures is producing voluntary stuttering (*i.e.,* syllabic repetitions) prior to speech production (Saltuklaroglu & Kalinowski, 2011; Saltuklaroglu, *et al.,* 2004). Active syllabification inhibited stuttering 70%, whereas passively listening to the same stimuli prior to speech production inhibited stuttering between 40 - 50%. Inhibition of stuttering became more effective when using linguistically similar productions as the first syllable from the utterance (Saltuklaroglu & Kalinowski, 2011).

A common element between all behavioral stuttering therapies is the temporal expansion (*i.e.,* producing prolongations) of speech (Kalinowski & Saltuklaroglu, 2005). Being that prolongations are a form of overt stuttering, this active strategy is likely to engage mirror systems. Passive procedures to engage mirror systems occur when perceiving second speech signals (Kalinowski & Saltuklaroglu, 2005). As perception and production simultaneously activates mirror systems, it is likely that perception of second speech signals releases the central neural block therefore inhibiting stuttering. Support for the mirror system's involvement is garnered by immediate and dramatic reductions in stuttering when perceiving auditory, visual, and combinations of auditory and visual speech gestures. Dynamic and flexible characteristics of the mirror system allow for perception of gestural intention across modalities and from incomplete information (*i.e.,* stuttering inhibition while perceiving compressed and expanded speech or sinusoidal speech analogs) (Guntupalli, *et al.,* 2005; Saltuklaroglu & Kalinowski, 2006).

Finally, findings from the current studies further support hypotheses of the GMSI that perception of second signals inhibit stuttering rather than simply reducing it. This distinction is made to aide in understanding temporal precedence and the nature of stuttering inhibition via the perception of second speech signals. Future stuttering episodes may be inhibited when the neural block is released via engagement of the mirror system. This is to say that if the neural block has begun and the production system is in its repeated oscillatory pattern during stuttering, presentation of second signals will only properly engage mirror systems to release the central block when a second copy of the planed gestural trajectories is sent. This is to say that if a PWS is in a block presentation of second signals will not stop the block but will act to inhibit the following utterance, unless the PWS halts the current production and resends the anticipated gestural productions. This notion is anecdotally supported by findings from the first study. When participants were in a stuttering episode and the fluent speaker began to speak, the block remained. Interestingly, in most every instance after the stuttered word was produced the following words were produced fluently. Future inhibition of stuttering as opposed to reductions can also be interpreted from carry over fluency effects from sentence to sentence productions under DAF and FAF. This concept was empirically tested in Saltuklaroglu, *et al.* (2009) who reported that 84% of stuttering occurs on initial syllable productions during NAF, DAF and FAF; however, stuttering was not present during choral speech conditions where the participant enters an ongoing signal. They also reported stuttering inhibition of approximately 70% during the AAF conditions. Proportion of stuttering on the initial syllable during NAF conditions was 45%, whereas during AAF conditions it was 34%. This reduction in stuttering frequency during initial syllable productions indicates that even when no second signal was present, stuttering was inhibited from perceptions of previous second signals. As AAF and the generation of the second signal are contingent upon initial speech productions from participants, a signal is not present during initiations. Findings from the second study that the 2 COMBO condition was more effective at inhibiting stuttering than the 1 COMBO condition supports these inhibitory claims. More gestural information was presented in the 2 COMBO condition, which likely enhanced mirror system engagement and increased the future inhibitory levels.

Study Limitations and Implications for Future Research

Although the current study did have some limitations, it provided foundational results on which to base future studies. To control for content the first study used oral reading to elicit speech production. Some participants reported that they were much more fluent during oral reading as compared to monologues or conversations. Another limitation with using oral reading is participants only perceived auditory gestures from the fluent speaker as both speakers had to view the orthographic text. Regardless of levels of stuttering inhibition, a majority of participants self-reported the difficulty with attending to their productions when attempting to block out the fluent speaker. Furthermore, multiple fluent speakers were used during this study due to the difficulty in timing of participant recruitment; however, one was used for 7 of the participants and the same researcher using similar teaching methods trained all participants. Future studies may examine single memorized utterance productions under similar feedback conditions to account for allocation of attentional resources. Other variations may include recorded or synthesized speech so all participants hear the same stimuli. Lastly, researchers should further examine the spatiotemporal proximity between the speakers.

The second study used telephone scripts during phone conversations with naïve store clerks that were thought to elicit the most naturalistic reactions; however, occasionally stores would not pick up and other venders or stores had to be substituted. Due to adherence to federal guidelines, researchers were unable to record both sides of the conversation and had to capture the unaltered downstream audio from the participants only. Participants occasionally extrapolated from the scripts by answering and asking additional material not provided in order to maintain a naturalistic communication exchange. Future studies should examine various forms of altered feedback during scripted telephone conversations while being audio-visually recorded.

Summary

There are three common findings between the experiments. First, stuttering was immediately and dramatically inhibited during the perception of the second speech signals during the spatiotemporal and hierarchical alterations. It was found that an analogous lead speaker condition to DAF inhibited stuttering to equivocal extents as the lag speaker condition in shadow speech. This finding is further supported by 70% stuttering inhibition during scripted telephone conversations under AAF. Two combinations of DAF and FAF offered more robust inhibitory effects than one combination of DAF and FAF. Second, inhibition of stuttering in both studies challenges fundamental hypothetical notions regarding stuttering reduction during the perception of second signals. Pacing and rhythm models suggest that perceiving second signals produces external pacing signals that reduce stuttering. Findings that stuttering is inhibited during lead speaker conditions and during self-paced perception of combinations of AAF challenge these claims. Stuttering inhibition during conditions that increase demands on the speaker challenge notions purported by the demand and capacity model. Both studies increased demands on participants; however, significant reductions in stuttering frequency occurred. Finally, results from the current studies support the GMSI. Significant inhibitions of stuttering were noted during all experimental conditions. The temporal order of speakers' spatial alignments and multiple combinations of AAF signals indicate the dynamic and flexible gestural-based mechanism involved during stuttering inhibition.

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APPENDIX A: INCLUSIONARY QUESTIONNAIRE

Participant information form

Participant No. _________ Today's Date and Time: ________/________/ ____________ AM PM

Sequence:___ (Researcher only)

Participant's Name (Initials): ____

Age:__ Gender: M / F Ethnicity:_______________

Medical History Questionnaire

Have you ever experienced or been diagnosed with any of the following, or are you experiencing any of the following at present? Please circle the appropriate response and explain any "Yes" answers below.

1. Visual difficulties, blurred vision, or eye disorders	Yes	No
2. Blindness in either eye	Yes	No
(If Yes to either of the above, have problems been corrected)	Yes	No
4. Hearing problems	Yes	No
5. Learning disabilities (problems of reading, writing, or comprehension)	Yes	No
6. Communication disorders	Yes	No
7. Cognitive problems	Yes	No
8. Severe head trauma/injury	Yes	No
5. Stroke	Yes	No
6. Epilepsy or seizures	Yes	No
7. Neurological surgery	Yes	No
8. Paralysis	Yes	No
9. Anxiety disorders	Yes	No
10. Depression	Yes	No

11. Claustrophobia Yes No

12. Any Neurological, Psychological, or Emotional problems Yes No

Please explain any “Yes” responses:

____
______

Do you have any family members who have speech/language/hearing/ or neurological deficits? Yes No

If yes please list the condition: ____________________

How familiar are you with people who have speech/language/hearing/ or neurological deficits?

Very familiar Not familiar at all
1 2 3 4 5 6 7

APPENDIX B: INSTITUTIONAL REVIEW BOARD APPROVAL FOR EXPERIMENT I

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building• 600 Moye Boulevard • Greenville, NC 27834
Office **252-744-2914** • Fax **252-744-2284** • **www.ecu.edu/irb**

TO: Joseph Kalinowski, PhD, Dept. of CSDI, ECU

FROM: UMCIRB KK

DATE: July 8, 2011

RE: Expedited Category Research Study

TITLE: "Shadow speech inhibits stuttering."

UMCIRB #11-0399

This research study has undergone review and approval using expedited review on 7.6.11. This research study is eligible for review under an expedited category number 6 & 7 which include collection of data from voice, video, digital, or image recordings made for research purposes. It is also a research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of **7.6.11** to **7.5.12**. The approval includes the following items:

- Internal Processing Form (dated 6.8.11)
- Informed Consent (version date 6.21.11)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.

APPENDIX C: INFORMED CONSENT DOCUMENT FOR EXPERIMENT I

1907-2007 CENTENNIAL

East Carolina University

UNIVERSITY HEALTH SYSTEMS
of Eastern Carolina

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Shadow speech inhibits stuttering

Principal Investigator: Joseph Kalinowski
Institution/Department or Division:
East Carolina University
Department of Communication Sciences and Disorders
Address: 3310L Health Sciences Building
Greenville, NC 27858
Telephone #: 252-744-6091

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of volunteers who are willing to take part in research.

Why is this research being done?
The purpose of this research is to examine the effect of the lead and lag speaker positions during shadow speech. The decision to take part in this research is yours to make. By doing this research, we hope to learn how stuttering is affect by various speaker positions during shadow speech.

Why am I being invited to take part in this research?
You are being invited to take part in this research because you are a typical developing adult who stutters. If you volunteer to take part in this research, you will be one of about 12 people to do so.

Are there reasons I should not take part in this research?
You should not participate in this study if you have cognitive, reading or uncorrected visual or hearing deficits.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research procedures will be conducted in an office setting at ECU. The total amount of time you will be asked to volunteer for this study is 20 minutes.

What will I be asked to do?
You are being asked to do the following: Read a prepared text alone then read a prepared text aloud with a second speaker while you are audio-visually recorded.

What possible harms or discomforts might I experience if I take part in the research?
It has been determined that the risks associated with this research are no more than what you would experience in everyday life.

What are the possible benefits I may experience from taking part in this research?
We do not know if you will get any benefits by taking part in this study. This research might help us learn more about stuttering inhibition. There may be no personal benefit from your participation but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?
We will not be able to pay you for the time you volunteer while being in this study.

What will it cost me to take part in this research?
It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?
To do this research, ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- Any agency of the federal, state, or local government that regulates human research. This includes the Department of Health and Human Services (DHHS), the North Carolina Department of Health, and the Office for Human Research Protections.
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff and faculty who oversee this research.

How will you keep the information you collect about me secure? How long will you keep it?
All data (audiovisual and other) collected from this study will remain confidential. Participants' names or other identifying information will not be used in the results for any public presentations of research findings or published research articles. Data will be coded to conceal participant identity. All participant/research files will be maintained in a locked filing cabinet in the Stuttering Lab in the Department of Communication Sciences and Disorders. All participant videos will be stored on an encrypted external hard-drive kept in a lockable cabinet in the stuttering research laboratory at ECU.

What if I decide I do not want to continue in this research?
If you decide you no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping. You will not lose any benefits that you should normally receive.

Who should I contact if I have questions?
The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-744-6091 Monday – Friday 10am – 5pm.
If you have questions about your rights as someone taking part in research, you may call the Office for Human Research Integrity (OHRI) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the OHRI, at 252-744-1971

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) **Signature** **Date**

APPENDIX D: INSTITUTIONAL REVIEW BOARD APPROVAL FOR EXPERIMENT II

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board Office
1L-09 Brody Medical Sciences Building• 600 Moye Boulevard • Greenville, NC 27834
Office **252-744-2914** • Fax **252-744-2284** • **www.ecu.edu/irb**

TO: Joseph Kalinowski, PhD, Dept of CSDI, ECU

FROM: UMCIRB KK

DATE: July 8, 2011

RE: Expedited Category Research Study

TITLE: "Stuttering inhibition under multiple altered auditory feedback signals during scripted telephone conversations."

UMCIRB #11-0400

This research study has undergone review and approval using expedited review on 7.6.11. This research study is eligible for review under an expedited category number 6 & 7 which include collection of data from voice, video, digital, or image recordings made for research purposes and it is also a research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. (NOTE: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b)(3). This listing refers only to research that is not exempt.)

The Chairperson (or designee) deemed this **unfunded** study **no more than minimal risk** requiring a continuing review in **12 months**. Changes to this approved research may not be initiated without UMCIRB review except when necessary to eliminate an apparent immediate hazard to the participant. All unanticipated problems involving risks to participants and others must be promptly reported to the UMCIRB. The investigator must submit a continuing review/closure application to the UMCIRB prior to the date of study expiration. The investigator must adhere to all reporting requirements for this study.

The above referenced research study has been given approval for the period of **7.6.11** to **7.5.12**. The approval includes the following items:

- Internal Processing Form (dated 6.8.11)
- Informed Consent (dated 6.21.11)

The Chairperson (or designee) does not have a potential for conflict of interest on this study.

The UMCIRB applies 45 CFR 46, Subparts A-D, to all research reviewed by the UMCIRB regardless of the funding source. 21 CFR 50 and 21 CFR 56 are applied to all research studies under the Food and Drug Administration regulation. The UMCIRB follows applicable International Conference on Harmonisation Good Clinical Practice guidelines.

APPENDIX E: INFORMED CONSENT DOCUMENT FOR EXPERIMENT II

1907-2007 CENTENNIAL

East Carolina University

UNIVERSITY HEALTH SYSTEMS *of Eastern Carolina*

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Stuttering inhibition under multiple altered auditory feedback signals during scripted telephone conversations.

Principal Investigator: Joseph Kalinowski
Institution/Department or Division:
East Carolina University
Department of Communication Sciences and Disorders
Address: 3310L Health Sciences Building
Greenville, NC 27858
Telephone #: 252-744-6091

Researchers at East Carolina University (ECU) study problems in society, health problems, environmental problems, behavior problems and the human condition. Our goal is to try to find ways to improve the lives of you and others. To do this, we need the help of volunteers who are willing to take part in research.

Why is this research being done?
The purpose of this research is to examine the effect multiple altered auditory feedback signals on stuttering during scripted telephone conversations. The decision to take part in this research is yours to make. By doing this research, we hope to learn how stuttering is affect by various altered auditory feedback signals.

Why am I being invited to take part in this research?
You are being invited to take part in this research because you are a typical developing adult who stutters. If you volunteer to take part in this research, you will be one of about 12 people to do so.

Are there reasons I should not take part in this research?
You should not participate in this study if you have cognitive, reading or uncorrected visual or hearing deficits.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research procedures will be conducted in an office setting at ECU. The total amount of time you will be asked to volunteer for this study is 30 minutes.

What will I be asked to do?
You are being asked to do the following: Read a scripted telephone conversation as you are audiovisually recorded during altered and non altered feedback conditions. In the altered feedback conditions your voice will be digitally

altered then fed back to you via headphones. The listener on the other end of the telephone will only hear your unaltered voice. In the nonaltered feedback condition no feedback will be provided and a typical telephone conversation will occur.

What possible harms or discomforts might I experience if I take part in the research?

It has been determined that the risks associated with this research are no more than what you would experience in everyday life.

What are the possible benefits I may experience from taking part in this research?

We do not know if you will get any benefits by taking part in this study. This research might help us learn more about stuttering inhibition. There may be no personal benefit from your participation but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?

We will not be able to pay you for the time you volunteer while being in this study.

What will it cost me to take part in this research?

It will not cost you any money to be part of the research.

Who will know that I took part in this research and learn personal information about me?

To do this research, ECU and the people and organizations listed below may know that you took part in this research and may see information about you that is normally kept private. With your permission, these people may use your private information to do this research:

- Any agency of the federal, state, or local government that regulates human research. This includes the Department of Health and Human Services (DHHS), the North Carolina Department of Health, and the Office for Human Research Protections.
- The University & Medical Center Institutional Review Board (UMCIRB) and its staff, who have responsibility for overseeing your welfare during this research, and other ECU staff and faculty who oversee this research.

How will you keep the information you collect about me secure? How long will you keep it?

All data collected from this study will remain confidential. Participants' names or other identifying information will not be used in the results for any public presentations of research findings or published research articles. Data will be coded to conceal participant identity. All participant/research files will be coded with an identification number and maintained in a locked filing cabinet in the Stuttering Lab in the Department of Communication Sciences and Disorders. All participant videos will be stored on an encrypted external hard-drive kept in a lockable cabinet in the stuttering research laboratory at ECU.

What if I decide I do not want to continue in this research?

If you decide you no longer want to be in this research after it has already started, you may stop at any time. You will not be penalized or criticized for stopping. You will not lose any benefits that you should normally receive.

Who should I contact if I have questions?

The people conducting this study will be available to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at 252-744-6091 Monday – Friday 10am – 5pm.
If you have questions about your rights as someone taking part in research, you may call the Office for Human Research Integrity (OHRI) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the OHRI, at 252-744-1971

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) Signature Date

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

____

Person Obtaining Consent (PRINT) Signature Date

APPENDIX F: TELEPHONE SCRIPTS FOR EXPERIMENT II

Similar to Zimmerman, *et al.,* (1997), each participant initiated the conversation with a “Hello” and ended the exchange with a “Thank you for your time”.

1. Video Store: Can you tell me if you have the movie “The Kings Speech”? What are your membership requirements?
2. Museum: What is the special exhibition currently going on? How much is general admission and admission to the special exhibition? What are your weekend hours? Do you have audio guides?
3. Dry Cleaner: How much do you charge to dry clean a man’s sport jacket? If I drop it off in the morning, may I pick it up the same day? Are you open on Sundays?
4. Office Supply: Do you sell external hard-drives? Where are you located? What time do you close today? Thank you for your time.
5. Florist: Can you tell me how much your long-stem roses are per dozen? How much are a dozen carnations? Do you take American Express?
6. Hotel: What are your weekend rates for a double room? Do you have a fitness center? Do you have a swimming pool?
7. Hardware Store: Do you have a set of metric socket wrenches? What time do you close today?
8. Conference Center: Do you have a conference room to accommodate a party of 10? Do you cater? Do you have a lounge in your facility?
9. Hair Salon: How much do you charge for a man’s shampoo, cut, and blow dry? Do I have to make an appointment?

10. Department Store: What are your hours of operation? Do you have any specials going on? Where is your store located, I'm from out of town and coming from Greenville?
11. Restaurant: Do you have a Sunday brunch? What time do you open on weekdays? Do you have a children's menu?
12. Copy Center: Do you copy homemade DVD movies? What is your charge per DVD copy? What are your weekend hours?
13. Bookstore: I was wondering if you have the book outliers by Malcolm Gladwell in stock? Is that hard or soft cover? How much is it?
14. Sporting Goods: Do you carry rollerblades? And do you also carry snowboards? Are you open on Sunday nights?
15. Bakery: Do you make birthday cakes? How many days' notice would you require? Do you take American Express?

APPENDIX G: PARTICIPANTS DESCRIPTIVE STATISTICS FOR EXPERIMENT II – AGE AND GENDER.

Participant	Gender	Age
1	M	26
2	M	49
3	M	30
4	M	72
5	F	24
6	M	45
7	M	21
8	M	42
9	M	21
Means	N/A	36.7
Standard Error	N/A	5.7

APPENDIX H: MEANS AND STANDARD ERRORS FOR TOTAL SPOKEN AND STUTTERED SYLLABLES AS A FUNCTION OF SCRIPT FOR EXPERIMENT II.

Script	Mean Syllables Spoken	Standard Error	Mean Syllables Stuttered	Standard Error
Video	45.4	7.0	7.8	1.6
Museum	66.0	10.8	14.8	5.3
Dry Cleaner	64.1	10.1	9.0	1.9
Office	45.6	5.1	5.7	1.5
Florist	55.9	3.5	6.0	1.1
Hotel	72.9	11.7	11.0	2.1
Hardware	33.3	3.2	4.4	1.2
Conference	60.2	14.7	9.7	4.2
Hair Salon	46.4	6.1	6.9	2.4
Department	69.7	7.7	8.8	3.7
Restaurant	50.7	6.1	5.2	1.8
Copy Store	46.0	3.7	8.2	1.7
Book Store	61.4	6.2	4.6	1.3
Sporting	48.1	5.5	6.1	2.2
Bakery	48.9	4.0	9.4	2.2