THE EFFECT OF SPEECHEASY® EXPOSURE ON THE SYLLABLE CONSTITUENT DURATION IN SPEAKERS WHO STUTTER

By

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<tr>
<td>AAF</td>
<td>A feedback mechanism in which the auditory signal is altered</td>
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<td>BTE</td>
<td>A type of auditory device placed behind the ear</td>
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<td>A syllable structure comprising a consonant, a nucleus, and a coda</td>
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<td>DAF</td>
<td>A feedback mechanism in which the auditory signal is delayed.</td>
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<td>dBHL</td>
<td>The unit of hearing loss measurement in an audiogram</td>
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<td>F</td>
<td>Formant is an acoustic property used to characterize vowel features</td>
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<td>A frequency altered feedback is an auditory mechanism in which the frequency of the signal is altered before being introduced as a feedback to the listener</td>
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<td>FFT</td>
<td>Fourier Forman transition is a type of visual representation of frequency across time</td>
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<td>LPC</td>
<td>Lineal Prediction Coding is a type of acoustic means of measuring spectral information especially vowel formants</td>
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<td>LTAS</td>
<td>Long Term Average Spectrum is a used to capture acoustic information such as conversational over a period of time</td>
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<tr>
<td>msec</td>
<td>Millisecond is a measure of one thousandth of a second</td>
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<td>NAF</td>
<td>Normal auditory feedback is an unaltered feedback of an acoustic signal</td>
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<td>SPSS</td>
<td>A computer software program used for analyzing text</td>
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<td>SSI</td>
<td>Stuttering Severity Instrument is a norm referenced manual for assessment of stuttering severity</td>
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Abstract of Thesis Presented to the Graduate School
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THE EFFECT OF SPEECHEASY® EXPOSURE ON THE SYLLABLE CONSTITUENT
DURATION IN SPEAKERS WHO STUTTER

By
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Chair: Kenneth Logan
Major: Communication Sciences and Disorders

Purpose: To examine the effect that simultaneous presentation of DAF and FAF signals
has upon the timing of speech sound segments in adolescents and adults who stutter.

Method: 8 speakers who stutter (6 males and 2 females) with mean age of 21.75 years ($SD$
= 5.37, Range =16 to 31 years) participated in oral reading tasks without and with SpeechEasy®
device. 10 fluent CVC words in both conditions were spectrographically analyzed for speech
rate, stuttering frequency, and syllable constituent duration (onsets, peaks and codas).

Results: Speech rate was not significant different in the fluent speech of speakers who
stutter with and without the SpeechEasy® device. Speakers who stutter produced significantly
less stutter-like disfluency when wearing the SpeechEasy device than when not wearing the
device. Syllable constituents were not significantly different between the conditions.

Conclusions: Speakers did not appear to be treating the AAF signal as a choral model or
purposively elongating speech segments to reduce the variability of speech sound movements.
These speech patterns were discussed in relation to two contemporary models of stuttering
( Neuropsycholinguistic model and the Variability Model). A non-significant trend toward
lengthening of syllable onsets suggests that a subgroup of speakers who stutter use the
SpeechEasy as a choral model to reduce the variability of speech movements and enhance fluency.
CHAPTER 1
BACKGROUND AND INTRODUCTION

Altered Auditory Feedback (AAF) is a term that is used to describe a collection of methods that are used to adjust the speech patterns of people who stutter by altering the type of input that a speaker’s auditory system receives during speech production. Howard (2004, p.43) has referred to it as “alterations to recurrent auditory information.” Two common forms of AAF are delayed auditory feedback (DAF) and frequency altered feedback (FAF). A substantial percentage of people who stutter exhibit enhanced fluency and improved speech naturalness when given access to AAF signals as they are talking (Stuart, Kalinowski, Rastatter, Saltuklaroglu, & Dayalu, 2004). Though the effect of AAF devices on speech fluency has been well researched (e.g., Hargrave, & Kalinowski, 1994; Kalinowski, Armson, & Stuart, 1995; Kalinowski, Guntupalli, Stuart, & Saltuklaroglu, 2004; MacLeod, Kalinowski, Stuart & Armson, 1995; Perkins, Rudas, Johnson, Michael, & Curlee, 1974; Sparks, Grant, Millay, Walker-Batson, & Hynan, 2002; Turnbaugh, & Guitar, 1981), the exact mechanisms through which the AAF devices enhance speech fluency are not entirely understood. The present study was conducted to address this gap in the literature by examining the effect that simultaneous presentation of DAF and FAF signals has upon the timing of speech sound segments in adolescents and adults who stutter. Based upon past research into the effects of DAF upon speech production, it was expected that speakers who stutter would show substantial improvements in speech fluency while speaking in conjunction with AAF signals and that the fluency speech would be characterized by a lengthening of speech sound segments, i.e., use of slower articulation rate.

**Altered Auditory Feedback Approaches**

As noted above, there are two major forms of AAF that have been studied in conjunction with speakers who stutter. These conditions are Frequency Auditory Feedback (FAF) and
Delayed Auditory Feedback (DAF) (Antipova, Purdy, Blakeley, & Williams, 2008; Stuart et al., 2004). These conditions, along with a few others that involved alterations in speech associated auditory signals (e.g., auditory masking, metronomic stimulation) have been well researched in terms of how they affect speech production and fluency in people who stutter and people who do not stutter. Descriptions of each of these approaches are presented in the following sections.

**Delayed Auditory Feedback**

In delayed auditory feedback (DAF), the playback of a person’s speech is delayed through use of electronic circuitry so that a person hears acoustic signals slightly after they have been produced. That is, the acoustic signals associated with a speaker’s spoken utterances are picked up by a microphone, converted into electrical signals, and routed to a signal processing system that is capable of delaying the time at which the corresponding electrical signal is released for playback to the speaker. Thus, in the context of speech production, DAF results in a speaker hearing the various consonants and vowels that he or she has spoken well after the sounds have been articulated. This is in contrast to normal auditory feedback (NAF), wherein speakers have access to acoustic information about spoken utterances at virtually the same time they have been produced. Put another way, the delayed playback of the acoustic signal creates the perception of hearing one’s speech as an echo. Theoretically, delays in auditory feedback under DAF can range anywhere from 1msec to infinity; however, in most research applications of DAF, delays in auditory feedback have been set to intervals between 50msec and 500msec. Conversely, most applications of DAF in clinical contexts applications have featured delays within the range of 50 msec to 100 msec. As will be discussed later, this is because many speakers find that longer delays (i.e., delays that exceed approximately 150 msec) to be difficult to talk under without reducing articulation rate to such an extent that speech sounds unnatural.
The use of DAF during speech production has been studied extensively since the 1960s. Initially, such research was primarily laboratory-based and designed to describe the ways in which the approach affected speech fluency of speakers with impaired fluency and speakers with typical fluency. From the 1950s through the early 1980s, there was substantial interest in using DAF therapeutically, as a means of training speakers who stutter to regulate their articulation rate during connected speech (i.e., so-called prolonged speech). From the mid-1990s until present, advances in electronics have resulted in miniaturization of DAF systems. Consequently, DAF can now be delivered through the use of devices that resemble hearing aids and through software applications that run on personal electronics devices such as cell phones.

**Auditory Masking**

The use of auditory masking through presentation of white noise during speech production also has been studied since at least the 1960s. In this condition, white noise is presented binaurally at a loudness level that rends it difficult for a speaker to hear his or her own speech while talking (Kalinowski, Armson, Roland-Mieszkowski, Stuart, & Gracco, 1993). Thus, white noise essentially “masks” the speaker’s ability to hear what he or she is saying at a particular moment in time. Auditory masking is similar to DAF in that the speaker hears something other than the typical speech-associated acoustic information while talking; however, it differs from DAF in that the temporal properties of the auditory feedback are not changed as they are under DAF. Rather, the speaker’s ability to hear what they are saying is basically obscured.

Most of the auditory masking research was conducted during the 1960s and 1970s. Work done with speakers who stutter revealed that the fluency improvements that are associated with auditory masking are significant, but generally smaller in magnitude than those associated with DAF. Another limitation is that auditory masking research has been largely confined to laboratory settings. Thus, the long-term effects of auditory masking on fluency in real-world
contexts are unclear. It also has been claimed that auditory masking reduces the frequency of physically tense “blocks” in speech production with speakers who stutter; however, this has not been empirically tested. Lincoln, Packman, and Onslow (2006, p. 73), noted that there has been relatively little research on the use of auditory masking with speakers who stutter in recent years. This may be one reason for the apparent decline in interest for the use of auditory masking as a treatment technique for stuttering.

**Frequency Altered Feedback**

The most recently developed form of altered auditory feedback to be used with speakers who stutter is frequency altered feedback (FAF). This approach is similar to DAF in that a person’s spoken utterance is captured by a microphone, converted to an electronic signal, and then routed to a signal processing system. Rather than delaying the release of the electronic signal, as in DAF, the processing system shifts the frequency information associated with original signal either up or down by either a full octave or some fractional portion of an octave. Thus, the person hears his or her speech at a frequency range that is different from the one that is customarily used.

Applications of FAF have featured frequency shifts ranging from 1/4 to 1 full octave (Antipova et al., 2008; Lincoln, Packman, & Onslow, 2006; Pollard, Ellis, Finan, & Ramig, 2009). As will be explained further below, findings from research studies that have examined the effect of FAF on fluency with speakers who stutter are inconclusive (cf., Kalinowski, Armson, Roland-Mieszkowski, Stuart & Gracco, 1993; MacLeod, Kalinowski, Stuart & Armson, 1995). Several researchers have reported that FAF enhances fluency to a significant degree, but to an extent that is less than that observed with DAF. Others have reported greater facilitative effects upon fluency for FAF than DAF, and still others have failed to find significant fluency improvements under FAF at all. The reasons that FAF might enhance fluency with speakers who
stutter are not well understood. At the very least, FAF provides speakers who stutter with access to speech signal that reflects the content and timing of what they are saying in a way that differs from their usual auditory feedback and without the introduction of extraneous signals such as loud noise (Howell, 2004).

**The SpeechEasy® Device**

The SpeechEasy® is a type of the altered auditory feedback device that was developed in 2001. The device is capable of providing both DAF and FAF signals to a speaker simultaneously. A toggle switch on the device also enables a wearer to terminate the DAF and FAF processing, which results in the device producing normal auditory feedback. The ® device is similar in appearance to a digital hearing aid. Normally, it is worn on only one ear (i.e., monaurally). It consists of a microphone, signal processor, and a small speaker that allows for presentation of acoustic information into a wearer’s ear canal. The early versions of the SpeechEasy® featured either completely–in-canal (CIC) or behind-the-ear (BTE) designs. With these early models, the device was fitted with a custom ear mold, through which the altered auditory signals were delivered to the wearer’s ear canal. In more contemporary applications, the DAF and AAF signals are presented to the speaker via a BTE configuration in combination with a vented ear tube, which reduces the wearer’s sensation of ear occlusion and makes it possible to hear both the altered and auditory signals and normal auditory signals through the ear in which the device is worn.

The DAF and AAF features on the SpeechEasy® device are programmable; however, programming features are only accessible with use of proprietary software, which means that a wearer is typically not able to change these settings without the assistance of a professional who distributes the device (Pollard et al., 2009). According to Kiefte and Armson (2008), the SpeechEasy® device and other miniature devices like it represented an improvement over older
DAF and FAF devices in that they are portable, cosmetically appealing, and capable of being used easily in real-world situations. Since its commercial release in 2001, the effects of SpeechEasy® on various speech tasks have been investigated in several studies involving speakers who stutter (Pollard et al., 2009). These studies are described further below. A few studies have also examined the effect of the SpeechEasy® device on the naturalness of speech in speakers who stutter.

**Effects of AAF on Fluency-Related Measures**

This section contains an overview of research that has examined the effects of AAF on speech fluency with people who stutter. A number of studies have examined the effects of DAF alone, FAF alone, and DAF+FAF simultaneously (e.g., the SpeechEasy® device) in laboratory and short-term clinical settings. Characteristics of several of those studies are presented in Table 1, which appears below. As can be seen in the Table, speech sampling tasks in these studies often include oral reading and monologue speech. Conversational settings in clinical and real-world setting are included in some studies, as well. The most common dependent variables are percentage of syllables stuttered and speech rate. Some studies have also examined the types of disfluency produced by participants (e.g., prolongation, repetition, blocking) as well as disfluency duration and frequency, and speech naturalness. Participants in these studies have covered nearly the entire life span, ranging in age from 13-81 (Appendix D).

Fluency improvements have been noted in nearly all studies that have tested the effects of AAF devices. The amount of fluency improvement often varies across tasks, and several researchers have reported that significant individual variability is common. Lincoln et al. (2006) reviewed the outcomes associated with a number of recent studies that have involved AAF devices, and reported that DAF generally results in greater fluency improvements than FAF. Outcomes with the SpeechEasy® device show fluency improvements on the order of 30% to 60%
when the device is worn. The SpeechEasy® fitting protocol calls for instructing patients to prolong speech sounds while wearing the device. Prolonged speech patterns essentially involved reduced articulation rate, and the effectiveness of that strategy in improving fluency with speakers who stutter is well documented (Bothe, Davidow, Bramlett, & Ingham, 2006). Use of prolonged speech while wearing the device seems to lead to better fluency improvement than use of the device without such instructions, but use of the device along still seems to yield immediate improvement in fluency. Pollard and colleagues found that participants who showed immediate fluency improvement with the SpeechEasy® device did not necessarily maintain those improvements when reexamined 3 to 4 months later.

Along with reducing the frequency with which stuttered syllables occur, AAF devices also yield increases in participants’ speech rate. Speaking rate is a broad term that includes both articulation rate and speech rate. Articulation rate refers to the number of phones, syllables, or words uttered per second in a fluent speech sample. In calculating articulation rate, typically, pauses and other disfluent segments such as prolongations and repetitions are excluded from the speech sample (Hall, Yairi, & Amir, 1999; Logan, Byrd, Mazzocchi, & Gillam, 2011). Studies in the literature indicate that speakers who stutter can attain improved speech fluency under AAF conditions while using either a typical articulation rate or a faster-than-normal articulation rate (Hargrave & Kalinowski, 1994; Kalinowski et al., 1993; 1995; MacLeod et al., 1995).

Speech rate, on the other hand, refers to the total number of phones, syllables, or words per unit of time in speech samples that include the aforementioned disfluency types (Kelly & Conture, 1992; Logan et al., 2011), and as such is a better reflection of real-world fluency performance. Speech rate is affected by the number and duration of disfluencies that a speaker produces. Thus, speakers who stutter usually exhibit slower speech than speakers who do not
stutter (Bloodstein, 1994). Speech rate also is affected by the kind of speaking task being performed as well. For instance, children who stutter demonstrate faster articulation rates and speech rates during sentence generation tasks than they do during monologue conditions (Logan, et al., 2011). Speakers who use AAF devices, then, usually exhibit an increase in speech rate because of the accompanying reduction in disfluency frequency (e.g., Armson, & Kiefte, 2008).

Other factors to consider are the effects that the delay setting for DAF and articulation rate have upon fluency improvement. Sparks et al. (2002) examined the effects of delay setting speech rate on frequency of stuttering (and consequently, speech rate) during a DAF condition. In three male participants, oral reading rate decreased slightly in participant who stuttered severely (4.1 syllables/s in the 55 and 80msec delay conditions to 3.9 syllables/sec in the 105 msec delay condition). Also, they observed that the number of stuttering episodes in conditions without DAF (mean = 27.6) decreased considerably under DAF conditions (mean = 1.3) for the severely impaired speakers when they used a fast articulation rate. Also, when a fast articulation rate was employed without a DAF condition, the participants with mild stuttering did not increase in the frequency of stuttering; the opposite pattern was observed, however, for speakers with severe stuttering under no DAF. According to Sparks et al. (2002, p. 196), “there may be variability among subjects with regards to the effects of rapid speaking rates.” Hargrave and Kalinowski (1994) found that fluency under DAF improved at both typical and fast articulation rates, but that fluency improvements under the fast articulation rate condition were significantly less than those under typical articulation rates. In another study of interactions between articulation rate and DAF use, Kalinowski et al. (1995) reported similar findings, and argued that use of slow articulation is not critical for fluency improvement under DAF. This is contrast to Wingate’s (1970) observation that one common feature of auditory based conditions that
enhance fluency is their tendency to evoke slowed rate of speech, and that slowed rate is necessary antecedent for fluency improvement. Others have shown that reduction in stuttering frequency in individuals under AAF occurs without sacrificing naturalness of speech (Armson & Kiefte, 2008; Stuart et al., 2004; Stuart, Kalinowski, Saltuklaroglu, & Guntupalli, 2006).

As noted above, the effectiveness of DAF and FAF in reducing stuttering frequency has been measured in various laboratory conditions and in some situations of daily living. Specific to the SpeechEasy® device, a number of studies have examined the efficacy of combining DAF and FAF in facilitating speech fluency (Armson, & Kiefte, 2008; Armson, Kiefte, Mason, & De Croos, 2006; O’Donnell, Stuart et al., 2004; Stuart et al., 2006). Among the general outcomes of this research are the following: (1) Reduction in stuttering frequency when speaking on the telephone and public speaking (Armson, Foote, Witt, Kalinowski, & Stuart, 1997; Kalinowski et al., 2004; O’Donnell et al., 2008; and Pollard et al., 2009); and (2) Reduction in stuttering frequency in both oral reading and conversation (Armson & Stuart 1998).

**Segmental Effects of AAF**

In addition to studying the effect of AAF upon relatively broad aspects of behavior such as stuttering frequency and speaking rate, others have examined the ways in which AAF affects more discrete variables, such as the duration of speech sound segments, using various acoustically-based measures of speech such as those based on the spectrogram. According to Logan et al. (2011) examination of events at the segmental or sub-syllabic level can provide information about speech timing and coordination, and as such can lead to inferences about a speaker’s speech motor control. Subsequently, it is possible that examination of segmental and syllabic level phenomenon of speech produced under AAF can provide insight into the mechanisms that underlie fluency improvement in this context. In essence, these mechanisms can be studied by investigating the finer aspects of speech articulation.
Spectrographic Analysis

According to Fucci, & Lass (1999) the spectrograph was developed in the 1940s. The spectrograph is an instrument which utilizes a series of filters used to analyze various features of speech sounds. It gives a visual representation of acoustic energy across a range of frequencies as function of time. Basically, the spectrogram functions by way of filters. A filter is a parameter that enhances some frequencies (in hertz) and attenuates others across the frequency spectrum. The spectrum is one parameter used in the acoustic description of vowels. Due to differences in vocal structure, it is essential to consider the context of vowel occurrence to adequately analyze and identify the specific qualities of consonant-vowel transition. According to Kent, & Read (1996), there are different ways of analyzing spectral information. The two main ways are Linear Prediction Coding (LPC) and Fourier Formant Transition (FFT). The LPC is mostly used to identify vowel formants. FFT is a type of visual representation of frequency across time. FFT analysis represents harmonic components as multiples of fundamental frequencies. To capture energy distribution in connected speech (e.g., a paragraph-length sample), a Long Term Average Spectrum (LTAS) is employed. The LTAS is a signal which merges the glottal source as well as the spectrum or resonant characteristics of the vocal tract and represents them on the spectrum. The LTAS is thus a Fourier formant transition spectrum of the frequencies that comprise the speech sample. The FFT is then used in analyzing shorter forms of speech within the LTAS. When a harmonic is close to a fundamental frequency, there is an increase in intensity which is more visible on the FFT.

Kent, and Read (1996) reviewed the basic properties of formants. In the English vowel system, the first three formant frequencies are needed to characterize the value of a vowel. Formant 1, 2 and 3 refer to specific features of the most active articulator (the tongue) in the production of the speech sounds. Formant 1 corresponds to the height of the tongue relative to
the floor of the mouth. Formant 2 mostly provides information about the advancement of the
tongue in the oral cavity. Formant 3 refers to the tenseness or laxness of the tongue during the
production of the speech sound. Consequently, low vowels such as /a/ have high F1 frequency
and high vowels such as /i, u/ have low F1 frequency. Back vowels such as /u, o/ have low F2
frequency and front vowels /i, e/ have high F2 frequency. In the literature, F2 is mostly used in
describing and distinguishing vowels on the spectrogram because it relates to the movement of
the tongue. F1 and F3 do not project the same perceptual information for the place of
articulation. F2 transition is used to measure the movement of articulators from one sound to
subsequent sound. Various studies have used F2 to measure differences in stuttering speech and
noted that speed of speech and the movement of articulators could contribute to the quality of
vowel segments. F2 transition information has implications for broader speech measures such as
speech rate as well. For example, Gay (1978) demonstrated that increases in speech rate were
accompanied by superimpositions of articulatory movements associated vowels. He found also
that the onset frequency of F2 was higher for faster speech rate while the midpoint or center
frequencies remained the same regardless of speech rates, and at fast rates the articulators moved
towards the vowels much earlier and much closer to the initial consonant closure. Another
measure that is often derived from spectrographic analysis is voice onset time (VOT). VOT is
defined by Ladefoged (2006) as the period between the release of articulators for a consonant
and the onset of voicing for a following vowel. VOT of children’s -aided speech in non-AAF
conditions has been measured extensively in single words, sentences, and conversational
responses (e.g., Adams, 1987) and in sentence imitation tasks (e.g., Zebrowski, Conture &
Cudahy, 1985).
Applications to Stuttering Research

Measures such as these have been used to compare the performance of speakers who do stutter with those who do not during various speaking task. Robb, Lybolt, & Price (1985) analyzed changes in VOT in speakers who stutter under DAF conditions following intensive therapy and found that there was no change in the mean VOT across sampling conditions. Robb et al. (1985) did observe some variability in fundamental frequency and VOT values from the pre to post treatment and demonstrated that vocalization time reduced in speech following intensive therapy with DAF. They also noted that an increase in fluency may not necessarily be accomplished by changing the fundamental timing gestures. However, fluency may be accomplished by increasing the vocalization time with adjustments in perturbations of motor sequencing.

De Nil, and Brutten (1991) compared the difference in mean VOT on target words containing initial /sk/ clusters between children who stutter and children who do not stutter under a time pressure and found that the stuttering group had more variability in their VOT than the non-stuttering group. They also found that an increase in consonant cluster complexity typically resulted in a relative decrease in phone transition time within the cluster. Zebrowski et al. (1985) reported that children who stutter demonstrated a slower VOT than children who do not stutter as indicated by longer initial consonant and vowels under NAF conditions. Falck, Lawler and Yonovitz (1985) investigated fundamental frequency measures in non-AAF conditions prior to moments of stuttering and fluent speech and found a general decline in mean fundamental frequency (F(0)) as the moment of stuttering approached.

Lingual movement is the relative position of the tongue with respect to sound production. In the measurement of lingual movements, time measured points are plotted corresponding to specific tongue movement. Robb, Blomgren and Chen (1998) demonstrated that F2 transitions
showed a greater tongue movement in a closed lip posture in preparation for consonant-vowel transition in stutterers than in non-stutterers. They however found that for F2 onset transition values, there was a higher value for /i/ compared to the /u/ and /a/ tokens. Moreover, the onset values for stops were higher than the fricatives at 60msec compared to 30msec and that for the stuttering group, when vowels are preceded by stops, there was a lower frequency at 30 msec time point than 60msec point.

While Robb et al. (1998) and Gay, Ushijima, Hirose and Cooper (1974) found a difference in degree of tongue movement in adults who stutter and adults who do not stutter, Chang, Ohde, and Conture (2002) did not find any significant difference in tongue movement in co-articulation. The difference in lingual movement was attributed to atypical lingual co-articulation behavior. Also, faster tongue movement was observed in bilabial context than in alveolar context in children who do not stutter. They attributed this pattern to less organization and control of the phonological encoding abilities of the temporal and spatial aspects of the mechanism of speech and language production or to the lower-level motor control processes in speech production confirming the findings by Robb et al. (1998).

**Rationale and Purpose for Present Study**

From previous research, we know about the effects of AAF on broad discourse-level variables such as overall speech fluency and speech rate. We generally know that in the AAF condition there is evidence of improved speech rate and speech fluency. In terms of order of benefit, we also know that people who stutter benefit from DAF most when reading, followed by monologue and conversational speech. At the segmental and syllabic level, the literature has also shown that the fine-grained aspects of speech production in speakers who stutter are in some ways similar to those of speakers who do not stutter, but that some relatively subtle differences do exist as well between fluent and stuttered speech and between speakers who do and do not
stutter. For example, for speakers who stutter, lowered frequency and decreased voicing are observed at pre-stuttering moments. Also, children who stutter have shorter F2 transition durations than fluent children at low risk of stuttering (Yaruss & Conture, 1993). It is also known that there is more variability in voice onset time in the speech of speakers who stutter than in speakers who do not stutter (De Nil & Brutten, 1991).

On the other hand, relatively little is known about the effects of AAF on segmental and sub-syllabic-level variables. Most spectrographic analysis of speech from speakers who stuttered have been used compare the performance of that group with typical speakers or compare fluent speech with speakers who stutter under normal auditory feedback conditions. Relatively little is known about how speakers’ articulatory coordination patterns are modified by AAF exposure. This study was intended to provide additional information about this topic.

The purpose of the present study was to examine how aspects the duration of syllable constituents were affected by the simultaneous presentation of DAF and FAF through the SpeechEasy® device. To date, most studies of AAF effects on speech production have been done using DAF. Little is known about how the SpeechEasy® device affects performance of these variables. In the present study, syllable constituent duration was compared in perceptually fluent words that were elicited with and without the use of the SpeechEasy® device. It was hypothesized that, without input from the SpeechEasy® device, speakers who stutter would show less fluent speech, slower speech rates, and shorter, and perhaps more variable, segment durations than they would with use of the device. It is anticipated that the results will add to the data about temporal features of stuttered speech, provide additional information about speech performance during aided and non-aided speaking conditions, and provide additional insight into the reasons why speakers tend to speak more fluently when using the SpeechEasy® device and
other forms of AAF. Research questions were as follows: (1) Does use of the SpeechEasy® device affect the speech fluency of speakers who stutter? (2) Does use of the SpeechEasy® device affect the speech rate of speakers who stutter? (3) Does use of the SpeechEasy® device affect the duration of specific syllable constituents (i.e., onset, rime, and coda) in speakers who stutter?
Table 1-1. Outcomes of AAF devices in studies of people who stutter.

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Ages</th>
<th>Tasks</th>
<th>Device</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antipova et al. (2008)</td>
<td>8</td>
<td>Teens &amp; adults</td>
<td>M (2 sessions)</td>
<td>DAF; DAF+FAF</td>
<td>DAF and DAF+FAF improved fluency. Improvement varied with setting. 75 ms delay, and 75 ms delay with -1/2 octave shift produced most improvement. Stuttering frequency in both control reading conditions (79%) and (61%) in monologue tasks. Speech rate increase in reading task (8%) and monologue task (15%); In naturalness rating with device increased in control reading condition (3.3) and monologue (3.2). Fluency improvement in “no vowel prolongation condition”: M (30%), OR (42%), C (36%); In vowel prolongation condition: M (36%), OR (74%), C (49%). Great individual variability. Mean stuttering frequency for NAF significantly higher (80%) than for FAF; more disfluencies under fast rate to normal speech rate condition</td>
</tr>
<tr>
<td>Armson &amp; Kiefte (2008)</td>
<td>31</td>
<td>Adults</td>
<td>M, OR</td>
<td>SE</td>
<td>Median overall satisfaction of device use with median score (2.0) on 7 point scale. Stuttering frequency decrease by 87% under DAF at fast rate; 72% under DAF at normal rate.</td>
</tr>
<tr>
<td>Armson et al. (2006)</td>
<td>13</td>
<td>Adults</td>
<td>M, OR, C</td>
<td>SE</td>
<td>Stuttering frequency reduced by 85% under FAF; greater during NAF when observers present; FAF shows no difference 7/7 have less stuttering in initial lab assessment w/ SE; 5/7 show less stuttering in follow up lab session; 5/7 show less stuttering in daily situation. Less stuttering immediately post-fitting, but no effect 4 months later; individual variability in stuttering frequency and subjective impressions</td>
</tr>
<tr>
<td>Hargrave et al. (1994)</td>
<td>14</td>
<td>18-52</td>
<td>OR</td>
<td>DAF, FAF, M,</td>
<td></td>
</tr>
<tr>
<td>Kalinowski et al. (2004)</td>
<td>105</td>
<td>7–81</td>
<td>Q</td>
<td>SE</td>
<td></td>
</tr>
<tr>
<td>Kalinowski, et al. (1993)</td>
<td>9</td>
<td>16-52</td>
<td>OR</td>
<td>DAF, FAF, M,</td>
<td></td>
</tr>
<tr>
<td>Kalinowski et al. (1999)</td>
<td>8</td>
<td>Teen &amp; Adults</td>
<td>M (w/ &amp; w/o audience)</td>
<td>FAF</td>
<td></td>
</tr>
<tr>
<td>O’Donnell et al. (2008)</td>
<td>7</td>
<td>Adults</td>
<td>M, OR, T</td>
<td>SE</td>
<td></td>
</tr>
<tr>
<td>Pollard et al. (2008)</td>
<td>11</td>
<td>Adults</td>
<td>OR, C</td>
<td>DAF, FAF</td>
<td></td>
</tr>
</tbody>
</table>
Table 1-1. Continued.

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Ages</th>
<th>Tasks</th>
<th>Device</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sparks et al. (2002)</td>
<td>4</td>
<td>Teen &amp; Adults</td>
<td>OR</td>
<td>DAF</td>
<td>No improvement in stuttering frequency for 2 participants with mild stuttering; significant improvement for 2 participants with severe stuttering. With device, stuttered syllable significantly reduced (90%) during oral reading, and (67%) during monologue; with device, stuttering rate significantly reduced and at 4 months regardless of speech task; no significant different in naturalness between initial fit and 4 month post fitting but judgment showed naturalness sounding with device.</td>
</tr>
<tr>
<td>Stuart et al. (2004)</td>
<td>8, 15</td>
<td>M, OR</td>
<td>ITE/CIC device</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: M = monologue, OR = Oral reading, C = Conversation, T = Telephone call, DAF = delayed auditory feedback, FAF = frequency altered feedback.
CHAPTER 2
METHODS

Participants

Participants were 8 speakers who stutter (6 males and 2 females). The mean age of the participants was 21.75 years ($SD = 5.37$, Range =16 to 31 years). Prior to data collection for the study, each of the participants completed the Self-Rating of Stuttering Scale (Logan, 2009), which contains 12 questions about different aspects of stuttering. Participants rated themselves on a 0 to 7 scale regarding the severity of each stuttering aspect (low scores are more favorable than high scores). Overall, the participants’ mean rating for scale items having to do with stuttering severity was 3.88 ($SD = 1.32$). This means that the participants perceived themselves, on average, to have a moderate level of fluency impairment. Several other scale items dealt with personal factors and reactions to stuttered speech. Overall, the participants’ mean rating for these scale items was 3.09 ($SD = 1.29$). This means that the participants perceived themselves, on average, to have mildly-to-moderately negative personal reactions to stuttering.

The participants were selected from a larger study that is being conducted at the Speech Fluency Laboratory in the Department of Speech, Language, and Hearing Sciences at the University of Florida. Criteria for participant inclusion for the larger study were as follows: (1) a diagnosis of developmental stuttering which was of at least mild severity; (2) the ability to speak English with native competence; (3) no reported history of speech-related neurological dysfunction or trauma; (4) normal functioning on an oral peripheral examination; and (5) normal functioning on a pure tone audiometric screening at 20 dB HL.

Each of the participants in the study was self-referred for concerns about stuttering. Diagnoses of stuttering were made by a certified speech-language pathologist who had over 30 years’ experience working with speakers who stutter. Six of the 8 participants were able to
provide information about family history of stuttering. Of these, 4 (67%) participants reported a positive family history of stuttering: 2 cases reported having a brother who stuttered; 1 reported having a mother and father who stuttered; and 1 reported having a niece and nephew who stuttered. With regard to age of onset for stuttering, 4 of the 8 participants reported that their stuttering began during the preschool, and the remaining 4 reported that it began during the early elementary school years.

Data Collection

Speech Samples

Prior to data collection for the present study, the participants each underwent a comprehensive fluency assessment in the Speech Fluency Laboratory in the Department of Speech, Language, and Hearing Sciences at the University of Florida. The comprehensive evaluation took place over the course of three one-hour sessions that were held over the course of three weeks. The evaluation included analyses of the participants’ spontaneous speech during conversation and narration as well as completion of various stuttering-related questionnaires and surveys. Data collection for the activities reported upon during the present study took place during the second and third sessions.

Analyses for the present study were based upon samples of oral reading which were elicited in the Speech Fluency Laboratory from each of the participants during the second and third research sessions. Two samples – one with the SpeechEasy® device, one without the SpeechEasy® device – were elicited from each of the participants. Both samples were recorded using a digital camcorder (JVC Model GZ-MG680) in the present of a male researcher. The oral reading speech sample that was elicited during research session 2 (i.e., the first of the two samples) was produced under normal auditory feedback (NAF) conditions. That is, participants read the passage without the use of the Speech Easy device. The oral reading speech sample that
was elicited during research session 3 (i.e., the second of the two samples) was elicited under altered auditory feedback (AAF) conditions. That is, participants read the passage while wearing the Speech Easy device.

As noted in Chapter 1, the SpeechEasy® is an assistive tool used with adolescents and adults who stutter. It resembles a hearing aid in appearance, but instead of amplifying sound, it provides two forms of altered auditory feedback (AAF), mono-aurally. The two AAF forms that are delivered through the device are delayed auditory feedback (DAF) and frequency-altered feedback (FAF). In the present study, the delay time for DAF was set to 60 msec for all speakers, which resulted in them hearing their spoken words at a slight delay (i.e., an echo) in either the right or the left ear. The frequency alteration for FAF was set to +0.5 octaves, which resulted in speakers hearing any words they said at a higher pitch than normal in either the right or left ear. These settings are ones that are recommended for initial trial uses of the device in the SpeechEasy® Training Manual.

Ear placement for the device (right or left ear) was determined by patient preference, per procedures specified in the SpeechEasy® training manual. Participants were asked which ear they usually used when talking on the telephone. Whichever ear was indicated by the participant, the opposite ear was selected for device placement. The model used in the present study was the Comfort Fit, which features behind-the-ear placement for the device, along with a clear plastic tube that inserts into the ear canal. The plastic tube is fitted with a vented dome to protect the tissue in the ear canal from irritation. Use of the SpeechEasy® device did not eliminate access to normal hearing during speech. That is, speakers also could hear their spoken words in real time at the customary frequency, binaurally.
For 7 of the 8 participants, the stimulus that was used to elicit the oral reading samples was the Washington passage found on the Stuttering Severity Instrument –4 (SSI-4; Riley, 2008). The Washington passage features a total of 122 words and 228 syllables. For the remaining participant, the reading passage that was used to elicit the oral reading sample was the “Ghost” passage also found on the SSI-4. The Ghost passage features a total of 255 words and 378 syllables. The estimated reading level for both passages is adult. Each of the participants was seen individually. He or she sat across a table from a member of the research team. The research assistant presented the printed passage to the participant and asked him or her to read it aloud at a comfortable loudness level.

Prior to eliciting the sample in the SpeechEasy® condition, the researcher briefly explained the basic characteristics of the device. Participants were informed that they would be hearing their own voice through the device while they spoke, and that playback of their voice would be altered such that it sounded slightly echoed and at a higher pitch than normal. The examiner then placed the device on the person and proceeded to familiarize him or her with it via a simple counting task (i.e., count from 1 to 10) and a recitation task (i.e., say the days of the week and the months of the year). The participants were then presented with the reading passage and asked to read it aloud. At this point, the participants had not been given any specific instructions about how to talk while wearing the SpeechEasy® device. This procedure deviated from the procedure in the SpeechEasy® manual, wherein participants are fitted with the device and then immediately instructed to prolong their speech sounds slightly while talking. Participants were also instructed to vocalize either “um” or “mmm” if they were unable to hear their voice through the SpeechEasy® due to fixed articulatory postures that result from inaudible sound prolongations.
Target Words

Both of the reading passages contained many single-syllable words that featured CVC syllable structure. To identify target words for acoustic analysis in the present study, the following procedure was used. First, the researcher identified all one-syllable CVC words within the passage. Then, he listened to the recordings of the participants as they read their particular passage in the Without SpeechEasy® (SE) and With SpeechEasy® (SE) conditions. Each of the target words in the Without SE condition was analyzed for fluency. If the word was spoken fluently in that condition, the same word was examined in the With SE condition to see if it was also spoken fluently. If it was, then the match pair of words was selected for further analysis in the present study. This process was repeated until 10 fluent matched CVC word-pairs were identified across the With SE and Without SE samples. This approach allowed for control over the phonetic structure of the target words, as well as the syntactic environment within which the words occurred. If one participant did not produce a CVC word fluently in either of the reading conditions, that word was not selected for inclusion in the acoustic analysis.

In addition to CVC structure, the initial phonemes of the words that were chosen for acoustic analysis began with either plosive or fricative consonants. This approach allowed for reliable measurement of the onset duration for each target word. Moreover, words that feature consonants in the word-initial position are more likely to be stuttered than words that feature an empty onset (Bloodstein, 1981). Syntactically, each of the target words occurred at the head of their respective phrase structures or was lexical items that occupied the head positions and dominated the other words in their syntactic structure. Pure vowels and diphthong were selected to be representative of different vowels.
Data Analysis

Instrumentation

The video data were transferred from the digital video camera to a secure research server and then converted from .MOV file format to .MPEG format using AVS4YOU® video conversion software. This allowed for video editing in Windows® Movie Maker. Each video file was opened in Windows® Movie Maker and the files were then converted into audio (.wav) files to allow for spectrographic representation. The video provided evidence of both primary and secondary characteristics of stuttering during the reading. Only the primary stuttering characteristics were considered in the present study. Once the audio files were converted into .wav format, they could be acoustically analyzed using a spectrographic software program—Wavesurfer™, version 1.8.5 (Sojlander & Beskow, 2006).

Fluency Analysis

The researcher opened each audio recording and listened to it as it played aloud. While listening to the recording, the researcher marked syllables upon which the participant showed evidence of stuttered speech. Examples of behaviors that coincide with stuttering judgments included repetition of syllables or sounds with syllables, sound prolongations, and physically tense blocks in speech production. The number of syllables stuttered in a reading passage was summed and divided by the total number of syllables in the passage. This yielded the percent of syllables stuttered for a particular passage, a commonly-used metric of stuttering severity. This process was performed for both reading samples that a participant provided.

Speech Rate

Speech rate was computed by measuring the total amount of time that a participant took when reading a passage. Time measurements for the passages were performed using Wave surfer. The researcher generated a spectrogram for the acoustic recording of a passage and then
dragged the timing cursor over the entire spectrographic image (i.e., from the beginning of the passage to the end). This yielded the overall duration for the passage. The total time spent speaking was divided into the total number of syllables in the passage, to yield syllables per second for the passage. Speech rate is sensitive to both disfluency frequency and duration. That is, speakers who produce relatively many speech disfluencies and/or very long disfluencies tend to have slower speech rates than speakers who do not. The approach used for speech rate assessment in the present study was consistent with previous research (e.g., Logan et al., 2011) in which speech rate included pauses, other disfluencies, and fluent words.

**Syllable Analyses**

Durational characteristics of primary syllable constituents were measured by locating the specific target words for a participant on the spectrographic image within the Wavesurfer™ program (Sojlander & Beskow; 2006). Duration of specific acoustic events was measured by locating the onset of a syllable constituent and then dragging the cursor on the Wavesurfer™ spectrogram window to the offset of the syllable constituent. Temporal measurements for the various acoustic segments were computed to three decimal places. The phonetic characteristics of the target words (CVC structure, with either plosive or fricative consonants in the onset position and the coda position) made the identification of syllable constituent boundaries possible and increase the likelihood of maintaining adequate reliability for the comparative spectrographic measurements.

Acoustic analyses in the present study were focused upon the primary syllable constituents, i.e., syllable onset, syllable nucleus, and syllable coda. These basic measure could be combined, as well, to yield rime duration (i.e., syllable nucleus + syllable coda), and syllable duration (i.e., the sum of all three syllable constituents). The duration of these constituents was measured
within each of the target words and entered into a data base. Definitions of the syllable constituents are provided below:

- **SYLLABLE ONSET** (msec). The syllable onset is the duration measured from the onset of acoustic energy indicated by onset of the oral release of the initial consonant sound to the onset of voicing of the nucleus vowel.

- **SYLLABLE PEAK** (msec). The nucleus forms the peak of the syllable. It is the measurement of the duration of the vocalic or the part of the syllable with most sonority. It corresponds with the duration between the offset of the onset consonant(s) and the onset of the coda consonant(s).

- **SYLLABLE CODA** (msec). The coda is the measurement between the offset of the vowel/nucleus of the syllable and the onset of the oral release of the acoustic energy associated with the final consonants in the target word.

- **RIME** (msec). The rime is the addition of the nucleus and the coda durations. The rime was the measurement of the part of the syllable that consists of the nucleus of the syllable and the consonants (syllable code) that come after it.

- **SYLLABLE DURATION**. This is the measurement of the onset of the initial consonant associated with the syllable onset to the offset of the final consonant associated with the syllable coda.

**Statistical Analysis**

Because of the relatively small sample size, and associating about concerns about meeting the assumptions necessary for use of parametric statistics, a non-parametric approach was used to analyze the data. The speech rates and syllable constituent analyses for speakers who stutter were analyzed using the Wilcoxon test. The stuttering frequency within reading passages with and without the SpeechEasy® was compared using the Wilcoxon test, as well. All statistical tests were performed using PASW Statistics (SPSS version 18).

**Measurement Reliability**

Assessment of intra- and inter-judge reliability was done for the spectrographic measurements that were done to compute speech rate and also syllable constituents’ duration. Intra-judge (i.e., the researcher versus himself) and inter-judge (i.e., the researcher versus a
graduate student in the Speech, Language and Hearing Sciences Department at University of Florida) measurements were computed by reassessing the data of two participants. All words from both of the participants were reassessed on the spectrogram along with the overall duration of the reading passage.

**Intra-Judge Reliability**

The following average intrajudge mean differences were found for each measurement: (1) Syllable onset: $M = 0.006$, $SD = 0.042$; (2) Syllable peak: $M = -0.007$, $SD = 0.035$; (3) Syllable coda: $M = 0.013$, $SD = 0.026$. The original and re-measured duration values for syllable onset, $t(39) = 0.846$, $p = 0.403$, and for syllable peak, $t(39) = -1.325$, $p = 0.193$, were not significantly different. However, the original and re-measured duration values for syllable coda, $t(39) = 3.259$, $p = 0.002$, were significantly different. This difference was not considered practically important, however, because the size of the difference (approximately 1/100 of a second) was considered to be well within the acceptable range for the goals of the present study.

**Inter-Judge Reliability**

For interjudge reliability measurement, the following average error differences were found for each measurement: (1) Syllable onset: $M = -0.008$, $SD = 0.023$; (2) Syllable peak: $M = -0.006$, $SD = 0.022$; (3) Syllable coda: $M = 0.053$, $SD = 0.023$. The original and re-measured values for syllable onset, $t(18) = -1.450$, $p=0.164$, for syllable peak, $t(18) = -1.129$, $p=0.274$, for Syllable code $t(18) = 0.989$, $p=0.336$, were not significantly different.
CHAPTER 3
RESULTS

This Chapter discusses results related to the analysis of speech produced with and without the use of the SpeechEasy® device.

**Stuttering Frequency**

Results of differences in the percentage of stuttered syllables during reading samples with and without use of the SpeechEasy® device are presented in Figure 3-1. As can be seen, the mean frequency of stuttered syllables was over two times greater in the Without SpeechEasy® condition than it was in the With SpeechEasy® Condition. Statistical analysis indicated that the difference in stuttering frequency between the two conditions was statistically significant, $Z = -2.38$, $p = .017$, Inspection of individual data showed that 7 of the 8 participants showed reductions in stuttering frequency during the SpeechEasy® condition.

**Speech Rate**

Figure 3-2 provides results related to speech rate analysis in the oral reading conditions with and without use of the SpeechEasy® device. As can be seen, the mean speech rates during the two conditions were similar, and participants varied considerably in their performance. Statistical analysis indicated that the difference in speech rate between the two conditions was not statistically significant, $Z = -0.560$, $p = .575$.

**Speech Rate and Stuttering Frequency Relationships**

Stuttering frequency values from the With SE condition were divided into the stuttering frequency values from the Without SE condition to yield a percent change score across the two conditions. Similarly, speech rate values from the With SE condition were divided into speech rate values from the Without SE condition to yield a percent change score in speech rate between the two conditions. The relationship between the two percent change scores was examined using
non-parametric statistics to determine whether the amount of change in a participant’s stuttering frequency was associated with the amount of change in their speech rate. Results showed a moderate correlation between the two variables, rho = .524; however, this was not statistically significant, \( p = .183 \).

**Syllable Constituents**

**Syllable Onsets**

The syllable onset is the duration indicated by onset of the oral release of the initial consonant sound to the onset of voicing associated with the syllable peak. Figure 3-3 provides mean results related to constituent duration of the syllable onsets in the oral reading conditions without and with SpeechEasy\textsuperscript{®} device. The mean syllable onset durations during the two conditions indicated a higher mean for participants with SE. However, statistical analysis indicated that the difference in mean onset duration between the two conditions was not statistically significant, \( Z = -1.260, \ p = .208 \).

**Syllable Peaks**

The nucleus is the most sonorous part of the syllable. It corresponds with the measurement of the duration of the vocalic part of the syllable. Figure 3-3 provides results related to mean syllable nucleus duration in the oral reading conditions with and without use of the SpeechEasy\textsuperscript{®} device. As can be seen, the mean nucleus durations of the without SE was higher than with SE condition. But the statistical analysis indicated no statistically significant difference, \( Z = -0.840, \ p = .401 \), in mean syllable peak duration between the two conditions.

**Syllable Codas**

The results for syllable coda without SE and with SE are provided in Figure 3-3. The coda is the measurement between the offset of the nucleus and the onset of the coda in the target word. The mean syllable coda durations between the two conditions were similar, and participants
showed minimal variation in their performance. Statistical analysis indicated the difference between the two conditions in syllable coda duration was not statistically significant, $Z = -0.700$, $p = 0.484$.

![Figure 3-1: Mean percent of syllables stuttered during oral reading with and without use of the SpeechEasy® (SE) device. Error bars represent +/- 1 SD.](image)

![Figure 3-2: Mean speech rates during oral reading with and without use of the SpeechEasy® (SE) device. Error bars represent +/- 1 SD.](image)
Figure 3-3: Mean durations in milliseconds for syllable onsets, peaks, and codas during oral reading without and with the SpeechEasy® device.
CHAPTER 4
DISCUSSION AND CONCLUSION

The purpose of this study was to investigate how various temporal aspects of speech were affected by the simultaneous presentation of DAF and FAF through the SpeechEasy® device. More specifically, the research questions in this study examined the effect of the SpeechEasy® device on the speech fluency, speech rate, and duration of specific syllable constituents (i.e., onset, rime, and coda) of speakers who stutter. In this section, the results pertaining to each of these variables are summarized and then discussed in relation to two contemporary models of stuttering: the neuro-psycholinguistic model (Perkins, Kent & Curlee, 1991) and the Variability Model (Packman, Onslow, Richard & Van Doorn, 2006).

Speech Rate

Generally, the mean speech rates observed in the present study during oral reading were consistent with those reported in previous studies of speech rates issues in AAF environments. In many studies, the participants’ speech rate had not been appreciably different for conditions without AAF than it was for conditions with AAF conditions (Armson & Kiefte, 2008; Armson & Stuart, 1998; Hargrave & Kalinowski, 1994; Howell et al., 1987; Kalinowski et al., 1993; MacLeod et al., 1995; Stuart et al., 2004, 2006). This is somewhat surprising, given the fact that AAF conditions tend to contain fewer disfluencies, which consume time, than non-AAF conditions, and might be explained by an interaction with DAF delay settings. For example, Kalinowski et al. (1993) found that speech rates under DAF were slower for delay settings under 50 msec than over 50 msec. In the present study, the mean difference in speech rate between AAF and non-AAF conditions was not statistically significant, which is consistent with results from Armson and Kiefte (2008). Inspection of the individual data showed that 5 out of 8 participants showed an increase in their speech rates; however, only 1 of these 5 showed an
increase in rate of more than 10%. The remaining 3 participants showed slower speech rates during the AAF condition than during the non-AAF condition; however, only 1 of these three showed decrease of more than 10%. In a broader sense, the findings in the present study are consistent with those of Kalinowski et al. (1993), who refuted the notion that the fluency improvements found with AAF devices are dependent upon use of a reduced speech rate, and in fact could be attained with use of an increased speech rate.

As noted, previous research on use of DAF alone has yielded mixed conclusions about its effects on speech rate during oral reading tasks. In this study, the DAF delay setting was 60msec (along with +0.5 octaves shift in frequency). Armson and Kiefte (2008) reported no difference in speech rate between DAF and non-DAF conditions, using a similar setting. When speakers who stutter read aloud in a DAF condition (90-270msec), there is a general reduction (1.3:1) in the speech rate (Brokaw, Singh, & Black, 1966). Lee (1950) reported similar findings, demonstrating that when the delay feedback signal was increased, there was an increase in the time it took speakers who stutter to read a passage.

**Stuttering Frequency**

Results from the present study indicated that speakers who stutter produced significantly less stutter-like disfluency when wearing the SpeechEasy® device than when not wearing the device. The results of the individual data showed that 7 of the 8 participants showed reductions in stuttering frequency during the SpeechEasy® condition, and that average percentage of fluency improvement was 55% (range 19% to 88%). This is comparable to some previous research findings of fluency change during oral reading with AAF, but less than others. For example, Armson et al. (2006) showed fluency improvement during reading of between 74% and 42% in a laboratory setting. Stuart et al. (2004) also showed a 90% reduction in stuttering frequency during oral reading with the DAF device. Armson and Kiefte (2008) examined 11 females and
20 males with age ranges of 18 to 51 and found that for reading tasks, when the device was worn, there was a 100% reduction in frequency of stuttering as against 16.5% when the device was not worn. Pollard et al. (2008) on the other hand demonstrated a 58.3% reduced stuttering in treatment and 27.2% decrease in stuttering frequency during oral reading using SpeechEasy® during the withdrawal phase. Stuart et al. (2004) also examined the impact of SpeechEasy® on the speech of people who stutter and concluded that there was a significant reduction of stuttering of approximately 81%, when the AAF device is in place.

As noted above, the reasons for improvement in fluency under AAF is not always clear. For example, several studies (e.g., Hargrave & Kalinowski, 1994; Kalinowski et al., 1995; MacLeod et al., 1995) have observed that under AAF, improvement in fluency was not necessarily attributable to a reduced rate of speech. These findings were consistent with those of Andrews, Ashley, Feye, Huddinott, Howie, & Neilson (1983) who noted that the notion that stuttering frequency being decreased via reduced speaking rate is not universal. That seemed to be the case in the present study, as the moderate correlation between speech rate and stuttering frequency was not statistically significant.

In the present study, the amount of DAF delay setting was not manipulated. Other studies have manipulated DAF delay setting and reported that it has a significant effect on speech fluency improvement. In relation to previous literature on settings on DAF devices, when speakers who stutter read passages under different DAF settings (0-500msec with 100 msec increments) were tested on the same day, the 100 and 200msec setting were found to produce the most improvement in stuttering frequency (Webster, Schumacher, & Lubker, 1970). Tiffany, & Hanley (1956) demonstrated that under a180msec delay, speakers who stutter demonstrated a reduction in stuttering frequency when they read two passages a week apart. It is possible that
use of longer DAF settings with the SpeechEasy® device would have resulted in greater improvement in speech fluency. FAF setting was not manipulated either. At least one study has reported differences in stuttering frequency across FAF settings (Antipova et al., 2008). In that study, improvement varied with setting of 75 msec delay, and 75 msec delay with -1/2 octave shift produced most improvement.

It is also worth noting that in this study the participants were not cued before the reading task to slow their articulation rate. Such cueing is a recommended procedure during SpeechEasy® fitting, but was not introduced (at least for the data that were analyzed in this study) to remove the potential effect that such instructions might have had on participant performance. In other words, use of prolonged speech pattern makes it difficult to determine whether it is the device or the instructed speaking pattern that results in fluent speech. At least, one other study has examined the effect of instructing participant to use cued speech on speech fluency. Antipova et al. (2008) found that participants spoke more fluently under AFF when instructed to prolong than when not instructed to do so.

**Syllable Constituent Analysis**

Even though there have been a number of research studies that have examined segment-level performance in the speech of people who stutter, most of this work has either compared speakers who stutter with speakers who do not stutter or has examined segmental changes in relation to behavioral therapy approaches. Thus, there is no previous research to examine the effect of simultaneous presentation of DAF and FAF on the temporal properties of speech sound segments. Because of the lack of previous studies, an attempt to compare these findings with literature on fluent speech of people who stutter was made in the present study. It was thought that such research would provide a more sensitive assessment of possible changes as a result of exposure to the SpeechEasy® device.
Previous research has yielded mixed findings on how the temporal aspects of speech segment production differ between speakers who stutter and speakers who do not stutter different segment features. For example, Zebrowski et al. (1985) found no significant difference in VOT between young children who stutter and normally fluent children. In contrast, De Nil and Brutten (1991) compared VOT values between children who stutter and children who do not stutter under a time pressure and found more variability in the VOT of the stuttering group than in the non-stuttering group. Adams (1987) found that people who stutter had shorter VOTs and longer segment durations than speakers who did not stutter. Onslow, Adams, and Ingham (1992) found that vowel duration and intervocalic interval duration did not change after behavioral treatment with speakers who stutter.

In the present study, there were no significant differences in the duration of syllable onsets, peaks, or codas that were produced in fluent words under SpeechEasy® versus no-SpeechEasy® conditions. Inspection of individual data showed that there was relatively high consistency across participants in their durations of each of these constituents. It is possible that the speech timing patterns reflect conscious use of fluency management strategies such as regulated articulation rate on the part of the speakers. That might explain why the words were produced fluently during both reading conditions. Alternatively, Bloodstein and Ratner (2008) noted that even perceptibly fluent stretches of speech might contain imperceptible markers of disfluent speech. These minimal markers of disfluency might be detectable only with the aid of highly sensitive measurement techniques.

There was a tendency for participants to increase the duration of syllable onsets during the SpeechEasy® condition; however, this only approached statistical significance. Prolongation of consonants in the syllable onset position is a common fluency management strategy for stuttering
(i.e., slow, gentle onset). On average, onsets in the SpeechEasy® condition were about 19% than those in the no-SpeechEasy® condition. It is interesting to consider whether use of the SpeechEasy® device promotes use of this strategy by delaying the feedback that one receives about speech production. Future research with a larger sample size may be useful to clarify this issue.

**Models of Stuttering**

There have been many models of stuttering proposed over the years. Two of the more commonly cited ones today are the neuropsycholinguistic model (Perkins, Kent & Curlee, 1991) and the Variability model (V-model; Packman, Onslow, Richard & Van Doorn, 1996). Both models include linguistic and motor components to them, and thus seem well suited to explore in relation to the present findings.

**Neuro-psycholinguistic model.** The neuropsycholinguistic (NPL) model was introduced by Perkins et al. (1991). It attempts to model the mechanisms that lead speakers who stutter to produce interruptions in their fluent speech, and how such interruptions relate to the perception of stuttering. Perkins et al. proposed that fluent speech results from the efficient synchrony of segmental and suprasegmental systems. The segmental level relates to the speech sound segments that comprise the particular words in a spoken utterance. The suprasegmental level corresponds to the paralinguistic level and involves syllable-level factors that relate to pitch, loudness, and duration. The syllable is the basic unit around which the paralinguistic component finds expression and it is argued to form a frame for placement of segmental filler. For fluent speech to be produced, these systems need to be coordinated accurately and efficiently. When there is a disruption between the level of syllable processing and the level of segment content disfluent or stuttering episode occurs. According to the model, any disruption in system functioning which results in discoordination of these systems may lead to the types of disfluency
that characterize stuttering (repetitions of sounds or syllables, sound prolongations). According to this model, when the disfluencies occur in the absence of time pressure, they speaker experiences the break as disfluency. Conversely, when a speaker experiences disfluency under time pressure, it perceived as “stuttering.” As such, time pressure seems to be an integral internal or/and external component which applies on the linguistic/paralinguistic systems of speech. Perkins et al. (1991) defined time pressure as “the pressure to begin, continue or accelerate an utterance, whether fluent or disrupted” (p. 375).

Although the intent in the present study was not to test the main theoretical claims of the NPL model, it is interesting to consider how the present results relate to its basic features. One prediction of the model is that priming of either segmental or suprasegmental information should improve the coordination of the two systems, and thus reduce the frequency of disfluency. This mechanism is thought to underlie the choral reading effect which reliably yields very substantial fluency improvements. Some researchers (e.g., Kalinowski et al. 2004) have argued that devices like DAF and SpeechEasy® enhance fluency by mimicking the choral reading effect. That is, providing speakers with a model of the segments and timing patterns that they need to produce. Signals in DAF and SpeechEasy® contexts differ from true choral speech because the choral speech signal is always “behind” the speaker. Nonetheless, the choral reading possibility was partially supported in the present study by the fact that speech fluency did improve with the SpeechEasy®. However, this explanation is tempered by the fact that the speakers did not mimic the durational features that go along with DAF; that is, they did not increase duration to match the length of delay, but instead moved on to the next segment without necessarily hearing the current one being produced.
The Variability Model (V-model) was proposed by Packman, Onslow, Richard & Van Doorn (1996). It follows from the demand and capacity model of Wingate (1969) and Zimmermann’s (1980) model of stuttering as a disorder of movement. The model is used to describe contexts in which speakers are more likely to produce less stuttering episodes. It is based on the assumption that speakers who stutter have difficulties with the timing of their speech patterns. In the production of stressed syllables, there is an increase in neural and muscular activity which is evidenced by the increase of duration, extent, and velocity of the various structures of articulation (Ladefoged, 1982; Netsell, 1973). According to Bloodstein & Ratner (2008), stuttering occurs more frequently on stressed syllables than unstressed syllables. Speakers who stutter also tend to stutter at word-initial locations. Wingate (1984b) suggested that word-initial contexts often receive greater stress than other sentence positions, and hence pose difficulty for people who stutter because they are stressed. The V-model proposed that stressed syllables pose problems because it is a moment for which speakers must alter their speech motor system, which then results in a moment of stuttering. In addition, the more variability that is inherent in a particular utterance, the more stuttering episodes a speaker will produce. According to the model, speakers can potentially reduce variability by increasing the duration of particular segments or syllables.

In Chapter 1, participants were asked to count one to ten to familiarize themselves with wearing the device but no other instruction about the type of speech to use were given. As noted above, there was a trend in this direction in the present study, as some participants tended to increase the duration of syllable onsets, but overall this prediction was not supported in the present study. So overall, the present results were not consistent with this model either. In the end, it may simply be that use of the SpeechEasy® results in speakers devoting more conscious
monitoring to the act of speech articulation. That is, the introduction of altered auditory feedback promotes more precise proprioceptive monitoring, which in turn results in improved fluency. This possibility requires further assessment.

**Future Directions**

The present study was preliminary in nature and the sample size was relatively small. Directions for future studies may include comparing the temporal features of the fluent words of measures of people who stutter with and without AAF using larger samples, and while also making comparisons with speakers who do not stutter. With such an approach, it might be possible to gain better insight in the variability of segmental features than was possible in this study. Another area of potential study is to assess the extent to which fluency words in both conditions are perceived as being natural. Such an approach might provide additional insight into whether subtle motor-control differences exist between speaking conditions with and without AAF. Such findings could then be used to guide clinical decisions in terms of how AAF devices can be used for maximum benefit.

**Conclusion**

In conclusion, results of this study support the idea that use of the S[peechEasy]® device ameliorates stuttering, at least during the laboratory settings that involve oral reading. The mechanism through which such improvement occurs remains unclear. The present results showed no obvious changes in the duration of speech sound segments; thus, speakers did not appear to be closely imitating a choral model or purposively elongating speech segments to reduce the variability of speech sound movements. There was a non-significant trend toward lengthening of syllable onsets, a finding which could potentially be taken as support for either the NPL or V-models, but ultimately seems to fit the V-model a bit better. Since the prolonged
onset effect was not significant; however, this explanation is at most one that might fit a subgroup of people who stutter. Additional research is needed to explore this possibility.
APPENDIX A
LIST OF PASSAGE STIMULI

Washington

Washington- Part of the nation’s future oil supply may lie within some extraordinary organisms that have been called a “third form of life.”

A Colorado State University microbiologist reports obtaining pure hydrocarbon that could be converted to gasoline or lubricating oils from several of the organisms.

The oily substance is “energy-rich, definitely a lubricant, combustible and isn’t soluble in water,” says the researcher, Thomas Tornabene. And the oil is free of air-polluting sulfur.

The discovery now is only a laboratory phenomenon; any commercial application is some time away.

“Right now we are concentrating on the organisms’ basic mechanism,” Tornabene says. “We have two genetic engineers look at them to find ways of getting them to grow faster and to pump oil faster.”

Ghost Story

The talk over salad and fromage was about ghosts. My English friend Christopher Neville informed me that two of them haunt his house in the southern France, on the sunny terrace of which we were now having lunch. I don’t normally believe in spirits, but it seemed wise to suspend disbelief for the moment, since I would soon be entering a region of sorcery and hidden Grails, where heretics once marched defiantly into the bonfires of bloodthirsty crusaders: the land of the Cathars. Christopher’s ghosts were said to be knights from those medieval times. I don’t know whether he began studying the Middle Ages because of the ghosts or whether the ghosts arrived one day because he had taken an unusually keen interest in the Cathars. I do know that his knowledge proved invaluable.
The Cathars, I had read, were a kind and gentle people. They were dualists (man is bad, the spirit is good), they viewed the material world as corrupt, and they rejected certain important tenets of the powerful Catholic Church, including priests, the Trinity and the sacraments. The laying on of hands was thought to transform believers into the “Perfects” or Good Christians, who were from then on expected to abstain from sex and meat. The popularity of this gnostic faith threatened the reign of Pope Innocent III. In 1208, he sent Simon de Montfort on a crusade against the heretics. The crusade took its name from the town of Albi and was followed 25 years later by the Inquisition.
APPENDIX B
STIMULI WORD LIST

Washington
• Part
• That
• Called
• State
• Could
• Says
• Time
• Have
• Find
• Pump

Ghost
• Talk
• Them
• Would
• Kind
• But
• Friend
• Keen
• That
• Sent
• name
APPENDIX C

STATISTICAL RESULTS OF PARTICIPANTS

Table C-1. Descriptive Statistics with the mean and standard deviation values of speech rate, onset, vowel duration and coda duration during oral reading with and without use of the SpeechEasy® (SE) device

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratenose</td>
<td>8</td>
<td>3.322938</td>
<td>.3636836</td>
<td>2.0767</td>
<td>4.6069</td>
</tr>
<tr>
<td>Onsetwo</td>
<td>8</td>
<td>.054650</td>
<td>.0148317</td>
<td>.0407</td>
<td>.0860</td>
</tr>
<tr>
<td>Vdurwo</td>
<td>8</td>
<td>.0722250</td>
<td>.01634405</td>
<td>.05150</td>
<td>.09980</td>
</tr>
<tr>
<td>Codawo</td>
<td>8</td>
<td>.029588</td>
<td>.0100789</td>
<td>.0193</td>
<td>.0497</td>
</tr>
<tr>
<td>RateSE</td>
<td>8</td>
<td>3.452875</td>
<td>1.1463687</td>
<td>2.0658</td>
<td>4.8454</td>
</tr>
<tr>
<td>Onsetw</td>
<td>8</td>
<td>.0596150</td>
<td>.00914967</td>
<td>.04273</td>
<td>.06880</td>
</tr>
<tr>
<td>Vdurw</td>
<td>8</td>
<td>.069300</td>
<td>.0138380</td>
<td>.0532</td>
<td>.0977</td>
</tr>
<tr>
<td>Codaw</td>
<td>8</td>
<td>.0313250</td>
<td>.00375033</td>
<td>.02630</td>
<td>.03790</td>
</tr>
</tbody>
</table>

Table C-2. Z and 2 tailed test results of speech rate and syllable

<table>
<thead>
<tr>
<th></th>
<th>RateSE - Ratenose</th>
<th>Onsetw - Onsetwo</th>
<th>Vdurw - Vdurwo</th>
<th>Codaw - Codawo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z</td>
<td>-.560</td>
<td>-1.260</td>
<td>-.840</td>
<td>-.700</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.575</td>
<td>.208</td>
<td>.401</td>
<td>.484</td>
</tr>
</tbody>
</table>
# APPENDIX D

## DATA OF PARTICIPANTS

<table>
<thead>
<tr>
<th>Participant</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>F</td>
</tr>
<tr>
<td>Age</td>
<td>19</td>
<td>18</td>
<td>16</td>
<td>19</td>
<td>29</td>
<td>21</td>
<td>21</td>
<td>31</td>
</tr>
<tr>
<td>Family History</td>
<td>No</td>
<td>Mum and Dad</td>
<td>Brother</td>
<td>No</td>
<td>Brother</td>
<td>-</td>
<td>-</td>
<td>Niece, Nephew</td>
</tr>
<tr>
<td>Occupation</td>
<td>Student - College</td>
<td>Student - College</td>
<td>Student - High school</td>
<td>Psychologist</td>
<td>-</td>
<td>Student (college)</td>
<td>Attorney</td>
<td></td>
</tr>
<tr>
<td>Onset year</td>
<td>N/A</td>
<td>Early childhood</td>
<td>Childhood</td>
<td>7 years</td>
<td>3 years</td>
<td>-</td>
<td>7/8 years</td>
<td>2 years</td>
</tr>
<tr>
<td>Treatment History</td>
<td>Elementary/middle school</td>
<td>Elementary/middle school</td>
<td>High school</td>
<td>Private practice/middle school</td>
<td>2-12th grade, college</td>
<td>-</td>
<td>-</td>
<td>County school and college</td>
</tr>
<tr>
<td>Disfluency type</td>
<td>Choppy and forced</td>
<td>Blocks and repetitions</td>
<td>Difficulty with vowel sounds</td>
<td>Don’t remember</td>
<td>Blocks</td>
<td>Blocks</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Secondary behavior</td>
<td>Fix behavior when it is noticed</td>
<td>Try to push word out</td>
<td>Tightness in throat</td>
<td>Sound like having trouble getting the word out</td>
<td>Extra blinking, clenching foot, looking away, hand movement</td>
<td>-</td>
<td>-</td>
<td>Repetition, Prolongation, blocks</td>
</tr>
<tr>
<td>Most Difficult situations</td>
<td>Speaking in front of large number of people</td>
<td>Friends/family</td>
<td>-</td>
<td>Conversations</td>
<td>Going over reports at work</td>
<td>With strangers</td>
<td>-</td>
<td>Beginning a sentence or speaking for first time</td>
</tr>
<tr>
<td>Awareness of stuttering</td>
<td>Always</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- = Mean did not provide data for that question.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

Levi C. Ofoe was born in Tema, Ghana. He graduated from Presbyterian Boy’s Senior Secondary School, Legon in 1997. He received a Bachelor of Arts degree in Linguistics with Philosophy from University of Ghana in 2003. In 2005 and 2006, he studied Linguistics as an exchange student in Louisiana State University, Baton Rouge. He received a Master in Philosophy of Linguistics degree from University of Ghana in 2007. In the fall of 2008, Levi began graduate studies at the Speech, language and Hearing Sciences within the College of Public Health and Health Professions of the University of Florida. After completion of his Master of Arts degree in the fall of 2011, he began a clinical fellowship in the field of speech-language pathology.