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Rate change effects on acoustic duration measures on an adolescent who stutters

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RATE CHANGE EFFECTS ON
ACOUSTIC DURATION MEASURES ON
AN ADOLESCENT WHO STUTTERS

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ABSTRACT

The purpose of this study was to determine if reduced rate techniques have an effect on speech motor coordination of an adolescent. A literature review revealed that a reduced rate technique consistently promoted more fluent speech; however, the cause of that increase in fluency is not known. This study proposed three specific questions to determine if there was a shortening of the /s/ phoneme in clustered contexts when compared to singletons, if reducing the rate would cause the adolescent to produce more adult-like shortening patterns, and if the reduced rate technique caused a decrease in stuttering events. One eleven year old participated in this study by repeating previously recorded sentences each containing the /s/ phoneme in either cluster or singleton context. The single subject design utilized an ABA treatment method.

Results indicated the reduced rate did have an affect on the length of the /s/ phoneme during the treatment phase; however, the treatment induced a lengthening of /s/ in SC contexts only. Since the length of /s/ in SC contexts increased and the length of /s/ in SV contexts remained the same, SC and SV /s/ durations were similar during phase B. This is not the adult-like shortening behavior we would expect. When the treatment method was removed during phase A2, the participant shortened /s/ in clusters in an adult-like manner. The number of stuttering events decreased dramatically with the reduced rate technique: 15 events during phase A1, 5 in B, and 3 in A2.

REVIEW OF LITERATURE

Guitar's (2006) theory of stuttering integrated the components of a variety of previously proposed theories. He proposed that two inherited dispositions are the cause of the initial disfluencies produced by children who stutter. The first is a decreased ability to create and correct plans for the motor control of utterances. The second is an emotional temperament that is overly reactive to speech errors. Evidence that the motor plans of people who stutter (PWS) are not normal has been found in both acoustic and kinematic analyses of the fluent speech of adult PWS that was speech not as well timed as that of nonstuttering adults. It has also been shown that children have less speech motor control than adults. For PWS, the decreased ability to plan and execute utterances has been cited by proponents of interventions that increase fluency by decreasing speech rate (Neilson & Neilson, 1987). It is proposed that a slowed speaking rate provides the person with more time to plan and execute phonological coding, thus making them less error prone. Linguistic complexity may also cause breakdowns in speech. As the language complexity increases, the PWS has more information to process and can produce an increase of stuttering events. However, an initial study of the effects of a preschool intervention for stuttering demonstrated that improved fluency was obtained without slowed speech or improved motor control. The current study will examine the effect of slowing the speech on the control of fluency and speech timing of an eleven year, nine month old post-pubescent adolescent who stutters.

This review will present theories citing phonological coding as a core deficit in stuttering (Guitar, 2006; Kolk & Postma, 1993), language complexity as a contributing

factor in stuttering (Pearl & Bernthal, 1980), and the manner in which adults and children control speech motor acts.

Phonological Selection as a Core Deficit in Stuttering

Guitar's (2006) theory of stuttering includes a comprehensive interaction of constructs involved in stuttering. One central tenet of Guitar's theory is that speech and language functions in an individual who stutters are not as left-hemisphere dominant and therefore not as efficient as in a person who does not stutter. He cited brain imaging studies showing that during the speech of individuals who do not stutter, there is concentrated neuronal activation in the left hemisphere, while in PWS, neuronal activation is distributed more widely between the right and left hemispheres. The wide distribution of brain activity serving speech and language planning is hypothesized to indicate less efficiency demonstrated by slow processing errors. In PWS, the effects of this less efficient speech include an increase in speech errors, such as hesitations, repetitions, and prolongations.

Guitar (2006) suggested that the lack of hemispheric dominance in PWS causes speech errors in a manner consistent with Kolk and Postma's (1993) theory. This theory proposed that PWS are slower in selecting syllable frames and phonemes as part of utterance planning. As speaking rate increases, the person's slower selection system makes more errors. In addition, the speech production system is detecting and attempting to correct errors, but these attempts often end in the types of disfluencies that are common at the onset of stuttering. If an error is detected prior to the start of a syllable, the system may stop to reconfigure the utterance, producing a hesitation. If an error is

detected after a syllable has been started, the syllable may be repeated or a sound prolonged while the error is corrected.

The generation of an utterance's syllable shapes and phoneme strings interacts with higher levels of language processing such as word selection and selection of syntactic structures. It is not surprising then that research has shown that disfluencies are related to these levels of processing as well. Hannah and Gardner (1968) and Tornick and Bloodstein (1976) found that the number of stuttering events increased as the number of clauses in a sentence increased. Pearl and Bernthal (1980) found that passive sentences were produced with more stuttering behaviors than other sentence types. Bernstein, Ratner, and Sih (1987) found that other aspects of syntactic complexity were correlated with the number of disfluencies. In Guitar's model, inefficient word or syntactic structure selection processes would compete with speech production for available processing resources, creating more speech errors.

Speech Motor Control in Adults

Studies of slowed speech have been conducted for adult PWS showing kinematic and acoustic changes that occur. Zimmerman (1980a, 1980b, 1980c) conducted research to measure the movements of speech structures during fluent speech, finding that the fluent speech of adult PWS contained reduced amplitudes and velocities of articulatory movements as well as longer intervals between articulatory events. Zimmerman suggested that individuals who stutter could lessen the probability of motor breakdowns if they reduced articulator displacements and velocities and produced longer intervals between articulatory events. Prins and Hubbard (1990) studied acoustical durations of speech segments of young adult PWS participating in stuttering adaptation. They found

that rate change alone, by providing more time for motor linguistic processes, could be crucial to a reduction in stuttering frequency. Story, Alfonso, and Harris (1996) supported this contention in a study of the articulatory dynamics of three adult PWS before and after treatment. They discovered that the fluent speech of these adults at the end of treatment had characteristics of lower displacements and velocities compared to pretreatment measures, supporting that theory.

Smith and Kleinow (2000) compared the articulatory kinematics of adult PWS and non-stutterers to determine if a poorer speech movement pattern existed and if a change in speech rate affects both groups in the same way. They found considerable overlap between the groups on displacement and velocity measures at normal rates. When they slowed their speech rates, some of the adult PWS produced fluent speech with speech structure movements that were similar to the normally fluent control group. However, some of the adult PWS showed abnormal variability even with the reduced rate, suggesting that reduced rate does not necessarily increase utterance-to-utterance stability within a single articulator, nor does it consistently reduce the amplitude of movement. This shows that reducing rate alone is not enough for the PWS to increase control of their speech motor acts.

Speech Motor Control Development

Speech motor control in normal speakers appears to continue developing toward an adult-like level from ages 4 to 12. Children's speech segments are initially longer and show more variability than adult's speech at earlier ages, approaching adult like levels near puberty. Of particular interest to this study are data regarding the control of /s/ segment durations in singleton and consonant cluster contexts. Inasmuch as English is a

stress timed language, it is expected that /s/ segments will be shorter in s+consonant+vowel (sCV) syllable shapes than in s+vowel (sV) syllable shapes (i.e. *sly* vs. *sigh*), or perhaps even more noticeable in sCV vs. sCVCVC (i.e. *slow* vs. *slowpoke*).

Hawkins (1984) studied the development of /s/ segment durations in singleton and cluster contexts produced by typically developing children, aged 4 to 7 years, and compared those to adults. Adult speakers produced word-initial /s/ segments in /s/ + stop consonant clusters that were on average 73% of the duration of /s/ segments preceding vowels. In contrast, the children's /s/ durations were not shorter in the clustered than in the non-clustered contexts. In addition, the variability of the children's /s/ segment durations was greater. These results suggest less motor control because the children were speaking slower and with more variability than the adults. These measures were made again after 14 months at ages 5 to 8 years. At that time, the group average for the children showed a shortening of /s/ in clustered contexts to 87% of the duration of /s/ in singleton. The results after 14 months of development were closer to the adult's results, but were still longer than the adult's speech.

Smith, Kenney, and Hussain (1996) conducted a longitudinal study of temporal control of speech segments by older children, ages 7 to 11 years. They conducted a follow-up measurement 18 months later. The /s/ segment durations decreased by 10% over this time frame and the variability of /s/ productions from utterance to utterance decreased by 40%. However, neither measure was adult-like at the end of the experiment. Evaluation of the relative durations of individual children at the first and second measurements revealed that the same children produced relatively long segment durations at both times.

Treatment Approaches for Child and Adolescent Stuttering

The different treatment methods utilized to increase fluency manipulate the time and effort employed in production. Guitar (2006) described several fluency enhancing strategies used during fluency intervention. Flexible rate is one strategy that is taught to encourage the individual to speak at a reduced rate when a stuttering event occurs. This technique gives the individual adequate time to produce the necessary syllables at a reduced rate before returning to a normal speaking rate to continue the phrase. Guitar provides a movement metaphor, comparing this technique to completing an obstacle course. When a child is on an obstacle course, he or she must move slowly around the obstacles, but is able to run again when the course is free of obstacles. The same is true for speech with disfluencies.

Another popular method described is easy onset (Guitar, 2006). If the child who stutters approaches a feared speech sound with fear, his vocal folds are more likely to become tense and can cause a more severe stuttering event. If the child is able to learn the easy onset technique, when he approaches the feared speech sound, he can begin the sound by gently pressing the vocal folds together and gliding into the word. Guitar adds that this technique is most often useful when a vowel is the initial sound.

The light contact technique is taught to be utilized during initial consonant sounds (Guitar, 2006). When utilizing this technique, there are less chances of stopping airflow in the oral cavity which can cause a block. If the lips are pressed together lightly for the production of the speech sound /p/, the individual can ease into the word rather than pressing them together tensely, causing a longer blockage.

The proprioceptive fluency strategy stems from theories of stuttering which suggest that individuals who produce disfluent speech have dysfunctional auditory systems. This affects the manner in which they check speech for errors before or after they occur so the focus should somehow be focused away from the auditory system onto another system. This strategy requires the individual to focus on the feelings of the lips, jaw, and tongue during the production of speech. By focusing on the movements of these articulators, the inefficient auditory system is bypassed or put in the background.

Effect of Intervention on Speech Motor Control in Preschool CWS

Effects of slowed speech intervention on speech motor control measures have not been assessed in adolescents, however, speech motor control was assessed for preschool children following the Lidcombe Program. This intervention teaches parents to praise stutter-free speech and identify stuttered speech. Onslow, Packman, and Harrison (2003) conducted research to determine if this treatment method induced changes in acoustic measures of speech. Pre-treatment and post-treatment conversational samples were obtained from the 8 participants measuring voiceless voice onset time, voiced voice onset time, vowel duration, and intervocalic interval. Voice onset time is an important acoustic duration because a change in the duration of voice onset time can result in a listener's perception of the other "cognate" phoneme. An example of this perceptual (acoustic) effect of articulatory inaccuracy would be if the child produced a delay in voice onset time, causing a listener to perceive /p/ and not /b/. Vowel duration is important for speech sound correctness as the length of the vowel is the listener's acoustic cue for perceiving whether the following "cognate" consonant is voiced or voiceless. In the word "mob," the /b/ is perceived as the voiced consonant due to the longer duration of /ɑ/

whereas in the word "mop," the /p/ is perceived as the voiceless consonant due to the shorter duration of the /ɑ/. If the child would inappropriately change the vowel duration, the perception of the upcoming obstruent phoneme would be altered. The study also measured intervocalic interval which here will be the length of the vowels occurring between voiceless consonants (i.e., *tot*). This is the only dependent variable measured in this study that would not necessarily have consequences in phoneme identification. Onslow, *et al.* found that all 8 of the children who participated in their study produced significantly lower percentages of syllables stuttered after intervention, but this study found no evidence of consistent and systematic changes in the children's speech timing. However, as stated previously, many of these features are important to phoneme identification and therefore would not have been expected to change without a change in perceived speech sound correctness. Moreover, these measurements were made from recordings of parent-child interaction that were uncontrolled for phonetic context. As shown in studies before, typically developing children and CWS have less motor control, so it may be more revealing to review a post-pubescent adolescent who stutters (AWS).

The present study was undertaken to determine if reduced rate techniques have an effect on speech motor coordination. The particular characteristic of speech motor control measured was the shortening of /s/ from sV to sCV contexts. The particular questions addressed are as follows:

1. Does an AWS shorten /s/ in sCV compared to sV contexts?
2. Does slowing the speech of a AWS result in a more adult-like /s/ shortening in cluster contexts?
3. Is the shortening of /s/ in clusters affected by stuttering events?

MATERIALS AND METHODS

Design

The purpose of this study is to determine the effect of rate change on the speech motor coordination of an AWS. This study utilized a single-subject *ABA* research design. In this type of a research design, there is an *A* phase during which the dependent measure is repeatedly sampled to determine its average and variability. The *B* phase involves introduction of the independent variable (the reduced rate intervention) while continuing to measure the dependent variable. If the independent variable has an effect on the dependent variable there should be a change from the A phase to the B phase. Following the B phase the independent variable is removed to create a second A phase. If the treatment (the independent variable) had an effect during the B phase it is expected that the dependent variable will not return to levels similar to the first A phase, and generalization will be seen. In the present study there were three experimental sessions, one for each of the ABA phases. All sessions were conducted at the Louisiana State University Speech Language and Hearing Clinic in a sound treated booth.

Procedures

During each session, the participant was instructed to repeat 24 pre-recorded sentences, one at a time, presented in randomized order. These sentences were constructed so that each contained one /s/ in either a sV or sCV syllable context occurring as the onset of the verb phrase. The verbs “sold,” “sees,” and “sat” were used to elicit sV onsets and the verbs “stole,” “skis,” and “spat” were used to elicit sCV contexts. The sentences included the following verb phrases: sold a car, stole a car, sees a phone, skis alone, sat on me, spat on me. The context preceding the /s/ was changed by varying the

name of a person as the subject noun phrase, for example, “Pop sold a car,” “Bob sold a car,” “Dot sold a car,” and “Todd sold a car.” were all used as stimuli. Appendix A has a full listing of the sentence stimuli.

The subject’s sentence repetitions were recorded and analyzed. During the A phase, the participant was instructed to repeat the sentence after it was played. During the B phase, the participant was instructed to repeat the sentence after it was played and after the clinician had repeated the sentence at a reduced rate. Since this experiment was being conducted to measure acoustic durations during perceptually stutter-free speech, the participant was directed to identify moments of stuttering during the sentence repetition and repeat that sentence at the end of the session. The sentences that included disfluencies were analyzed separately.

One middle school student with a history of severe stuttering since his onset of speech participated in this study. He was 11 years, 9 months old at the onset of treatment. He was subjectively judged to be at or near puberty by the low fundamental frequency of his speaking voice. He was a monolingual English speaking resident of Louisiana. His mother completed a background history questionnaire regarding developmental and disfluency milestones for the adolescent, and the family’s cultural background.

The adolescent’s sentence productions were recorded with an Audio Technica ATM 15 lapel microphone and a Sony PRO II audiotape recorder. The experimenter digitized the recordings and produced waveform displays using the Sony Sound Forge Audio Studio software package. Cursors were positioned at two locations on the speech waveform indicating the beginning and ending of high frequency noise in the waveform

in the region of the /s/ segment. The number of stuttering events was also tallied during each session.

The reliability of the experimenter's judgments was assessed by requiring an experienced speech-language scientist to re-evaluate a randomly selected 20 utterances produced by the subject. The percentages of agreement were 92.5%.

RESULTS

The first question asked whether the AWS shortened the /s/ duration in sCV compared to sV contexts during the first A phase. Figure 1 shows the duration of the /s/ segments in singleton and clustered contexts for each of the fluently produced sentences during the first A phase. As seen here, the productions of /s/ in the sV contexts were consistently longer than those in the sCV contexts. The mean length of /s/ in sV words was 132.5 milliseconds (msec) with a standard deviation of 21.23 msec. The mean length of /s/ in sCV words was 88.5 msec with a standard deviation of 14.63 msec. On average, this adolescent produced a 67% shortening of /s/ in clustered contexts during the first A phase. A t-test revealed a significant difference between participant's productions of /s/ in consonant-vowel and /s/ in a consonant-consonant cluster [t= 4.34, df= 7, p<.003].

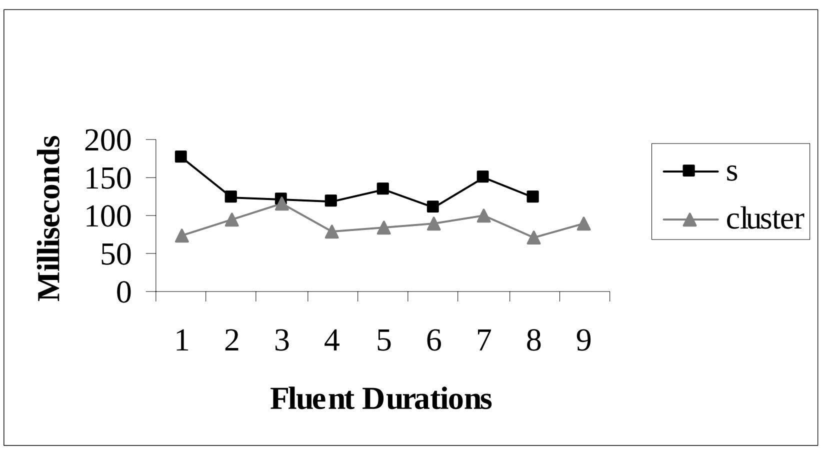

Figure 1. Duration of /s/ in singleton and cluster contexts during the first A phase

The second question asked if slowing the adolescent's speech would result in better control of shortening of /s/ segments. This question was answered by comparing the B and A1 phases. The /s/ durations in sV words appears to remain unchanged from the A1 phase with a mean in the B phase of 132.4 msec and a standard deviation of 16.64

msec. However, the /s/ durations in clustered syllable onsets appears to have risen. The mean length of /s/ in clusters was 120.6 msec with a standard deviation of 7.05 msec. As a result, during the B phase, there was no significant difference between the participant's production of /s/ in sV combinations and /s/ clusters [t= 1.86, df= 7, p<.106]. It appears that this adolescent's strategy for slowing his speech included selectively lengthening /s/ in clustered but not sV contexts. In doing so, he eliminated the expected shortening of /s/ in consonant clusters.

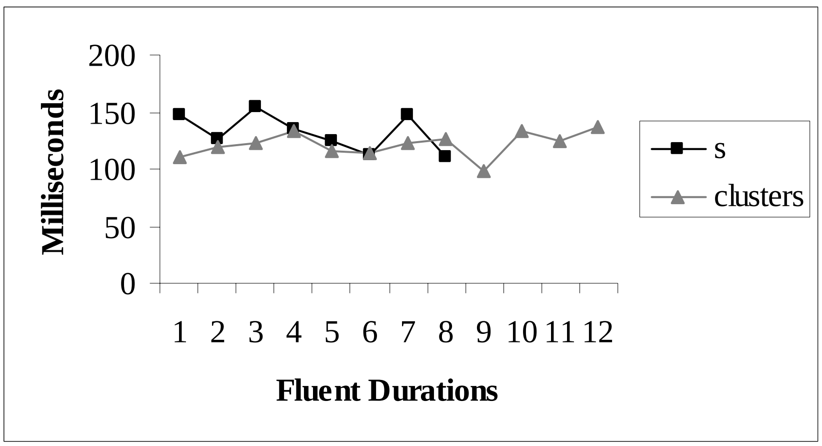

Figure 2. Duration of /s/ in singleton and cluster contexts during the B phase

If this change in /s/ duration were caused by the introduction of the slowed speech strategy, generalization should occur in A2. As shown in Figure 3, during the second A phase, the participant reestablished a distinction in the durations of /s/ in sV and sCV onsets. The mean /s/ duration in non-clusters was 124.1 msec with a standard deviation of 13.97 msec. The mean length of /s/ duration in clusters was 76.1 msec with a standard deviation of 10.53 msec. As seen in phase A1, the differences in /s/ duration in non-clusters and clusters was statistically significant in phase A2 [t= 8.52, df= 10, p<.0001]. It would appear that the adolescent has once again returned to a pattern of shortening /s/ productions in clustered contexts.

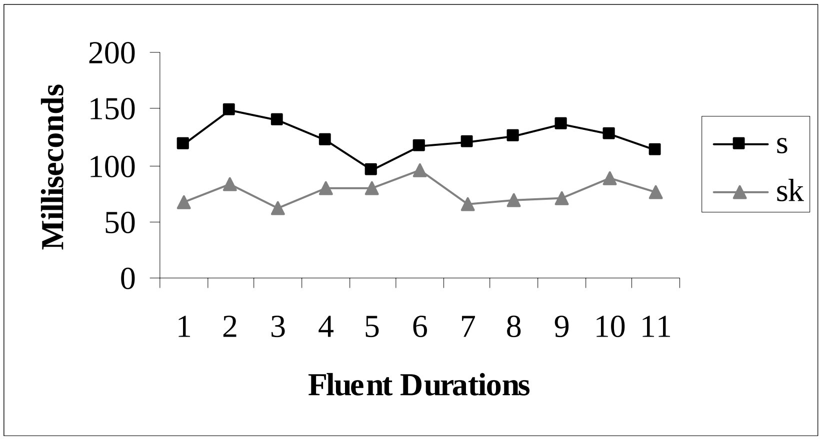

Figure 3. /S/ and /S/ Clusters in A2 Phase

A repeated measures ANOVA was calculated to determine if the shifts in /s/ duration in the sCV contexts across study phases were statistically reliable. The results of this analysis demonstrated that the average changes in /s/ duration from 88.5 msec in A1, to 120.6 msec in B, to 76.1 msec in A2 was statistically reliable at the $p <.0001$ level (F=37.59, df 2,8).

The purpose of slowing the speech of a PWS is to produce more fluent speech. The number of disfluent events was measured during each of the phases. The disfluent events consisted of blocks, prolongations, sound repetitions, and revisions and occurred at various times during the sentence repetition tasks. During phase A1, the participant produced 15 stuttering events. This number decreased markedly in phase B to 5 stuttering events. In phase A2, the participant produced only 3 stuttering events.

Since there was a high number of disfluencies in phase A1, duration measurements were made for the stuttering events. The /s/ durations in the stuttered productions were highly variable, as seen in Table 4. The mean /s/ duration in stuttered non-clusters was 107.3 msec with a standard deviation of 36.2 msec. The mean length of /s/ duration in stuttered clusters was 115.0 msec with a standard deviation of 30.7 msec. The

differences in stuttered /s/ duration in non-clusters and clusters was not statistically significant in phase A1 [t= 1.58, df= 8, p<.152]. It appears that the participant exhibited less speech motor control during stuttered events.

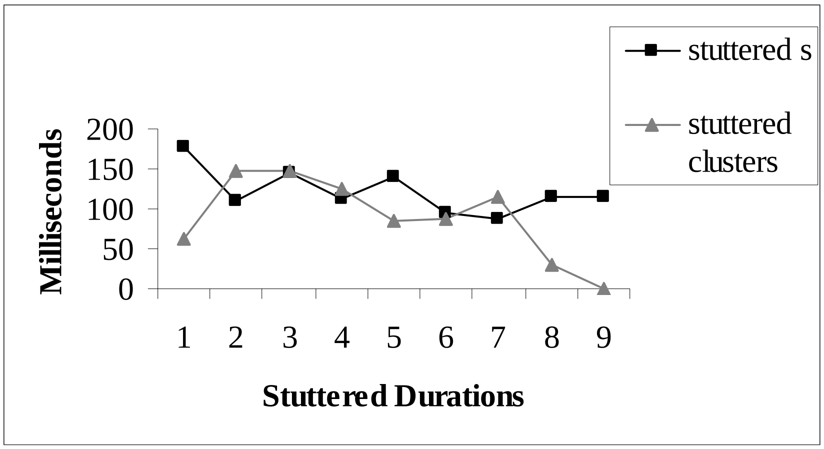

Figure 4. Stuttered /s/ and /s/ clusters in the first A phase

DISCUSSION

The first question of this experiment asks if a AWS shortens /s/ in sCV compared to sV contexts. The durations of the fricative /s/ in initial consonant-vowel position and /s/ in initial consonant clusters across repetitions of 24 stimuli sentences (i.e., *Pop sees a phone, Pop skis alone*) were measured using spectrograms. Results from phase A1 indicated the participant did control for /s/ in singletons and clusters as an adult would be expected to do. The participant produced a 67% shortening during production of /s/ in clusters. These results support Hawkins' (1984) study in which the adults produced 73% mean of cluster shortening in the adults in Hawkins' (1984) study. Therefore, during phase A1, the participant controlled for /s/ in sCV and sV context in an adult-like manner.

The second research question explored whether a reduction in speaking rate would increase the control of /s/ and /s/ cluster productions. When the treatment method (reduced rate) was introduced in phase B, there was no significant change in /s/ duration in initial consonant-vowel position. However, during phase B, the /s/ duration in initial cluster position increased significantly, meaning the duration of /s/ in clusters was close to the /s/ durations in non-clusters. This is not what we would have expected to happen. If the adolescent was speaking at a reduced rate, we would have expected him to control his speech better which would make a larger distinction between production of /s/ in consonant-vowel and consonant-consonant positions. Smith and Kleinow (2000) researched the effects of reduced rate on speech movement patterns of adults and discovered that not all adults produced a decrease in variability when speaking with a reduced rate. The result of increased variability during the reduced rate supports Smith

and Kleinow's findings that even at a slow rate, some adults still produce variability in speech-motor movements.

It is interesting to note that during the B phase, the reduced rate caused the participant to increase the duration of the /s/ clusters, while the duration of /s/ in non-clusters remained the same as in phase A1. The participant did not control for /s/ in non-clusters in an adult-like manner during the treatment phase. While the change in /s/ duration may be perceived as awkward, that change does not bring about a change in the phoneme that is perceived. This extends the Onslow, *et al*. (2003) study which only measured acoustic durations which would alter the phoneme if produced incorrectly (i.e., perceiving a /b/ instead of a /p/ due to shortening the voice onset time).

The reason the adolescent increased the duration of the /s/ in only the cluster form during the intervention could be related to linguistic complexity. It was seen that the adolescent produced /s/ in singleton at the same duration length in all three phases. This could be because the /s/ in singleton has a lower linguistic complexity. When adding another consonant into the utterance and forming a /s/ cluster, the linguistic complexity of that utterance increases. During the B phase, the adolescent reduced the rate of the /s/ clusters and produced the utterances with increased fluency. The reduced rate could have allowed the adolescent with enough time to process the increased linguistic complexity and produce the utterances more fluently.

Another question the present study sought to answer was if a reduced rate would decrease the amount of disfluencies. The number of stuttering events reduced dramatically from phase A1 with 15 stuttering events, to phase B with 5 stuttering events, to phase A2 with 3 stuttering events. The treatment method appeared to promote fluent

speech for the participant. Prins and Hubbard (1990) studied the effect of treatment consisting of reduced rate only and reported that by providing more time for motor linguistic processes, a reduction in stuttering frequency occurred. The results of this study supported Prins and Hubbard's findings, stating that a decrease in speaking rate causes a decrease in stuttering events.

5.1 Limitations of the Study

There are some limitations that exist in this study and could be altered for future experiments. Although a single-subject design is strong, looking at these changes across more adolescents may produce different results. Since this design has involved only one participant, there would be only one background population explored. Perhaps completing this study with participants of multiple backgrounds would yield different results. Many interesting questions for further study remain.

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APPENDIX

Reduced Rate Sentence Stimuli

Pop sold a car.	Dot sold a car.
Pop stole a car.	Dot stole a car.
Pop sees a phone.	Dot sees a phone.
Pop skis alone.	Dot skis alone.
Pop sat on me.	Dot sat on me.
Pop spat on me.	Dot spat on me.
Bob sold a car.	Todd sold a car.
Bob stole a car.	Todd stole a car.
Bob sees a phone.	Todd sees a phone.
Bob skis alone.	Todd skis alone.
Bob sat on me.	Todd sat on me.
Bob spat on me.	Todd spat on me.

VITA

Valerie Jean Courville was born and reared in New Iberia, Louisiana. Upon graduation from Catholic High School of New Iberia in 2001, she enrolled in Louisiana State University and Agricultural and Mechanical College of Baton Rouge to pursue a Bachelor of Arts degree in communication sciences and disorders, awarded in May 2005.

After completing her first year of graduate school in communication disorders, Ms. Courville was intrigued by the research opportunities available in her field of study. She then decided to complete a thesis research project in partial fulfillment of the requirements for her Master of Arts degree in communication sciences and disorders, to be awarded May 2007. Upon graduation, Ms. Courville plans to reside in San Francisco, California, where she will complete the necessary clinical fellow requirements to become a licensed speech-language pathologist.