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Changes in Disfluent Behavior During Adaptation in Stuttering

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CHANGES IN DISFLUENT BEHAVIOR DURING ADAPTATION IN STUTTERING

by

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B.A. SPEECH AND HEARING SCIENCES

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ABSTRACT

Purpose: The purpose of this study was to explore changes in disfluent speech during adaptation to better understand the mechanism for improving fluency in People Who Stutter (PWS). It was hypothesized that disfluencies would become less complex and shorter in duration with successive oral readings similar to changes noted in fluent speech.

Method: This study included seven participants who stuttered. Digital sound and video recordings were used to acoustically analyze disfluent speech at both the reading and word level. Group analysis was conducted to find patterns of change for both adapting and nonadapting subjects. The following measures were analyzed: frequency of stuttered events, frequency of pause events, overall time, disfluent time, fluent time, pause time, average disfluency time, and average pause time. A more detailed word analysis was conducted to compare duration of disfluent and fluent phonemic segments within the word for adapting participants.

Results: Four of the seven participants experienced adaptation. Group data revealed significant reductions in fluent speech and overall speech time when the first and fifth readings were compared. When readings other than the fifth reading were considered, significant reductions in most measures were achieved by the group. Word analysis showed significant reduction for disfluent segments for participant 11007. All other statistical word analysis was not significant. Variability of fluent and disfluent segments was measured using standard deviation. Higher variability was show for disfluent segments.

Conclusion: Although some significant reduction in disfluency duration with successive readings of a passage does occur, small sample size and high variability between subjects makes it challenging to identify patterns of change. High variability for disfluent segments compared to fluent segments across all adapting subjects gives insight into instability associated with the moment of stuttering.

KEY WORDS: stuttering, Persons Who Stutter (PWS), adaptation, acoustical analysis, duration

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INTRODUCTION

Stuttering is most commonly defined as a speech disorder characterized by disruptions in the forward flow of speech. Disruptions of this nature can be described as monosyllabic whole word repetitions, part-word repetitions, audible sound prolongations, or silent fixations/ blockages (ASHA, 1999). This definition might suffice; however, stuttering is often more than just an occasional break in fluency. Stuttering is also evident in outward behaviors such as the rate, pitch, loudness, inflectional patterns, articulation, facial expression, and postural adjustments of the speaker. It also has an internal component that relates to avoidance, fear, and anticipation (Bloodstein, 1995). So, although stuttering is broadly defined as disruptions in the forward flow of speech, it is a term that can encompass an immense variety of behaviors. A popular saying amongst people who stutter (PWS) and those who work with them is that "if you've met one PWS…then, you've met one PWS." So, it should be noted that there are many differences among PWS that can be seen in elements such as their severity, circumstances in which they stutter, reactions to their stuttering, and in a wide array of other factors (Fraser, 2007). This variability can also be related to the circumstances in which stuttering is known to diminish, such as adaptation. Adaptation is a reduction in stuttering that takes place during successive oral reading of the same material (Johnson & Knott, 1937). Because not all speakers experience adaptation and not all experience it to the same degree, it is another phenomenon that highlights variability. Because of the variability between PWS, etiology is best addressed by ideology and theory that accounts for all of the elements that make each PWS unique.

The etiology of stuttering is unknown, but many theories exist that attempt to explain the disorder. Popular theories range from specifically targeting anatomical differences, such as the basal ganglia, to relating stuttering to motor learning. However, recent evidence in the field of fluency suggests a shift in research towards a neurological component for etiology. Advances in technology have allowed investigation into neural mechanisms that relate to stuttering. Noninvasive brain imaging techniques including functional Magnetic Resonance Imaging (fMRI) and positron emission tomography (PET) have been used to understand brain-behavior relationships during speech and language tasks. A study in 2003 found that over-activation in the right hemisphere revealed by fMRI in PWS likely served a nonspecific compensatory role (Preibisch et al., 2003). Recent studies (Watkins et al., 2008; Chang et al., 2008) have found that there is a consistent pattern of abnormality across many different groups of people who stutter. An MRI method called diffusion-tensor imaging, which uses the movement of water to examine white matter in the brain, found that PWS consistently demonstrated left-hemisphere white-matter abnormalities. It is unclear whether these abnormalities are causal or resultant from years of stuttering. A possible neurochemical basis for this abnormality is also being considered from observed gene mutation lysosomal dysfunction in PWS (Buchel and Watkins, 2010). Stuttering is a complex disorder, and stuttered speech is a complex behavior. As such, it is unlikely to be triggered by one stimulus, but by several. These variables can be either external or internal, and can be grouped in different ways depending on the individual (Smith and Kelly, 1997). Because there is such a wide array of proposed theories for stuttering, but a lack of definitive support for any singular theory, further research into the analysis of stuttering is warranted. Research utilizing new technology is now looking at the interaction between genetics, anatomy, processing, and chemistry in PWS with promising beginnings.

Additional Aspects of Stuttering

There are several circumstances in which stuttering tends to diminish. These phenomena include the metronome effect, white noise effect, choral readings effect, response-contingent stimulation, and the adaptation effect (Bloodstein, 1995). These conditions have been the focal point of a considerable amount of research because understanding the mechanisms that facilitate fluency could have significant impact on treatment and clinical reduction of stuttering.

The metronome effect occurs when fluency is increased in PWS by pacing the speaker with a metronome. The speaker produces one word or syllable per metronome beat (Davidow, 2014). Two possible factors have been proposed to underlie the metronome effect. One such factor is that the phenomenon creates a rhythmic speech quality. This aligns with the idea that PWS often become more fluent when they speak in a way that is unusual for them. Another possible factor is that motor planning demands are reduced when speech rate is controlled (Bloodstein, 1995).

The white noise effect is the reduction in stuttering that can occur when a PWS is presented with 100-dB noise for a period of 100 minutes (Garber & Martin, 1974). It is unclear whether the white noise effect results from the masking of speech. Effects of adding loud noise to the background vary from speaker to speaker and do not facilitate complete fluency. Theories behind the white noise effect include that stuttering is an error of perception rather than motor ability (Cherry and Sayers, 1956). Inability to hear speech results in a reduction of the anxiety that contributes to stuttering (Shane, 1955).

Wingate (1970) later suggested that having to speak over background noise results in vocal change, and that noise may be acting as a distraction. There is not compelling evidence for any specific theory behind the white noise effect; however, this phenomenon does lead to consideration for dysfunctional auditory feedback mechanism as a possible cause of stuttering (Bloodstein, 1995). Another phenomenon, choral reading, results in an increase in fluency when a PWS listens to or speaks along with another speaker. Speech that is not perfectly synchronized has been found to be just as effective as speech that is not (Cherry and Sayers, 1956). Choral readings have also been found to be helpful in treatment, by helping clients practice appropriate pacing, pausing, prosody, and pronunciations (Nicolosi et al., 1996).

Response-contingent stimulation is a circumstance where stuttering can be modified based on punishment and reinforcement (Flanagan et al., 1958). Evidence suggests that when contingency is applied to PWS, there is a marked decrease in disfluencies. Hypotheses for why this occurs include operant conditioning, avoidance of stuttering by calling attention to it, and distraction. The mechanism behind this additional aspect of stuttering is not entirely understood; and when punishment and reinforcement are removed, stuttering returns to its original form.

By examining a conditions in which stuttering improves and exploring past and present theories perspective can be gained into the phenomena of stuttering and used to tailor treatment, evaluation, and future research.

Adaptation effect. The adaptation effect is yet another circumstance in which stuttering reduction occurs and is the current focus of this research. Johnson and Knott (1937) were the first to observe that a reduction of stuttering takes place in successive oral readings of the same material. Further research done by Wischner in the 1950s revealed a cycle of events surrounding stuttering regarding anxiety before and reduction of anxiety after a word has been spoken. So, during adaptation, fluency results from an on the spot unlearning of the anxiety response which relies on reinforcement. This is often referred to as an experimental extinction of learned-anxiety motivated response. These early studies cultivated renewed interest in the adaptation effect that has led to it becoming one of the most researched phenomena related to facilitating fluent speech for PWS (Wischner, 1952; Wingate, 1966; Bloodstein, 1995; Max & Caruso, 1998).

Since the published discovery of the adaptation effect in 1937, several additional facts about adaptation have been realized. The average decrease is typically a 50% reduction in stuttering across five readings of a material (Johnson et al., 1967). Harris (1942) found that there is relatively little transfer of this effect to different material. Bloodstein and Ratner (2008) summarized some of the evidenced trends in stuttering in “A Handbook on Stuttering” to include reductions being very evident during the first few readings, but progressively slowing over subsequent reading; most reduction occurring by the fifth reading; rate of adaptation decreasing with increases in the time interval between successive readings; irrelevance of passage length; and poor maintenance and generalization of fluency.

PWS differ in the degree to which they adapt. Some PWS fail to demonstrate the adaptation effect at all, while others may actually increase the frequency of their disfluencies (Prins, 1968). Studies have sought to determine why some PWS experience the effect and other do not, but have yielded no definitive conclusions. The only evidenced relationship is that less severe PWS are more likely to adapt (Quarrington, 1959). The phenomenon can be found in both adults and children (Neelley & Timmons, 1967).

Theories for adaptation. Many theories exist which attempt to explain adaptation. Theories in the 1950s and 1960s focused on a learning theory explanation. These theories about adaptation include the idea that the reduction in stuttering is a result of the experimental extinction of a learned anxiety response (Wischner, 1950). An on the spot unlearning occurs that relies upon reinforcement and facilitates fluency. Another theory claims that the occurrence of stuttering is fear reducing and that the reduction in fear results in a reduction of stuttering (Sheehan, 1958). So, stuttering allows a person to realize that the event of disfluency is not as bad as imagined, decreasing fear, and thus decreasing stuttering. A study by Johnson et al. (1967) claimed a reduction of stuttering results from a deconfirmation of expectancies also known as reactive inhibition, in which an inhibitory potential such as fatigue, results in a change of learning.

From the beginning, the adaptation effect has contributed to the idea that stuttering is learned. Johnson and Knott (1937) initially presented the idea that stuttering has a tendency to occur consistently in the same area from reading to reading of the same material. So, they hypothesized that these places where the stuttering occurred were the stimuli to which the stutterers reacted, and thus stuttering was the reaction. Johnson also stated that stuttering tends to follow the same laws of learning as other behaviors. Treatments for stuttering often use principles of learning theories to frame methods that include reinforcement, practice, and taught strategies.

A later theory proposed that adaptation is due to the rehearsal of reading material. A study by Frank and Bloodstein (1971) supports this theory by showing that the person with stutter (PWS) reduced their stuttering even when a choral reading was used rather than the individual stuttering alone. Repeated readings of the same material allowed for increased automaticity of the linguistic encoding processes required to produce the target utterances. So, they hypothesized that the person was adapting to the reading rather than their own stutter.

Oral expression opposed to silent rehearsal proved to be necessary for adaptation to occur. So, the idea that "adaptation is the result of greater ease and conviction in the serial ordering of speech movements through rehearsal of the motor plan" (Bloodstein, 1995) was developed by Bloodstein (1972) to account for this property. The act of speech production and practice was deemed crucial for the adaptation effect to occur.

Recent literature on adaptation has begun to re-examine the phenomenon as a result of motor learning. Max conducted a series of studies beginning in 1997 that sought to understand reduction in fluencies during the adaptation effect as a result of motor learning. One of the earlier studies by Max et al. (1997) identified adaptation as a result of repeated reading, rather than repeated stuttering. Max and Caruso (1998) later found evidence that improvements during adaptation differed from other fluency inducing conditions and more closely resembled skill improvements for nonspeech motor tasks.

Max and Baldwin (2010) found that adaptation could actually facilitate retention using two integrated approaches. Texts containing both repeated and novel sentences were used to differentiate practiced and situational effects. Stuttering frequency was determined for both the initial readings and retention tests to differentiate learning from performance. Results showed that decreases were experienced for both novel and repeated utterances, but were greater for repeated readings. Retention of repeated readings was maintained longer than for novel utterance. Of the ten subjects analyzed, eight exhibited adaptation on the repeated readings. Results were true for "most", but not all subjects (5 out of 8). Although this study's claim of "retention" may appear in conflict with the previously stated claim that adaptation is not maintained post-readings, the authors address this by stating that previous studies measure retention from the last reading, rather than the initial reading.

Acoustical Analysis

Acoustical analysis has been crucial to the study of stuttering and the adaptation effect. Due to high variability between persons with stutter (PWS), it can be challenging to define stuttering as a specific incident. Even expert researchers often have difficulty agreeing on instances of stuttering (Bloodstein, 1995). In order to analyze stuttering, effective measurements for categorizing the severity of stuttering must be utilized. Five ways for reliably measuring stuttering include frequency of stuttering, mean duration of stuttering, frequency of specified disfluency types, and ratings of severity.

Frequency of stuttering. Frequency of stuttering as a percentage of moments of stuttering or of stuttered words or syllables is the most familiar and frequently used measure of analyzing stuttering behavior. PWS can experience contextual variability and range from stuttering in common scenarios to stuttering only in situations of high anticipation of difficulty (Bloodstein, 1995). However, studies report that poor agreement on the frequency of stuttering is observed between trained judges at both the same and different speech clinics (Ingham & Cords, 1992). So, some degree of variability is expected between raters.

A study conducted by Jani, Huckvale, and Howell (2013) showed that by doing successive rather than simultaneous analysis of speech samples more accurate counts of disfluencies were yielded. So, successive assessment of stuttering frequency and duration should be utilized to increase accuracy during speech analysis. To minimize variability, a methodology for counting pauses and disfluencies, measuring durations, and calculating overall time should be established to ensure consistency throughout the analysis.

Speech rate. Acoustic measures of rate are used in this study to better understand adaptation. Measures of rate usually account for frequency and duration of stuttering and are highly correlated with frequency (Bloodstein, 1995). Studies have shown that both reading rate and frequency of pauses within sentences are closely related to judged severity of stuttering (Prosek, Walden, et al, 1979). Speech rate could be a useful tool when used in conjunction with other measures to quantify severity of stuttering because it can be descriptive in nature and can represent a measurable acoustic aspect of stuttering that changes from reading to reading during adaptation. Speech rate is reduced during adaptation in relation to increase in articulation rate, decrease in word/ vowel duration, and reduced consonant-vowel duration extent (Max & Caruso, 1998).

Duration of stuttering. Some PWS experience block durations that can last for over a minute or be less than a tenth of a second. By examining block duration across five readings for a single speaker, we can use duration as both a descriptive measure and standardized measure (SSI) in the analysis of the changes of disfluent behavior.

Pause duration and frequency. A pause is a temporary stop in action or speech. It is not always specified whether pauses are included or removed during measurement of fluent vs. disfluent speech. Pausing before or after instances of stuttering can be a sign of grammatical stress, but can also be an avoidance behavior or secondary concomitant to stuttering. A study by Chon, Sawyer, and Ambrose (2012) emphasized the importance of controlling for pauses when measuring speech rate, since pause-deleted vs. pause-included can significantly alter rate results. In order to avoid this problem, measuring pauses separately in terms of frequency and duration should be utilized. The separation of this measure may also exhibit some pattern of change during the adaptation effect.

Adaptation Effect and Acoustic Studies

Many acoustical analysis studies have been conducted on conditions that reduce stuttering, mainly examining fluent speech in relation to the adaptation effect. However, most analyses have focused on fluent rather than disfluent speech. This is likely due to the fact that stuttering behaviors can be highly variable between and within participants, there is not an agreed upon method for measurement, and it can be difficult to identify disfluencies on an audio without the visual input. So, developing and implementing reliable and efficient methods for measurement and comparison can be unwieldy (Sawyer, 2010). Cordes and Ingham (1994) also outline the shortcomings of observational methods for measuring stuttering. Acoustical analysis allows us to infer information regarding movement of the speech mechanism from sound waves and spectography. Early studies in the field of stuttering did not use acoustical analysis because the technology was not readily available. Similar to the way advances in neuroimaging have changed the direction of stuttering etiology theory, acoustical analysis has set the stage for a more quantitative investigation and in-depth description of stuttering. As challenging as it may be to analyze disfluencies, it is crucial to do so in order to understand how the speech mechanism changes during disfluent speech and to identify any commonalities that may exist between speakers.

In the 1990 study by Prins and Hubbard, acoustical duration segments of fluent speech were compared between PWS and normal-speaking participants. The aim of this study was to describe the changes in the fluent speech that accompanies adaptation and to ascertain whether it could have a causal relationship to the change in overall fluency. However, no obvious trends were found related to the analysis of segment durations across adapting, nonadapting, and nonstuttering participants. Segment durations analyzed included intervocalic intervals, stop-gap, voice onset time, and vowel duration. This lead the researchers to conclude that stuttering adaptation was not a result of surface parameter changes, but rather because repeated readings reduced demands on central motor-linguistic patterns. The amount of adaptation was also not shown to impact speech naturalness for listeners on the stutter-free segments between readings 1 and 5. Although fluent segment analysis did not show significant change in this study, that does not rule out change that could occur on parameters of disfluent speech. So, further examination of disfluent speech is warranted.

Prins and Hubbard were still convinced that the speech in readings 2-5 sounded more rhythmic and wanted to explore whether the fluent segments were becoming more rhythmic or the effect was a result of stutter reduction. Two participants were analyzed during five adaptation trials for the study. Interstress intervals (ISI) are defined by the space between onset of a stressed vowel to the onset of the next stressed vowel. The ISI in fluent speech of the participants was the focus of this analysis. The PWS demonstrated more variable duration than the normally speaking participants and also demonstrated a failure to increase constancy across readings. This lead the researchers to the interpretation that the perception of increased rhythm was due to decreased stuttering rather than more rhythmic fluency. The researchers also found that when speech motor demands were more complex, ISI became significantly longer in PWS as opposed to normal speakers (Prins & Hubbard, 1992).

Max and Caruso (1998) used acoustical analysis to explore their hypothesis that stuttering adaptation is caused by motor learning. Their study focused on fluent speech productions in order to compare changes to nonspeech motor tasks. In nonspeech motor tasks improvement is associated with increase in the time it takes to perform the task, whereas stuttering tends to be associated with decreased speech rate, increased duration of certain acoustic segments, and less variability on vowels. Fluent speech was used because it was more consistent across readings and speakers, and also because this study had a focus on facilitating fluency. They found that during the last of 6 repeated readings, there were statistically significant increases in articulation rate, decreases in word duration, decreases in vowel duration, and in consonant-vowel transition extent, with the extent being the milliseconds from the onset of the steady-state portion of the acoustical energy associated with the word-initial stop or fricative to the onset of the steady-state portion of the second formant associated with the following vowel. Other findings included decreased consonant-vowel rate and duration, and increased variability of both consonant-vowel transition extent and vowel duration. An observed reduction in F2 transition suggests that amount of articulatory displacement used after repeated productions on the same utterance was reduced in successive readings, which was more efficient, but did not necessarily indicate faster articulation. Shorter segment durations and reduced articulatory displacement resulted in increased articulation rate without increasing the speed of the articulatory movements. So, Max and Caruso concluded that improvements in fluency during adaptation were consistent with those of nonspeech motor tasks.

Most recently, Onslow, Packman, and Beer (2003) conducted a study on eight PWS and 8 normally speaking adults. Onslow et al. also sought to investigate changes in speech rate and acoustic durations during adaptation. A control group was used to determine whether the acoustic changes were merely a result of reduced stuttering. The dependent measures used were voice onset time, vowel duration, and articulation rate. Vowel duration was defined as the interval between the peaks of the first and last period of the waveform that showed characteristic form of vowels or diphthongs. Duration was measured only for vowels and diphthongs that were preceded by a consonant and voice onset time was defined as the interval between the onset of the plosive burst and the peak of the first discernible vocal fold activity. PWS were found to speak slower than control subjects and have longer vowel duration and voice onset times. Onslow et al. interpreted this to mean that there was no support for the motor learning hypothesis through analysis of articulation rate, voice onset time, or vowel duration. These findings contrasted with the results reported by Max and Caruso (1998). However, during the Onslow et al. study a decrease approaching significance was noted for voice onset time. Increase in articulation rate for both the control and experimental group was also observed, but was not statistically significant by the statistical methods chosen (Onslow et al., 2003). Onslow et al. conducted a much more conservative statistical approach than Max and

Caruso, and although some of the finding were in alignment, the statistical significance to support the theory of motor learning was not present.

A recent study by Venkatagiri (2013) looked at the consistency of disfluencies across reading in order to rule out motor learning. This study used acoustical analysis to obtain frequency counts for disfluencies, but did not attempt more in depth acoustical analyses of stuttered speech. The study found that previously fluent words could become disfluent in later readings, which they interpreted as an indication that motor learning explanation is improbable.

Although acoustical analysis studies have been done to describe and understand adaption, few if any exist which attempt to specifically analyze the changes in disfluencies at an acoustic level. Only one study was found that examined disfluent speech during the adaptation effect (Hasten et al., 2009). The study assessed the durations of disfluent words with regards to adaptation across three readings. The study found that disfluent phonemes experienced significant reduction in duration, while the following fluent phonemes remained relatively unchanged in terms of duration. This is a good indicator that additional complex and individualized analysis of the disfluent speech of multiple PWS could result in patterns and trends that might influence how we treat stuttering by giving insight into the moment of stuttering.

Rationale for Current Study

Although the phenomenon of adaptation has been studied from many angles, few studies were identified that have acoustically analyzed the variability in disruptions of the forward flow of speech across readings. Insight into patterns of change during this phenomenon could be useful. That is why this study aims to descriptively analyze disfluencies across readings with regards to duration at the reading and word level. It is hypothesized that disfluent behavior will change from reading to reading. Specifically, disfluencies will become shorter in duration and approach fluency, although they may persist. The reason for this hypothesis is that it is unclear whether disfluencies are completely reduced in a subsequent reading or if they gradually become shorter and less complex until they disappear in a later reading. Across subsequent readings, fluent speech rate increases; so, we hypothesize that disfluent speech time will also decrease. Because stuttered behavior is often unique to the individual, analysis will be conducted both between and within participants. This study will explore frequency, rate, and duration of stuttered segments.

Method

Participants

Selection and inclusion criteria for participants were retrieved from Dr. Richard Arenas' dissertation (Arenas, 2012). Participants were seven adults who stutter (four female; three male), ranging in age from 18 to 41 years of age (mean=27.3; SD=7.3). All participants were self-described to be PWS, started stuttering in childhood and had no known neurological impairments. All of the PWS reported having received treatment for stuttering at one time in their life. Participants classified as PWS scored 13 and higher on the Stuttering Severity Instrument-3. Scores of 0-10 translate into *very mild* severity rating, scores of 11-16 translate into *mild* severity rating, scores of 17-27 translate into *moderate* severity rating, 27 to 31 translate into *severe* severity rating, and scores of 32 and up translate into *very severe* severity ratings (SSI-3; Riley, 1994) (mean SSI-3 = 24.88; SD=11.12). The PWS completed the Overall Assessment of the Speaker's Experience of Stuttering (OASES) (Yaruss & Quesal, 2006). The OASES is a questionnaire that assesses the PWS in terms of their perceptions of their stuttering and is used as a measure of the impact that stuttering has had on their lives.

All seven participants were paid volunteers, with some recruited from the University of Iowa's Wendell Johnson Speech and Hearing Clinic where they were receiving treatment for stuttering and others recruited from the areas surrounding Iowa City. As shown in Table 1, participants who were acoustically analyzed varied in terms of age, gender, severity of stutter, and impact of stuttering behavior on the individual.

Table 1

Participant Summary

	11001	11003	11006	11007	12004	12005	12008
Age	*24*	*23*	*20*	20	*28*	*41*	*28*
Gender	*F*	*F*	*F*	*F*	*M*	*M*	*M*
SSI Severity	*Severe*	*Very Mild*	*Mild*	*Very Severe*	*Mild*	*Very Mild*	*Very Severe*
SSI Score	*32*	*16*	*22*	*39*	*24*	*16*	*40*
OASES	*37*	*49*	*53*	*46*	*32*	*71*	*70*

Experimenters and Setting

Digital recordings used for this study were gathered by Dr. Richard Arenas at the University of Iowa for his dissertation study. The current acoustical analysis for this study was done by the author and Dr. Amy Neel, Ph.D., CCC-SLP. The author and an undergraduate student assistant received training prior to acoustical analysis from Dr. Amy Neel, the thesis advisor. Analysis was conducted in the Speech Acoustics and Intelligibility Lab at the University of New Mexico.

Materials

A reading sample created in 2012 by Dr. Richard Arenas was used during this study to examine the adaptation effect. The words were selected using the English Lexicon Project (ELP) database (Balota, et. al., 2007). The ELP is a collection of normative data from speeded naming tasks for over 40,000 words across 1200 participants. Besides normative verbal response time data, the database also has lexical properties of the words (i.e. length of word, frequency of words, and parts of speech) to assist in stimuli selection to better test theories by reducing potential confounds in empirical studies. The goal of stimuli selection was to provide a set of 50 words that were similar to one another in verbal response time to be included in the reading passage.

The acoustical analysis software, Praat (Boersma & Weenink, 2015) was used for acoustical analysis and data collection. Copies of the 266 word/ 350-syllable narrative were used to count and transcribe disfluencies.

Procedures

Seven PWS read aloud a 266 word/ 350 syllable narrative, see Appendix A, successively with no delay between readings. At the first and second visits the PWS were asked to read the narrative 5 times in a row. Participants were instructed not to use any speech strategies during the readings and were recorded using digital audio and video.

During the present study, two experimenters individually analyzed both the digital audio recording and the video recordings of the participants performing the reading passage for disruptions in the forward flow of speech, specifically disfluencies and pauses. This was done successively (Jani et al., 2013) with multiple passes on both the video and audio for increased accuracy. Praat was further used to analyze the audio samples and identify disruptions. The experimenters analyzed the samples individually and then collaboratively to agree on a final count of disfluencies and pauses for more in-depth analysis.

The agreed upon counts for disfluencies were used to measure overall duration of pauses, disfluencies, fluent time, and disfluent time using Praat. Acoustical analysis also included measuring the entire reading time of each passage, total speech time (minus pauses and disfluencies), duration measurements for pauses and disfluencies, and elements within the disfluent words, specifically consonant and vocalic segments. Because a standard approach to acoustical analysis of stuttered speech could not be identified, advisor and student investigator created specific guidelines for analyzing readings.

Pause and disfluency scoring. Rules for identifying pauses and disfluencies included: defining pauses as any gap longer than 100ms that is not associated with an articulatory behavior, limiting each word to only one event, labeling pauses immediately followed by disfluencies as disfluencies, counting pauses as disfluencies if they contain unidentifiable sounds or vowel beginnings, and including word changes, additions, and omissions as they impact syllable count. Pauses, disfluencies, revisions, word changes, word additions, were all coded within an excel file. Differentiating normal pauses from disfluent pauses was challenging. Close analysis had to be conducted at the sound level to detect extraneous noises that could be related to tension. On questionable pauses, video was also analyzed to look for secondary concomitants and physical signs of struggle.

The overall reading times for each reading for each participant were measured. Guidelines included: beginning timing at the first consonant sound, not counting the reading's final pause, and calculating the total fluent speech time by subtracting the total pause and disfluency duration measures from the total time.

Disfluent time was calculated by adding all disfluencies and revision. Pause time consisted only of pauses. Fluent time was calculated by subtracting disfluent and pause time from the overall time.

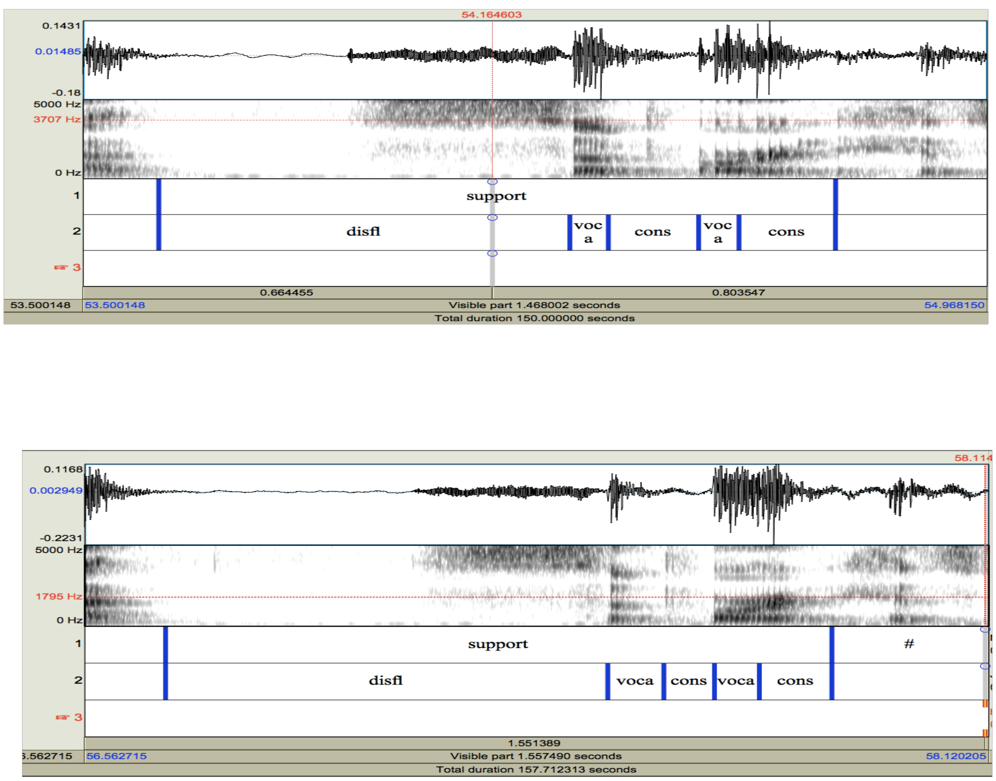
Duration measurement. Rules for measuring duration include: measuring the pause preceding a disfluency as a part of the disfluency, measuring disfluencies from the final phoneme of the previous word, measuring entire phoneme for disfluencies where the fluent consonant cannot be separated from the disfluent consonant such as "of...fff…fishing" and "was...sss...summer", measuring an unidentifiable sound at the end of the previous word preceding a disfluent word as part of the preceding word, measure duration from the end of the previous word to the last sustained production of the disfluent consonant for disfluencies characterized by sound repetition, measuring from the end of the previous word to the last sustained production before the vowel for prolongations and blocks, measuring VOT separately for stops when it is prolonged enough to be perceived as a disfluency, coding affricates and fricatives with an abnormal breathy portion before the vowel as f, and removing miscellaneous interruption to exclude it from the total fluent speech time. Many speakers also had multiple revisions and phrase repetitions. Because of this, rules related to revision included: excluding the first utterance and keeping the second utterance as fluent, and including the pause immediately after the first utterance as part of the disfluency.

Additional Acoustical Analysis of Words

In addition to frequency counts and duration measurement, word level assessment was also conducted. Ten words were selected for each speaker. Criteria for word selection required that words had to be stuttered consistently across all 5 readings for that speaker. When a speaker did not have words consistently stuttered across all readings, the criterion was reduced until the highest consistently stuttered words were selected. Words were measured for overall time, disfluency, vowel segments, and consonant segments. Vowel segments and consonant segments were divided based on each individual participants phonetic pronunciation of the target word.

Figure 1

Example of Acoustical Analysis using Praat



Reliability Measures

To test for data reliability, approximately 10% of all acoustic features were re-measured with inter- and intra- judge reliability. An undergraduate student in the field of speech-language pathology and the graduate student investigator separately re-measured two sentences per reading per participant. The undergraduate student used rules created by the advisor and student investigator on randomly selected sentences within the readings. Reliability had some variation, but was within an appropriate margin.

Table 2

Reliability Summary

Participant	**Inter-Judge Reliability Pearson Correlation Coefficient**	**Intra-Judge Reliability Pearson Correlation Coefficient**	**Inter-Judge p-value**	**Intra-Judge p-value**
11001	*.997*	*.999*	*<. 01*	*<. 01*
11003	*.999*	*.997*	*<. 01*	*<. 01*
11006	*.909*	*.998*	*<. 01*	*<. 01*
11007	*.981*	*.998*	*<. 01*	*<. 01*
12004	*.999*	*.999*	*<. 01*	*<. 01*
12005	*.994*	*.997*	*<. 01*	*<. 01*
12008	*.999*	*.999*	*<. 01*	*<. 01*

RESULTS

Adapting and Nonadapting Participants

The label of "adapting" was given when a decrease in the frequency of stuttered events from Reading 1 to Reading 5 was demonstrated. The reduction could be any decrease. Table 3 shows the adapting and nonadapting subjects, readings in which the greatest reductions occurred, and also the change in frequency of stuttered events. Figure 2 shows a graphical representation of the change for each participant.

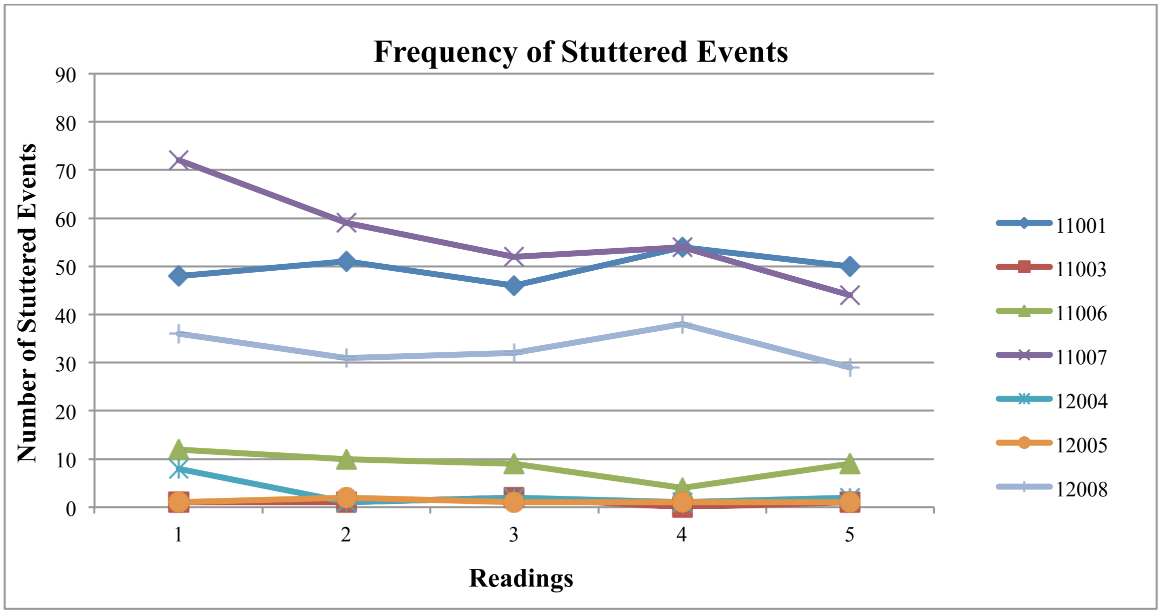
Table 3

Frequency of Stuttered Events Across 5 Readings for Each Participant to Determine Adaptation

Participants	Adapting	Nonadapting	Lowest Readings	R1	R2	R3	R4	R5
11001		*X*	*R3*	*48*	*51*	*46*	*54*	*50*
11003		*X*	*R4*	*1*	*1*	*2*	*0*	*1*
11006	*X*		*R4*	*12*	*10*	*9*	*4*	*9*
11007	*X*		*R5*	*72*	*59*	*52*	*54*	*44*
12004	*X*		*R2 and R4*	*8*	*1*	*2*	*1*	*2*
12005		*X*	*R1, R3, R4, R5*	*1*	*2*	*1*	*1*	*1*
12008	*X*		*R5*	*36*	*31*	*32*	*38*	*29*

Figure 2

Participants Across 5 Readings for Frequency of Stuttered Events



Group Data for Measurement Changes

Table 4 depicts the reductions that occurred from reading 1 to reading 5 across measures for each participant. In this adaptation study, four of seven participants (11006, 11007, 12004, and12008) demonstrated decreases in the frequency of stuttered events and could thus be labeled as undergoing the adaptation effect. Five out of seven participants (11001, 11007, 12004, and 12008) demonstrated decreases in the frequency of pause events. Six out of seven speakers (all except 12005) demonstrated decreases in overall time. Five out of seven speakers demonstrated decreases in pause time (11001, 11003, 11006, 12004, and 12008). Four out of seven speakers demonstrated decreases in disfluent speech (11007, 12004, 12005, and 12008). However, only three of the participants who experienced adaptation by the definition that uses the reduction of frequency of stuttered events also experienced a decrease in duration of total disfluent time. Six out of the seven speakers demonstrated decreases in fluent speech (all except 12005).

Table 4

Group Data for Measurement Decrease From Reading 1 to 5

Subjects	Frequency of Stuttered Events	Frequency of Pause Events	Overall Time	Fluent Time	Disfluent Time	Pause Time	Average Disfluency Time	Average Pause Time
11001		X	X	X		X		
11003			X	X		X		X
11006	X		X	X		X		X
11007	X	X	X	X	X		X	X
12004	X	X	X	X	X	X		X
12005					X		X	
12008	X	X	X	X	X	X	X	X

The Wilcoxon Signed Ranks Test, a non-parametric t-test, was also used to assess whether any of the measures demonstrated significant change for all of the participants (Wilcoxon, 1945). Assumptions for the Wilcoxon include that the data are paired and come from the same population, that each pair is chosen randomly and independently, and that the data are measured on an ordinal scale.

Analysis was conducted using the "classic" approach of reading 1 to reading 5. However, since each participant had variability on which reading they experienced the most reduction in stuttered events, reading 1 to the lowest readings was also conducted using the Wilcoxon Signed Ranks Test. Results are indicated in

Table 5. The hypothesis was supported for many measures using the Reading 1 to lowest calculations. Table 6 outlines the lowest readings for each participant across the measures. A high level of variability was noted regarding which reading was the lowest across participants and measures.

Results on the Wilcoxon Signed Ranks Test, shown in Table 5, indicate that the measures of overall time and fluent time exhibited significant decrease from reading 1 to reading 5. It also indicates that Frequency of stuttered events, overall time, fluent time, disfluent time, and pause time all indicated significant decrease from reading one to the lowest reading. Significant tests conducted had a moderate to large effect size as shown in Table 7. Figures 3-9 demonstrate graphical representations of the changes across measures across participants.

Table 5

Wilcoxon Signed Rank Test for Measures Across All Participants

Measures	**Significance of Reading 1 to 5**	**Significance of Reading 1 to Lowest**
Frequency of Stuttered Events	*.08*	*.027**
Frequency of Pause Events	*.310*	*.173*
Overall Time	*.028**	*.018**
Fluent Time	*.028**	*.018**
Disfluent Time	*.499*	*.018**
Pause Time	*.128*	*.028**
Average Disfluency Time	*.398*	*.018**
Average Pause Time	*.176*	*.028**

**Significance measured at $p \leq .05$*

Table 6

Lowest Readings Used on the Wilcoxon Signed Test

Measures	11001	11003	11006	11007	12004	12005	12008
Frequency of Stuttered Events	*Reading 3*	*Reading 4*	*Reading 4*	*Reading 5*	*Reading 2 and 4*	*Reading 1, 3,4, and 5*	*Reading 5*
Frequency of Pause Events	*Reading 2*	*Reading 3*	*Reading 2*	*Reading 1*	*Reading 5*	*Reading 2*	*Reading 4*
Overall Time	*Reading 2*	*Reading 4*	*Reading 4*	*Reading 5*	*Reading 5*	*Reading 2*	*Reading 5*
Fluent Time	*Reading 5*	*Reading 4*	*Reading 5*	*Reading 5*	*Reading 5*	*Reading 2*	*Reading 5*
Disfluent Time	*Reading 3*	*Reading 4*	*Reading 4*	*Reading 5*	*Reading 2*	*Reading 4*	*Reading 2*
Pause Time	*Reading 2*	*Reading 5*	*Reading 2*	*Reading 1*	*Reading 4*	*Reading 2*	*Reading 5*
Average Disfluency Time	*Reading 2*	*Reading 4*	*Reading 4*	*Reading 4*	*Reading 4*	*Reading 2*	*Reading 3*
Average Pause Time	*Reading 1*	*Reading 5*	*Reading 4*	*Reading 5*	*Reading 4*	*Reading 2*	*Reading 5*

Table 7

Effect Sizes (r=Z/√) for Wilcoxon Signed Rank Tests

Measure	1-5	1-Lowest
# Of disfluencies	*Not sig*	*.59*
# Of pauses	*Not sig*	*Not sig*
Overall time	*.59*	*.63*
Fluent time	*.59*	*.63*
Disfluent time	*Not sig*	*.63*
Pause time	*Not sig*	*.59*
Average Disfluency Time	*N/A*	*N/A*
Average Pause Time	*N/A*	*N/A*

Figure 3

Participants Across 5 Readings for Frequency of Pause Events

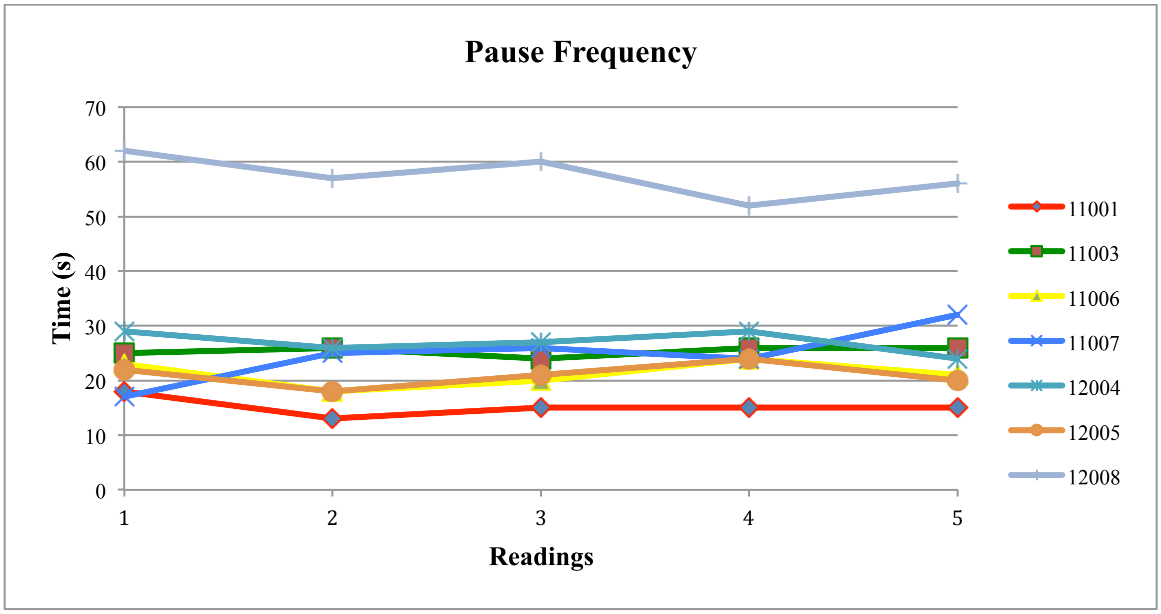


Figure 4

Participants Across 5 Readings for Overall Time

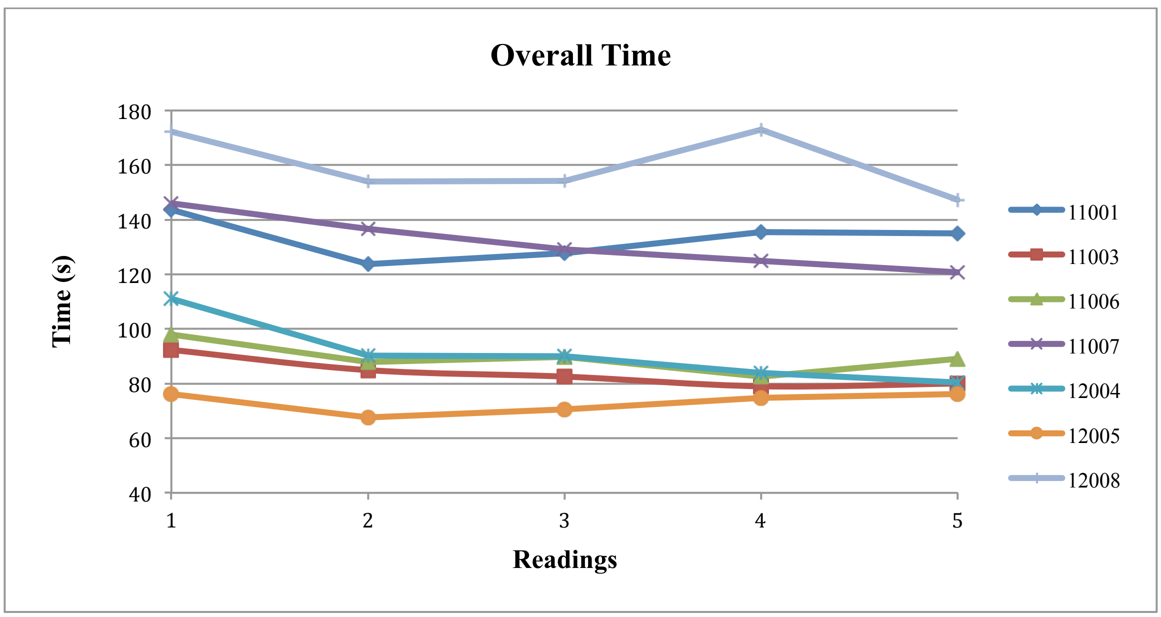


Figure 5

Participants Across 5 Readings for Disfluent Time

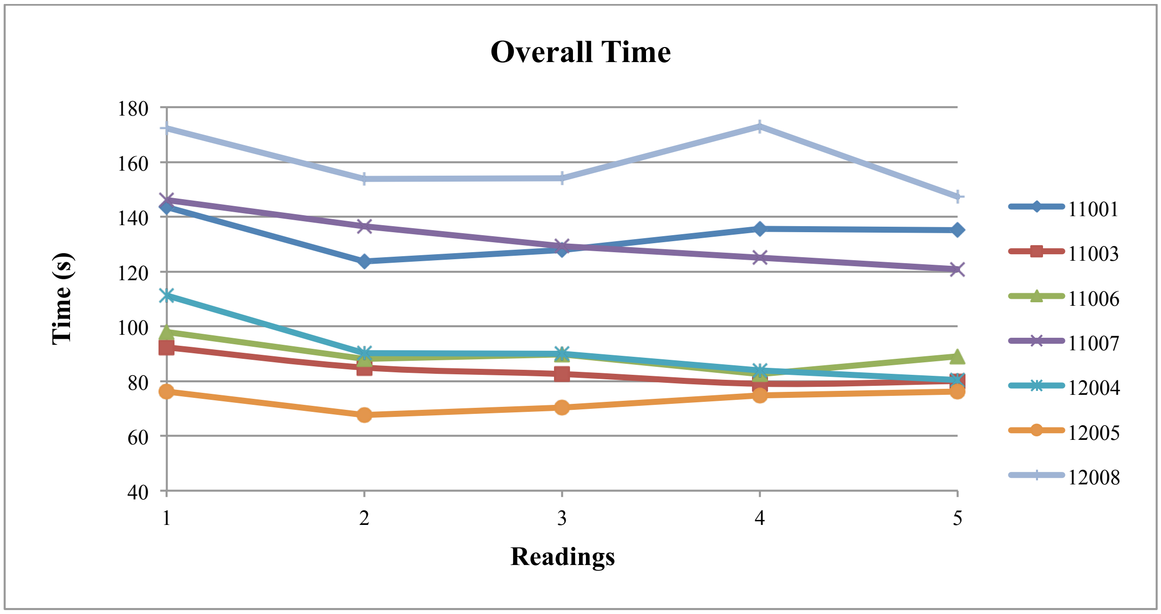


Figure 6

Participants Across 5 Readings for Fluent Time

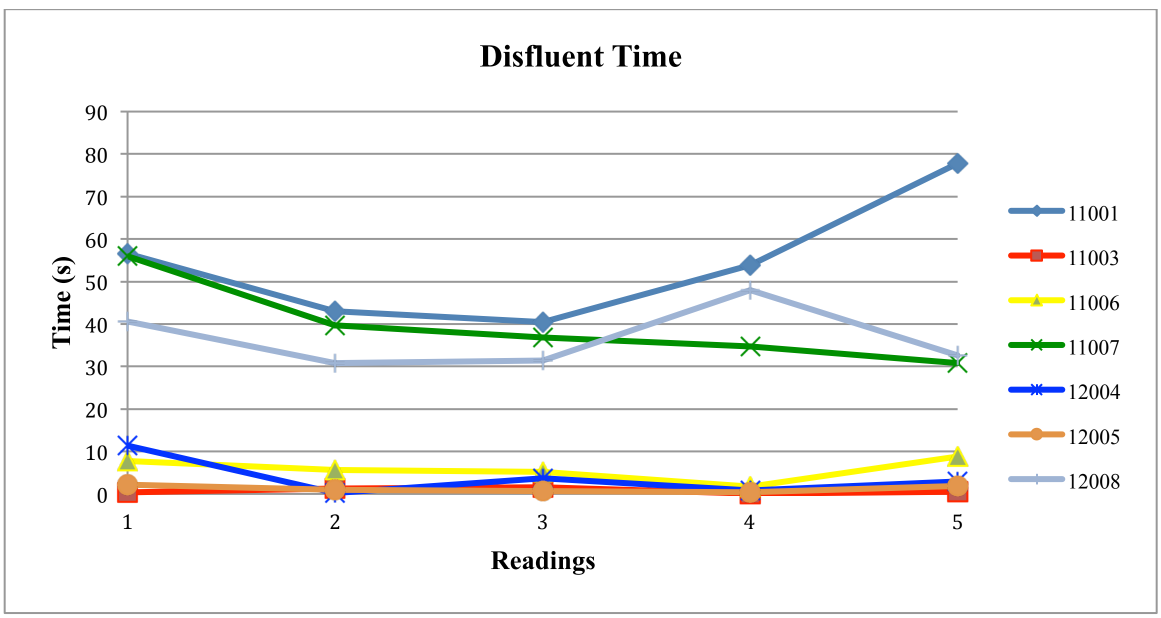


Figure 7

Participants Across 5 Readings for Pause Time

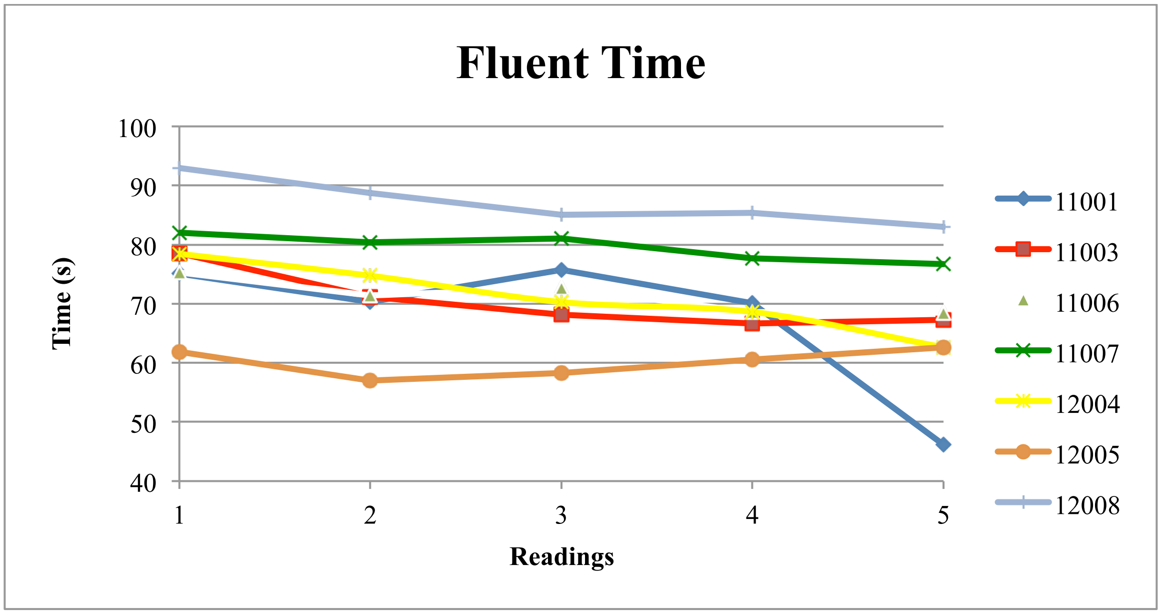


Figure 8

Participants Across 5 Readings for Average Pause Duration

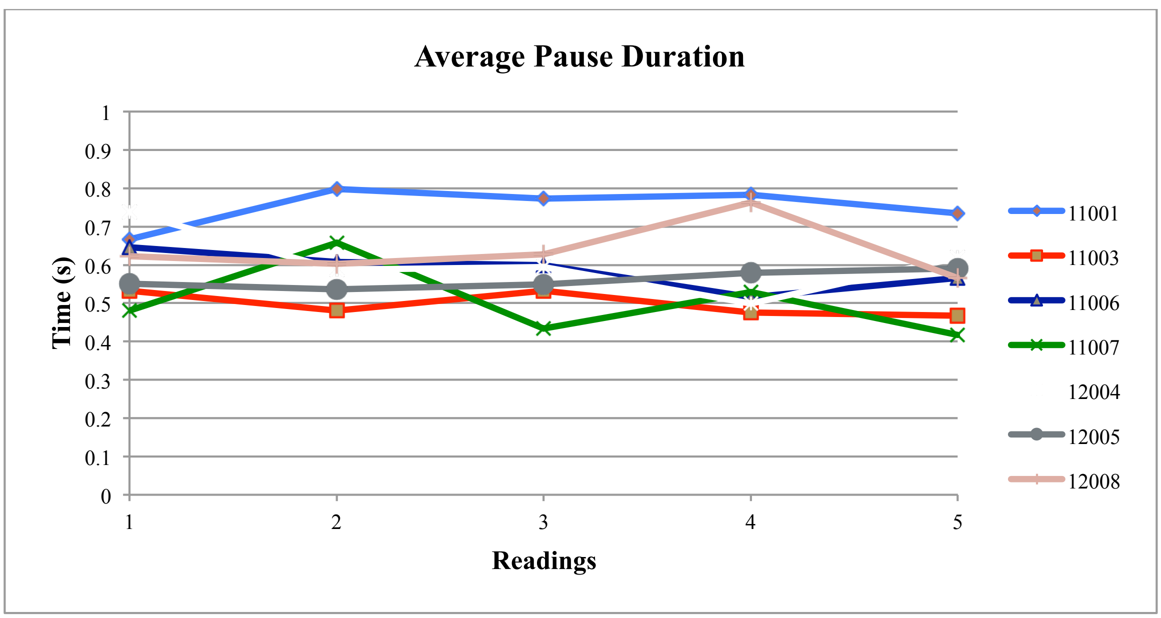
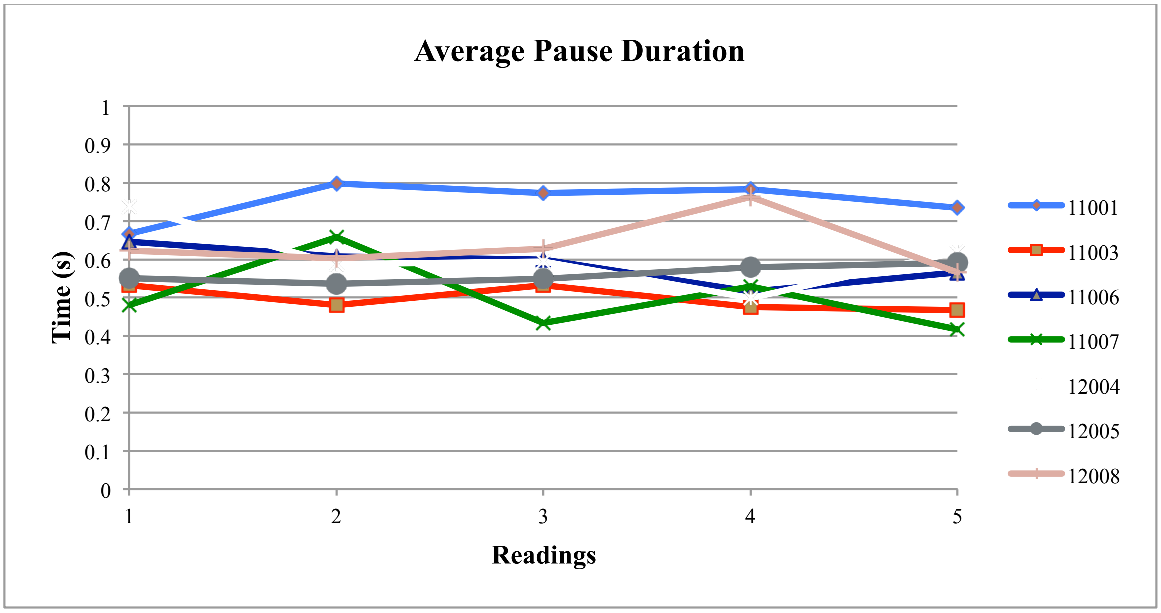


Figure 9

Participants Across 5 Readings for Average Disfluency Duration



Reading Passage Duration Summary by Participant

Participant 11001. Participant 11001 had a severity rating of *severe.* Participant did not demonstrate adaptation in terms of frequency of stuttered events as shown by an increase from 48 disfluencies in reading 1 to 50 disfluencies in reading 5. Participant did experience a decrease in pause events from 18 in reading 1 to 15 in reading 5, a decrease in overall time from 143.619s in reading 1 to 135.012s in reading 5, a decrease in fluent time from 75.082s in reading 1 to 46.149s in reading 5, and an increase in disfluent time from 56.546s in reading 1 to 77.859s in reading 5. Participant demonstrated an increase in frequency of disfluent events and disfluent time from reading 1 to 5. Table 8 outlines acoustic data for Participant 11001. Figure 10 shows general trends regarding each category of measurement.

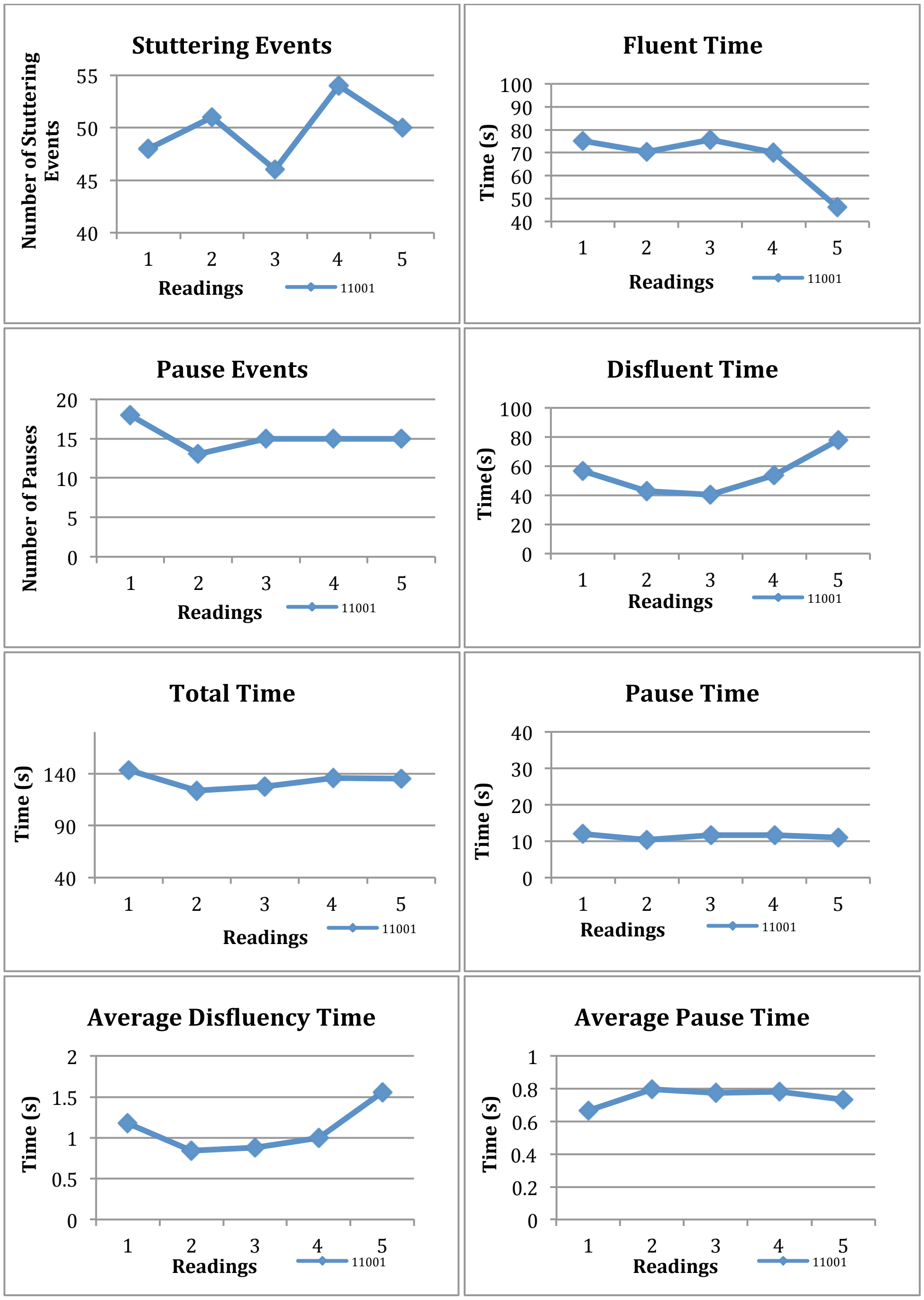
Table 8

Participant 11001 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*48*	*51*	*46*	*54*	*50*	*.042*	*-.042*
Pause Events	*18*	*13*	*15*	*15*	*15*	*-.167*	*-.278*
Overall Time	*143.619*	*123.689*	*127.81*	*135.568*	*135.021*	*-.060*	*-.139*
Fluent Time	*75.082*	*70.357*	*75.774*	*70.058*	*46.149*	*-.385*	*.009*
Disfluent Time	*56.536*	*42.954*	*40.442*	*53.774*	*77.859*	*.377*	*-.284*
Pause Time	*12.001*	*10.378*	*11.594*	*11.736*	*11.013*	*-.082*	*-.034*
Average Disfluency Time	*1.178*	*,842*	*.879*	*.996*	*1.557*	-	-
Average Pause Time	*.667*	*.798*	*.773*	*.782*	*.734*	-	-

Figure 10

Participant 11001 Measurement Trends



Participant 11003. Participant 11003 had a severity rating of *very mild.* Participant did not demonstrate adaptation in terms of frequency of disfluent events from 1 disfluency in reading 1 to 1 disfluency in reading 5. Participant experience an increase in pause events from 25 in reading 1 to 26 in reading 5, a decrease in overall time from 92.305s in reading 1 to 80.026 in reading 5, a decrease in fluent time from 75.552s in reading 1 to 67.329s in reading 5, and a decrease in disfluent time .441 in reading 1 to .547s in reading 5. Participant demonstrated no change in frequency of disfluent events and an increase in disfluent time from reading 1 to 5. Table 9 outlines acoustic data for Participant 11003. Figure 11 shows general trends regarding each category of measurement.

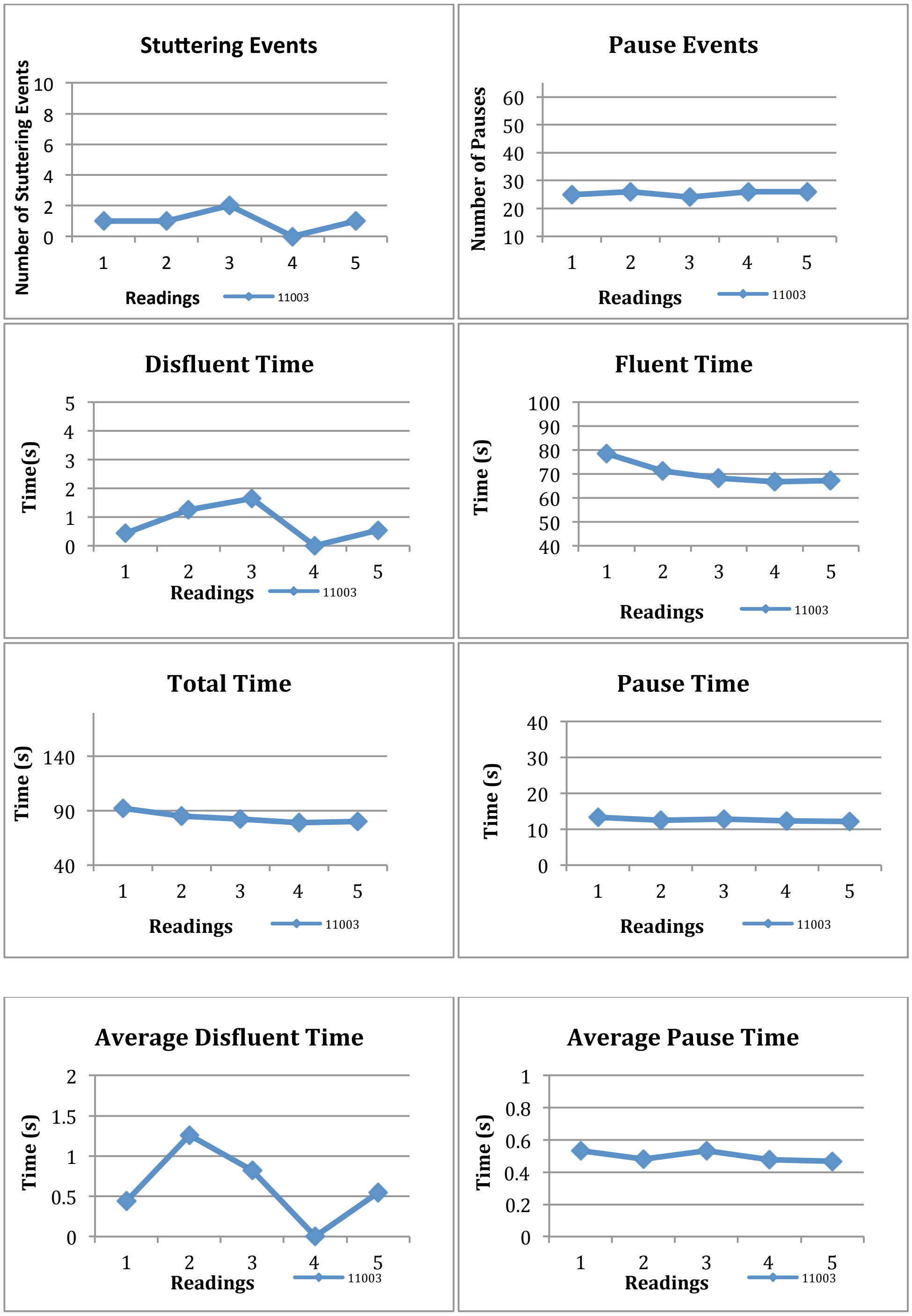
Table 9

Participant 11003 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*1*	*1*	*2*	*0*	*1*	*0*	*-1*
Pause Events	*25*	*26*	*24*	*26*	*26*	*.04*	*-.04*
Overall Time	*92.305*	*84.945*	*82.566*	*79.02*	*80.026*	*-.133*	*-.144*
Fluent Time	*78.552*	*71.184*	*68.17*	*66.66*	*67.329*	*-.143*	*-.151*
Disfluent Time	*.441*	*1.259*	*1.636*	*0*	*.547*	*.240*	*-1*
Pause Time	*13.312*	*12.502*	*12.76*	*12.36*	*12.150*	*-.087*	*-.072*
Average Disfluency Time	*.441*	*1.259*	*.818*	*0*	*.547*	-	-
Average Pause Time	*.532*	*.481*	*.532*	*.475*	*.467*	-	-

Figure 11

Participant 11003 Measurement Trends



Participant 11006. Participant 11006 had a severity rating of *mild.* Participant did demonstrate adaptation in terms of frequency of stuttered 12 disfluencies in reading 1 to 9 disfluencies in reading 5. Participant did experience a decrease in pause events from 23 in reading 1 to 21 in reading 5, a decrease in overall time from 98.004s in reading 1 to 89.135 in reading 5, a decrease in fluent time from 75.332s in reading 1 to 68.449s in reading 5, and an increase in disfluent time from 7.815s in reading 1 to 8.767s in reading 5. Participant did experience a decrease in a decrease in pause events, overall time, fluent time, and pause time. Participant demonstrated an increase in disfluent time from reading 1 to 5. Table 10 outlines acoustic data for Participant 11006. Figure 12 shows general trends regarding each category of measurement.

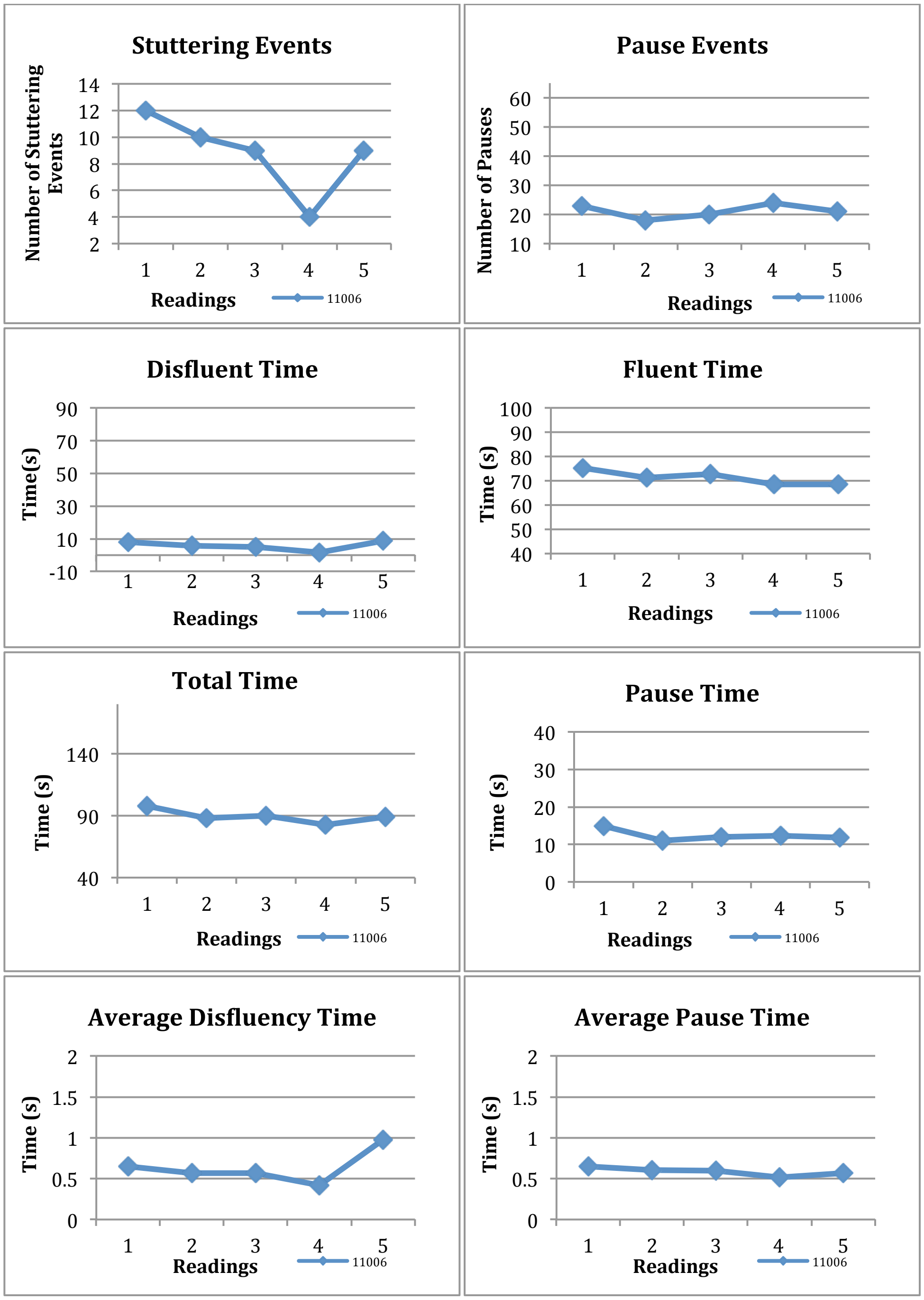
Table 10

Participant 11006 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*12*	*10*	*9*	*4*	*9*	*-.25*	*-.667*
Pause Events	*23*	*18*	*20*	*24*	*21*	*-.087*	*-.217*
Overall Time	*98.004*	*88.007*	*89.8*	*82.562*	*89.135*	*-.090*	*-.158*
Fluent Time	*75.332*	*71.38*	*72.697*	*68.536*	*68.49*	*-.091*	*-.09*
Disfluent Time	*7.815*	*5.687*	*5.131*	*1.665*	*8.767*	*.122*	*-.787*
Pause Time	*14.857*	*10.94*	*11.977*	*12.361*	*11.878*	*-.201*	*-.168*
Average Disfluency Time	*.651*	*.569*	*.570*	*.416*	*.974*	-	-
Average Pause Time	*.646*	*.608*	*.599*	*.515*	*.566*	-	-

Figure 12

Participant 11006 Measurement Trends



Participant 11007. Participant 11007 had a severity rating of *very severe.* Participant did demonstrate adaptation in terms of frequency of stuttered events with a decrease of 72 disfluencies in reading 1 to 44 disfluencies in reading 5. Participant did experience an increase in pause events from 17 in reading 1 to 32 in reading 5, a decrease in overall time from 146.129s in reading 1 to 120.761s in reading 5, a decrease in fluent time from 81.983s in reading 1 to 76.764s in reading 5, and a decrease in disfluent time from 55.983s in reading 1 to 730.751 in reading 5. Participant did experience a decrease in a decrease in, overall time, fluent time, and disfluent time. Participant demonstrated an increase in pause events and pause time from reading 1 to 5. Table 11 outlines acoustic data for Participant 11007. Figure 13 shows general trends regarding each category of measurement.

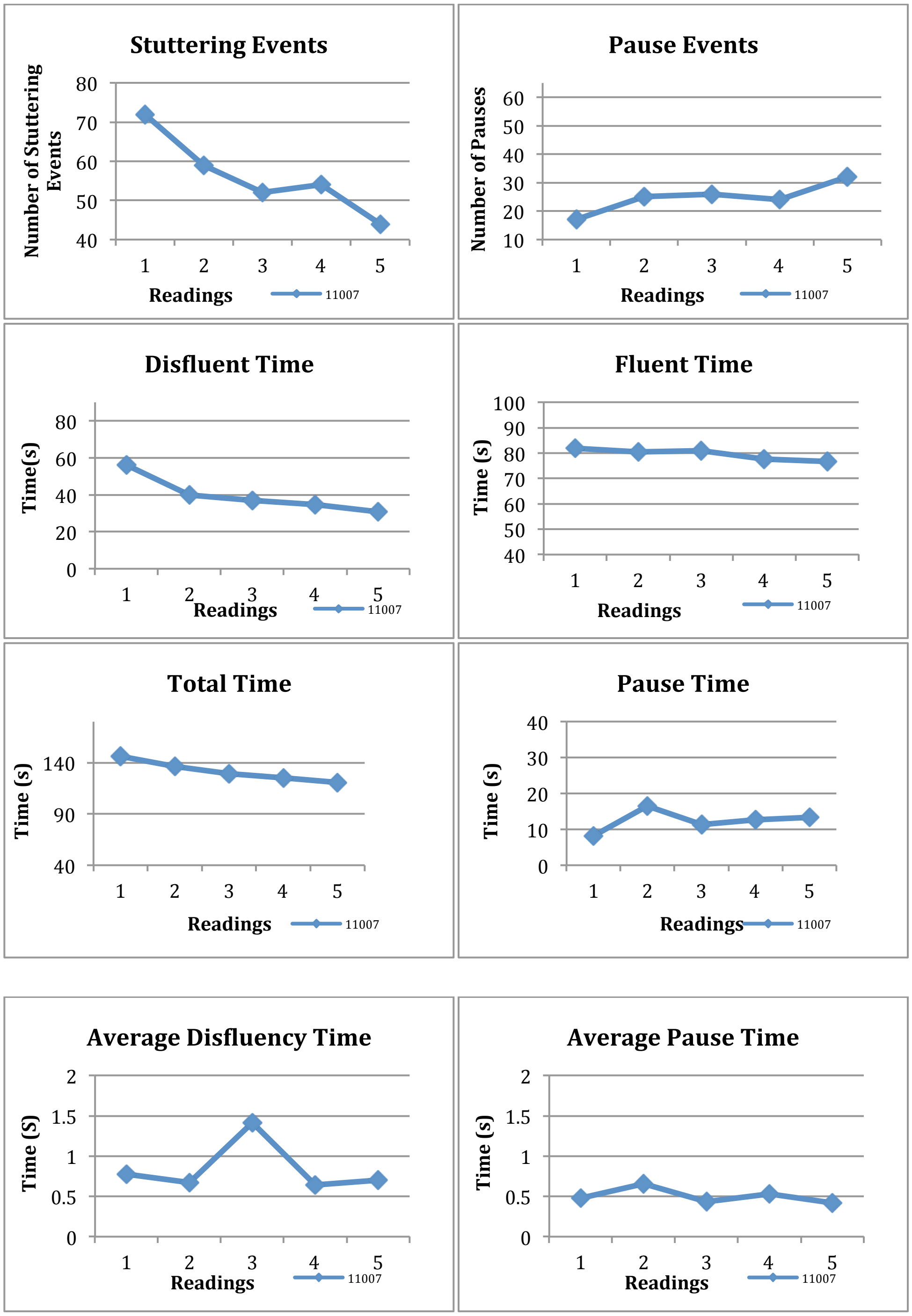
Table 11

Participant 11007 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*72*	*59*	*52*	*54*	*44*	*-.389*	*-.389*
Pause Events	*17*	*25*	*26*	*24*	*32*	*.882*	*.882*
Overall Time	*146.129*	*135.57*	*129.17*	*124.988*	*120.761*	*-.174*	*-.174*
Fluent Time	*81.983*	*80.388*	*81.056*	*77.644*	*76.674*	*-.065*	*-.065*
Disfluent Time	*55.983*	*39.772*	*36.832*	*34.657*	*30.751*	*-.451*	*-.451*
Pause Time	*8.163*	*16.46*	*11.282*	*12.687*	*13.336*	*.634*	*.634*
Average Disfluency Time	*.778*	*.673*	*1.412*	*.642*	*.699*	-	-
Average Pause Time	*.480*	*.658*	*.434*	*.529*	*.417*	-	-

Figure 13

Participant 11007 Measurement Trends



Participant 12004. Participant 12004 had a severity rating of *mild.* Participant did demonstrate adaptation in terms of frequency of stuttered events with a decrease from 8 disfluencies in reading 1 to 50 disfluencies in reading 5. Participant did experience a decrease in pause events from 29 in reading 1 to 24 in reading 5, a decrease in overall time from 111.162 in reading 1 to 80.37 in reading 5, a decrease in fluent time from 81.983 in reading 1 to 76.674 in reading 5, and a decrease in disfluent time from 11.344s in reading 1 to 2.859 in reading 5. Participant does not display an appropriate amount of disfluencies to conduct word level analysis. Participant did experience a decrease in pause events, overall time, fluent time, disfluent time, and pause time. Table 12 outlines acoustic data for Participant 12004. Figure 14 shows general trends regarding each category of measurement.

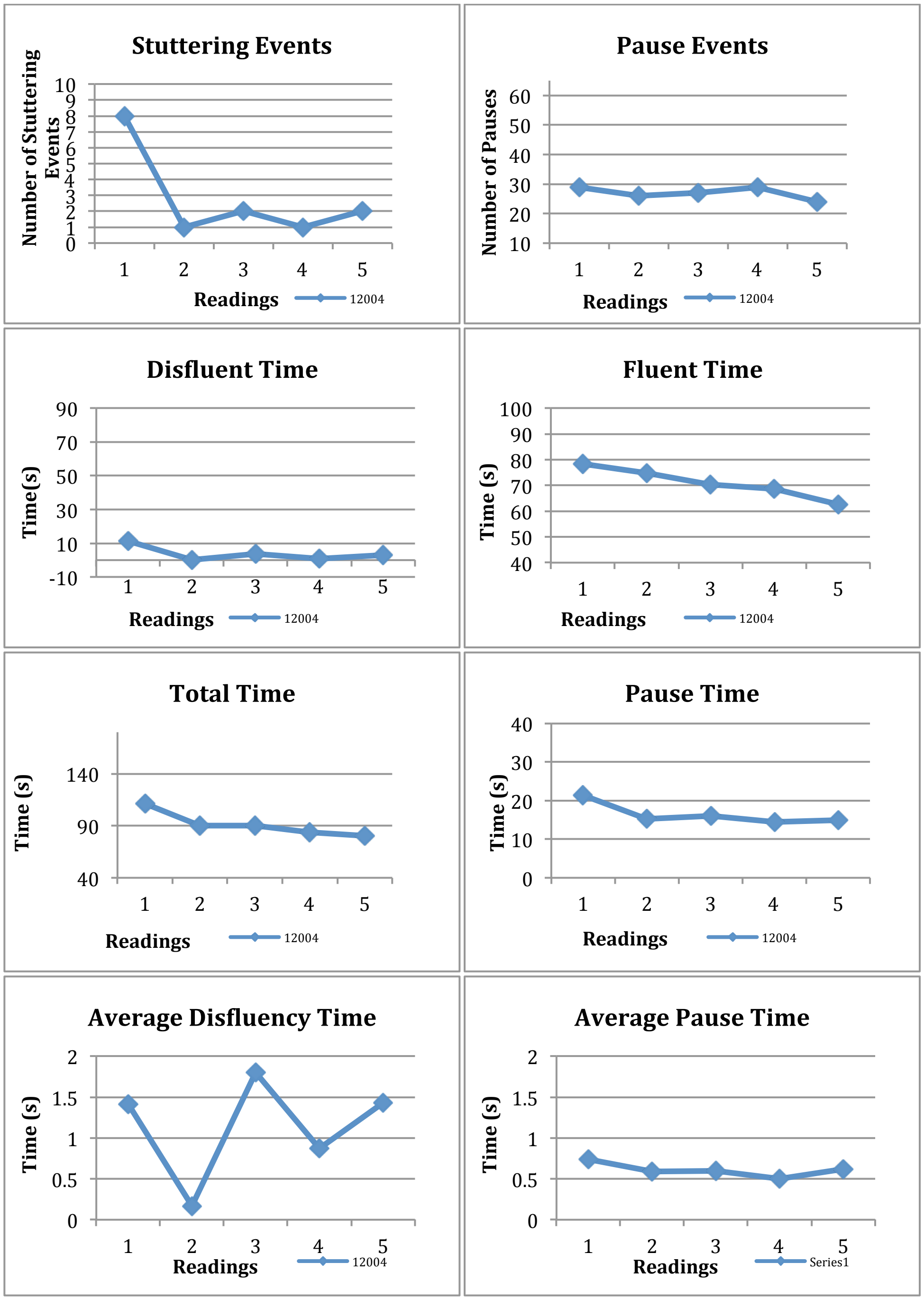
Table 12

Participant 12004 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*8*	*1*	*2*	*1*	*2*	*-.75*	*-.875*
Pause Events	*29*	*26*	*27*	*29*	*24*	*-.172*	*-.172*
Overall Time	*111.162*	*90.16*	*89.934*	*89.934*	*80.37*	*-.277*	*-.277*
Fluent Time	*81.983*	*80.388*	*81.056*	*77.644*	*76.674*	*-.065*	*-.065*
Disfluent Time	*11.344*	*.169*	*3.609*	*.871*	*2.859*	*-.748*	*-.985*
Pause Time	*21.416*	*15.261*	*16.052*	*14.456*	*14.876*	*-.305*	*-.287*
Average Disfluency Time	*1.418*	*.169*	*1.805*	*.871*	*1.43*	-	-
Average Pause Time	*.738*	*.587*	*.595*	*.498*	*.62*	-	-

Figure 14

Participant 12004 Measurement Trends



Participant 12005. Participant 12005 had a severity rating of *very mild.* Participant did demonstrate adaptation in terms of frequency of stuttered events with no change in number of disfluencies from reading 1 to reading 5. Participant did experience a decrease in pause events from 22 in reading 1 to 20 in reading 5, an increase in overall time from 76.098s in reading 1 to 76.265 in reading 5, an increase in fluent time from 61.869s in reading 1 to 62.585s in reading 5, and a decrease in disfluent time from 2.099s in reading 1 to 1.875 in reading 5.

Participant did experience a decrease in a decrease in pause events, disfluent time, and pause time. Participant demonstrated an increase in overall time and fluent time. Table 13 outlines acoustic data for Participant 12005. Figure 15 shows general trends regarding each category of measurement.

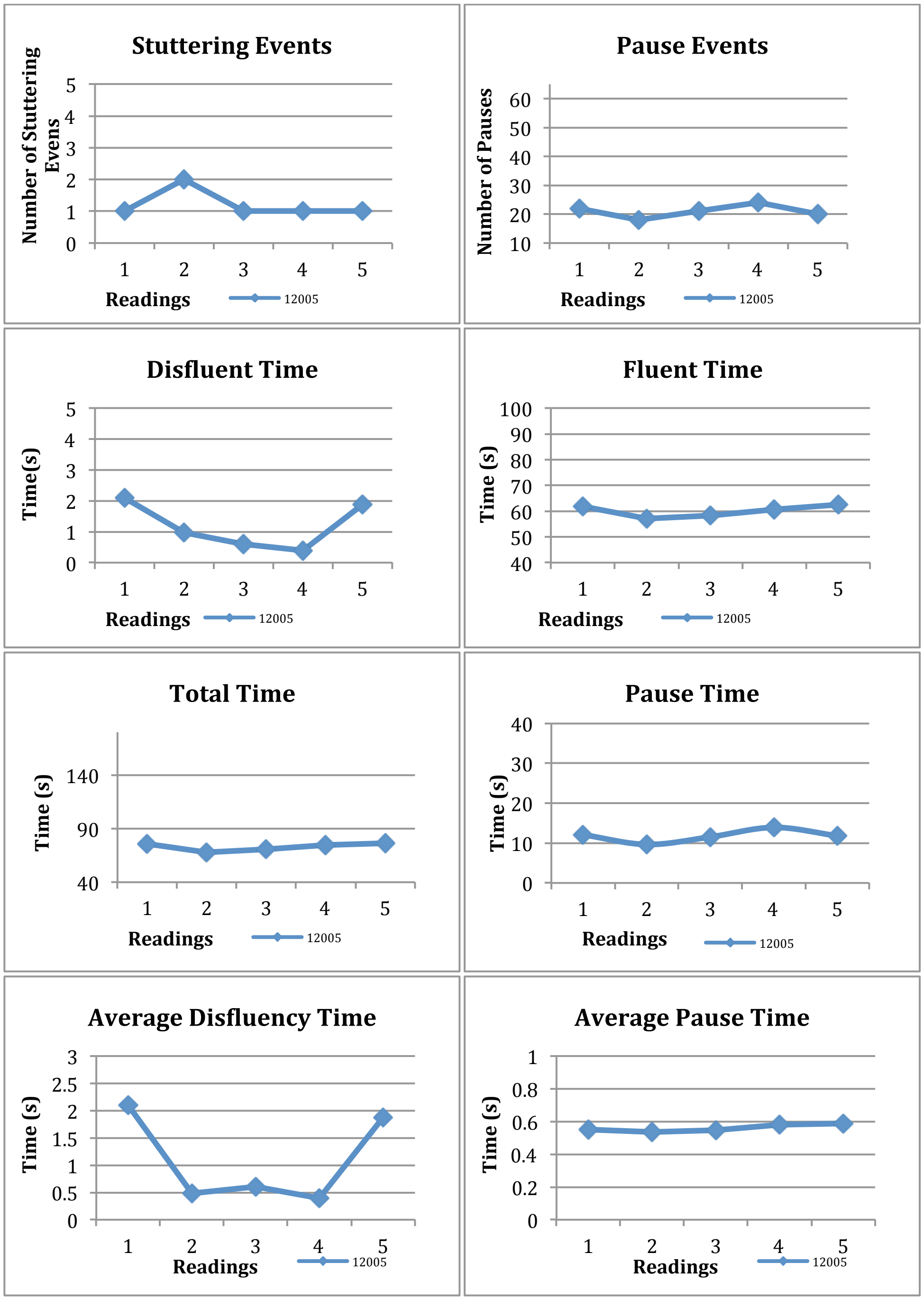
Table 13

Participant 12005 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*1*	*2*	*1*	*1*	*1*	*0*	*0*
Pause Events	*22*	*18*	*21*	*24*	*20*	*-.091*	*-.182*
Overall Time	*76.098*	*67.623*	*70.448*	*74.88*	*76.265*	*.002*	*-.111*
Fluent Time	*61.869*	*57.008*	*58.319*	*60.572*	*62.585*	*.012*	*-.057*
Disfluent Time	*2.099*	*.965*	*.603*	*.393*	*1.875*	*-.107*	*-.713*
Pause Time	*12.13*	*9.65*	*11.526*	*13.915*	*11.805*	*-.027*	*-.05*
Average Disfluency Time	*2.099*	*.483*	*.603*	*.393*	*1.875*	-	-
Average Pause Time	*.551*	*.536*	*.549*	*.58*	*.59*	-	-

Figure 15

Participant 12005 Measurement Trends



Participant 12008. Participant 12008 had a severity rating of *very severe.* Participant did demonstrate adaptation in terms of frequency of stuttered events with a decrease from 36 disfluencies in reading 1 to 29 disfluencies in reading 5. Participant did experience a decrease in pause events from 62 in reading 1 to 56 in reading 5, a decrease in overall time from 172.179s in reading 1 to 147.308s in reading 5, a decrease in fluent time from 92.971s in reading 1 to 83.008s in reading 5, and a decrease in disfluent time from 40.576s in reading 1 to 32.626s in reading 5.

Participant did demonstrate adaptation in terms of frequency of disfluent events from reading 1 to reading 5. Participant did experience a decrease in a decrease in pause events, overall time, disfluent time, fluent time, and pause time. Table 14 outlines acoustic data for Participant 12008. Figure 16 shows general trends regarding each category of measurement.

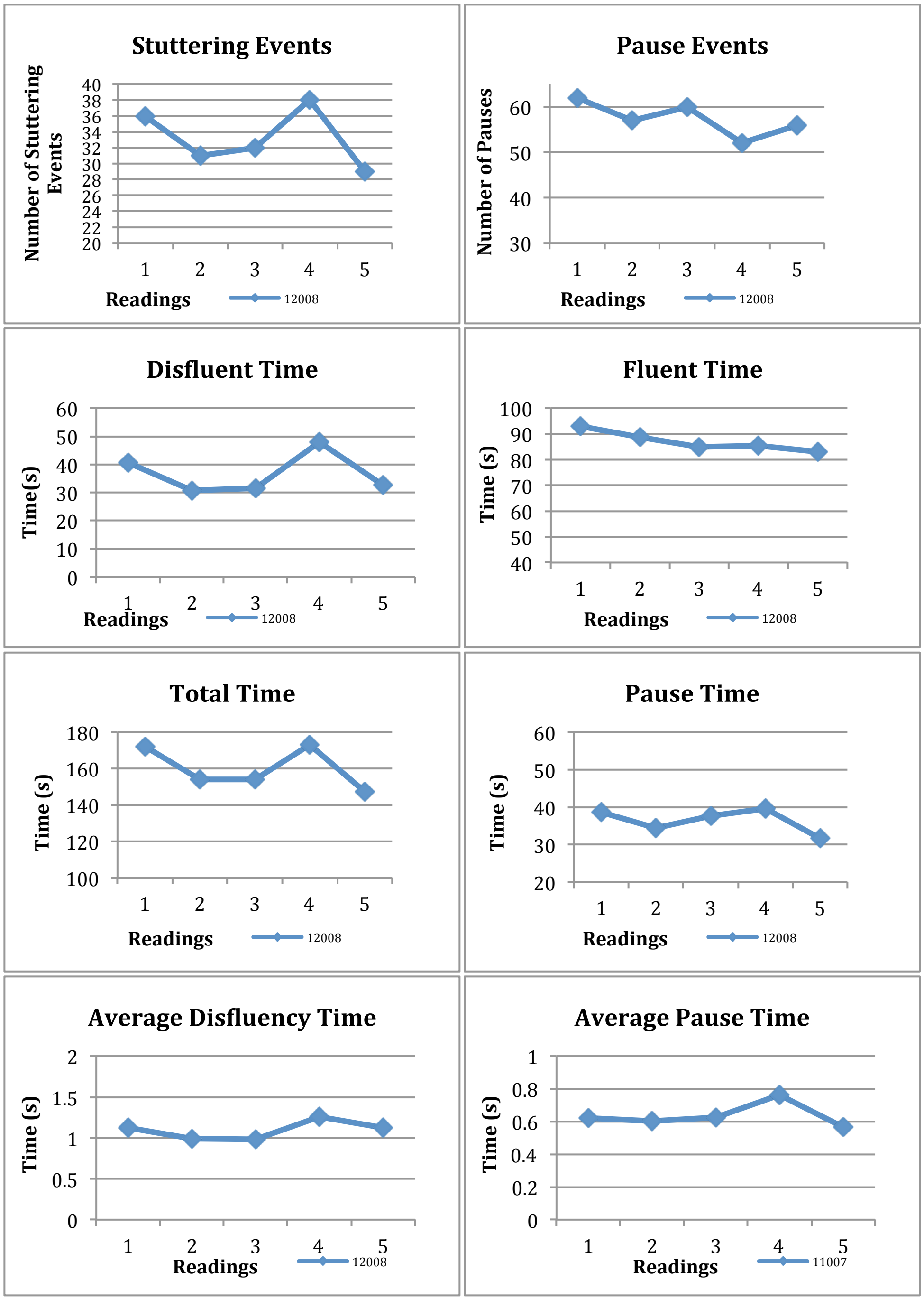
Table 14

Participant 12008 Data Summary

	Reading 1	Reading 2	Reading 3	Reading 4	Reading 5	%Change from R1 to R5	%Change from R1 to Lowest
Disfluent Events	*36*	*31*	*32*	*38*	*29*	*-.194*	*-.194*
Pause Events	*62*	*57*	*60*	*52*	*56*	*-.097*	*-.161*
Overall Time	*172.179*	*153.883*	*154.153*	*273.032*	*147.308*	*-.144*	*-.144*
Fluent Time	*92.971*	*88.766*	*85.069*	*85.408*	*83.008*	*-.107*	*-.057*
Disfluent Time	*40.576*	*30.747*	*31.464*	*47.941*	*32.626*	*-.196*	*-.196*
Pause Time	*38.632*	*34.37*	*37.627*	*39.683*	*31.674*	*-.180*	*-.180*
Average Disfluency Time	*1.127*	*.992*	*.983*	*1.262*	*1.125*	-	-
Average Pause Time	*.623*	*.603*	*.627*	*.763*	*.566*	-	-

Figure 16

Participant 12008 Measurement Trends



Word Analysis

A more detailed duration analysis of several words was conducted to examine changes in disfluent speech within words for adapting participants. Word analysis was conducted on all adapting participants and the nonadapting Participant 11001. Only four participants fit the criteria for adaptation by exhibiting a decrease in frequency of stuttered events from reading 1 to reading 5. Participants who fit the criteria included 11006, 11007, 12004, and 12008. Participant 12004 did not present with adequate disfluencies to conduct a word analysis on consistently stuttered speech across the five readings. Participant 11001 was included due to the high frequency of their stuttered events.

The word analysis targeted ten words that were consistently stuttered across the five readings. Each participant had a different set of ten words that they consistently stuttered on. Words were measured for overall word duration, disfluency duration, vocalic segment duration, and consonant segment duration. Vowel and consonant segments were the within word fluent phonemes. This analysis was conducted as a descriptive analysis of acoustic changes at the word level and to determine whether disfluencies, although they might persist, followed the hypothesized pattern of change and became shorter in duration with successive readings. Graphical representations of the word changes from readings one to five are presented in Appendix B for all analyzed words.

Some participants did not exhibit stuttering on ten words across all five readings. In these cases, disfluencies were analyzed for words consistently stuttered across 4, 3, and 2 readings. Standard deviations were totaled for each participant on the target words to find the variability of fluent and disfluent speech for each participant at the word level as seen in Table 15. Because such high variability was exhibited across the measures for each participant, variability at the word level between fluent and disfluent segments was conducted to assess any patterns. There was greater variability in disfluent speech for participants 11001, 11006, 11007, and 12008. Participant 11006 only had two words analyzed due to their small number of disfluencies consistently stuttered and the presence of frequent phrase repetitions overlapping with their disfluencies.

Table 15

Standard Deviation in Disfluent/ Fluent Speech Segments

Participants	**Fluent**	**Disfluent**
11001	*.037*	*.363*
11006	*.021*	*.042*
11007	*.052*	*.239*
12008	*.021*	*.467*
Average	*.031*	*.249*

Within each participant, a one way repeated measure nonparametric analysis of variance, the Friedman test, was conducted across time for ten words. The Friedman test was used to determine if significant change occurred for total word duration and disfluency duration across readings within participants. The hypothesis was that across readings, significant change would occur for both measures as speech normalized. Results could not be reported for participant 11006 due to the small sample of words. Participant 11001 was also analyzed; however, this participant was not an adapting participant. The only test that yielded significance was disfluency duration analysis for Participant 11007. Analysis of the data for this subject did show a general trend in the decrease of duration data for disfluencies within this participant. Sample size is too small to make any definitive statements on the patterns of disfluency and total word duration change; however, disfluencies were noted to be highly variable compared to the more stable fluent phonemes that followed them.

Table 16

Friedman Test Results for Each Participant

Participant	Test	Significance Level of Total Word	Significance Level of Disfluency
11001	Friedman	*.927*	*.3*
11006	Friedman	-	-
11007	Friedman	*.086*	*.046**
12008	Friedman	*.406*	*.077*

**Significance measured at p≤.05*

DISCUSSION

Results of the current study provide some support for the hypothesis that disfluent behavior changes from reading to reading during the adaptation paradigm. Specifically, disfluencies became shorter in duration and approach fluency, although they may persist through several successive readings. Acoustical analysis was conducted across many measures at both the reading and word level to assess change in duration of disfluent and fluent phonemic portions of words.

Group Data

Four participants exhibited adaptation in terms of frequency of stuttered events: participants 11006, 1007, 12004, and 12008. Participants 11007, 12004, and 12005 also experienced a reduction in total disfluent time. This could be considered potential descriptive evidence for the hypothesis that disfluencies become shorter in duration as the PWS approaches fluency. However, decrease in total disfluent time could also be a result of fewer disfluencies rather than gradual normalization of consistently stuttered words. Because of the contrast between disfluent speech increasing and frequency of stuttering events decreasing for participant 11006, we might begin to question the validity of using frequency of stuttering events to define adaptation.

The hypothesis was confirmed by some of the group data analysis. By using reading 1 to the lowest reading as opposed to the classic method of reading 1 to 5, significant decreases were found for the majority of measures. Using the classic method, significant reduction only occurred for the measures of fluent and overall time. Comparing reading 1 to the lowest reading, significant decreases were found for frequency of stuttered events, overall time, fluent time, disfluent time, pause time, average disfluency time, and average pause time. This is likely due to the fact that during adaptation, most reductions in disfluency tend to occur by the second reading (Bloodstein, 1995). So, across both adapting and nonadapting participants, the fifth reading was not necessarily the reading by which the most change occurred. In an adapting subject, reading 5 was always lower than reading 1; however, readings 2,3, or 4 could still contain a larger decrease than in reading 5, but the participant would still be labeled adapting as long as reading 5 was less than reading 1. So, the adaptation effect may not always account for the nonlinear variability that can occur across readings. The PWS does experience a decrease in disfluent behavior from reading 1 to the lowest reading; however, disfluencies are not necessarily gradually shortening in duration, normalizing in complexity, and approaching fluency as predicted.

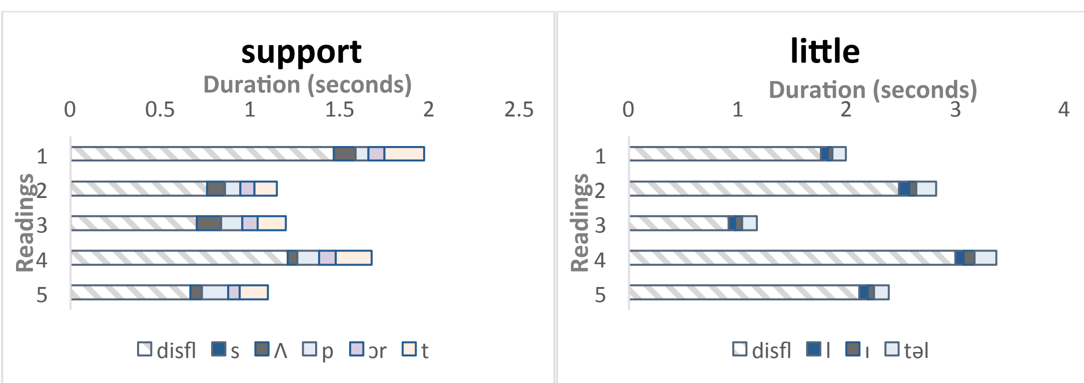
Word Analysis

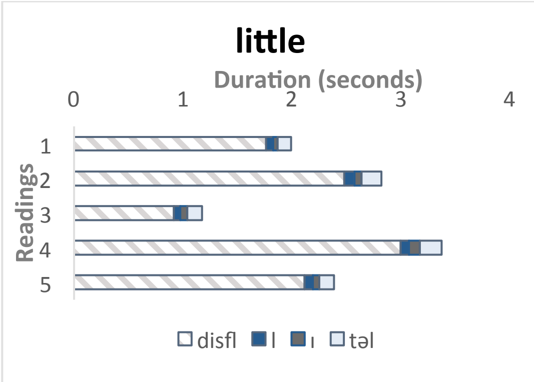
Word analysis was conducted for the adapting participants 11006, 11007, and 12008. Participant 12004 did not have enough disfluencies to conduct a thorough word level analysis. Participant 11001, although not an adapting subject, was also included due to the high frequency of their stuttered events. The goal was to select ten words that were consistently stuttered across the five readings and determine if change occurred at the word level in the direction of normalization. Word analysis using the Friedman test did not yield significant results regarding change in disfluencies or total word duration within participants. Disfluent segment duration for participant 11007 was the only instance of significant change. So, the null hypothesis that change did not occur, could not be rejected for total word time and most disfluency durations.

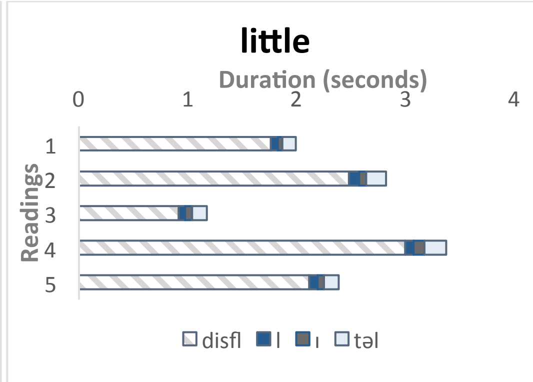
A descriptive finding analyzing variability using standard deviation, found that disfluent segments had higher variability than the following fluent phoneme segments within participants. The disfluent segments were described as "islands of instability" compared to their fluent counterparts. This has some implications as to the volatile nature of stuttered speech. This calculation in conjunction with the lack of significant change for disfluent segments may indicate that disfluencies are highly variable and erratic in their change, which does not align with our hypothesized findings. Figure 17 highlights this instability for Participant 12008.

Figure 17

Example Word Analysis for Participant 12008 to Highlight Variability







Although we did not find any statistically profound patterns at the word analysis level, descriptive findings for the variability in disfluent segments compared to the following fluent phonemic segments are promising with regards to the moment of stuttering. We can say that the variability of the disfluent segment compared to the relatively static fluent surrounding has implications for execution vs. motor planning. It implies that the motor planning is intact because the fluent phonemes are being carried out effectively; however, something may be occurring at the level of execution which is resulting in a fluctuating disfluency.

Variability

Across the participants, there was variability with regards to the complexity and duration of stuttered behavior, adaptation, and the number of disfluencies. Acoustical analysis practices were standardized as much as possible; however, individualization for each PWS had to be made due to the variation in their disfluent productions. Not all participants experienced adaptation and some participants had a limited amount of stuttered events.

Previous Research

A wealth of research exists relating stuttering to motor learning. Based on the current findings, we are in agreement with Venkatagiri (2013). Adapting speakers did not demonstrate consistency with regard to the gradual reduction and normalization of disfluencies from reading 1 to 5. Words were not consistently stuttered and disfluent segments fluctuated erratically. So, we believe motor learning cannot explain adaptation during stuttering. Motor learning may apply to fluent speech, which significantly decreased across the group data, however it does not apply to the disfluent speech in this study.

Clinical Implications

Although there was some evidence for normalization of stuttering during adaptation, it was overall not significant enough to make claims regarding clinical practice. The process and findings do reiterate one important point that could be useful for clinical thinking. On an acoustical analysis level, PWS exhibit a wide range of variability with regards to how their stuttering presents. Acoustical analysis frequently had to be adjusted to the individual and their behavior and defined using a modified set of rules. Seeing this variability between PWS is a reminder that treatment should be individualized according to the person.

Limitations

Several factors limit the interpretation of this study. First, the limited number of participants and the variability with regards to severity, gender, and age made it challenging to identify patterns of change. With such a disparity in attributes between speakers, patterns or lack of patterns could be due to differences between participants rather than a commonality of diagnosis.

Second, this study had a small sample size that was further diminished by the number of speakers who actually experienced adaptation. Small sample size made it challenging to utilize statistical analysis between subjects.

Lastly, acoustical analysis was challenging to standardize due to the variety of stuttering behaviors shown in both the audio recording and the videos. Each speaker had unique articulatory patterns, compensation for errors, and disfluent behavior that made it challenging to apply the same measurements across different speakers.

Directions of Future Research

Future research should examine the "islands of instability" exemplified during our word analysis by the disfluent segments. Research could focus on a larger sample size of PWS who exhibit consistent stuttering on at least ten words. Acoustical analysis could be expanded to look at the fluent segments before and after the disfluency, continuing to use standard deviation as a measure of variability. Analyzing disfluencies at the word level more thoroughly using articulatory and phonatory measures could be useful to describe whether the disfluency simplifies according to means other than duration. Future research may continue to look for patterns of change during stuttered speech. Controlling for variables such as severity and having a larger sample size could yield less contradictory results and make the identification of patterns more likely.

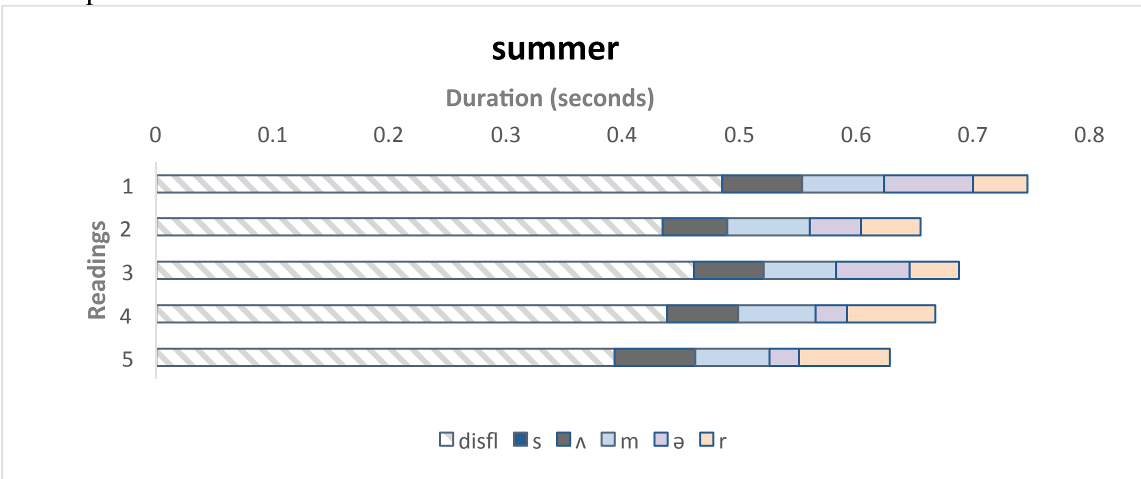
In conclusion, this study did find some data to support the hypothesis that disfluent behavior changes from reading to reading during the adaptation effect and that disfluencies will become shorter in duration and approach fluency, although they may persist. Analysis of group data across each measure showed that from reading 1 to the lowest reading, all measures except pause frequency had significant reduction. Other findings that support this hypothesis include the significance of disfluency duration decrease across readings for subject 11007 during word analysis. However, the most interesting finding is between disfluent and fluent segments at the word level. Variability across readings for disfluent segments implies a connection to the moment stuttering.

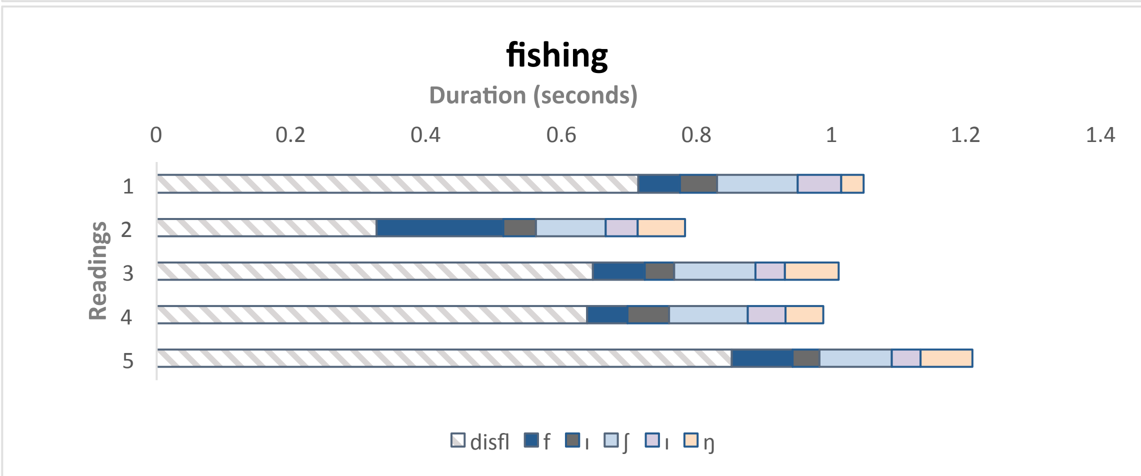
APPENDIX A. Reading Passage

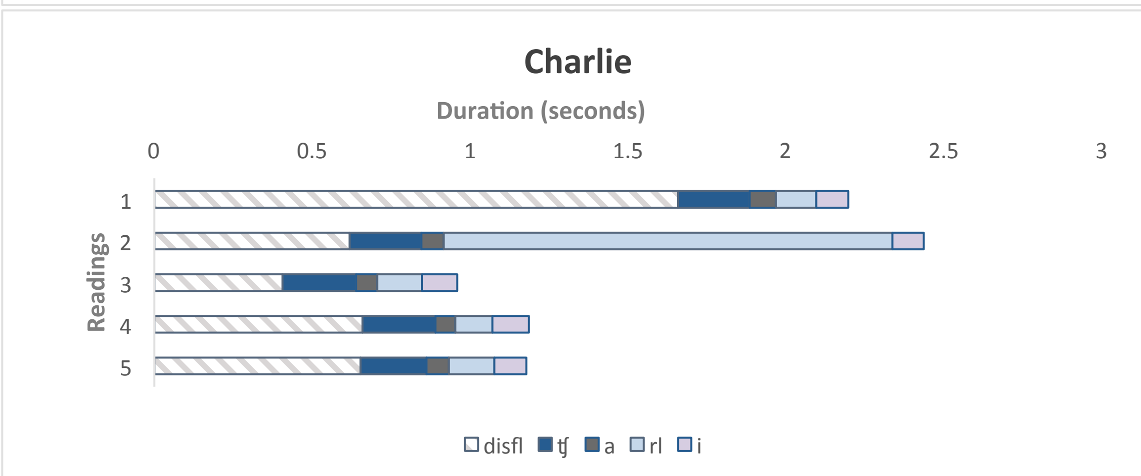
Charlie's parents are divorced and he lives with his mother. They live in the north where the weather requires a jacket all year round. That's why it was so exciting when his dad invited him to join him aboard a cruise ship over summer vacation. Charlie loved to travel and has always dreamed of fishing in the ocean. He was grateful to have the chance to finally spend time with his dad. However, Charlie became silent when his dad told him that he was also bringing Connie. When his dad and Connie got engaged, Charlie promised his mother that he would not support his father marrying Connie. Although he thinks his father and Connie make a good couple, he believes it's terrible that he is forced into a position of taking sides. Knowing that his mom is not selfish and she would understand, Charlie did eventually decide to accept the trip that his father offered. When Charlie headed to his mother's room to tell her about his decision to go on the cruise, he hoped she would forgive him. He planned the most charming and innocent defense that he could imagine. Once he started his speech he began to realize how foolish he was worrying about his mother's response. She was more than understanding and received the news with open arms. She told Charlie that he was her clever little prince and she loved him to pieces. Charlie could not stop smiling because he had the greatest mom in the entire world. He immediately called the agency to ask them to send the tickets

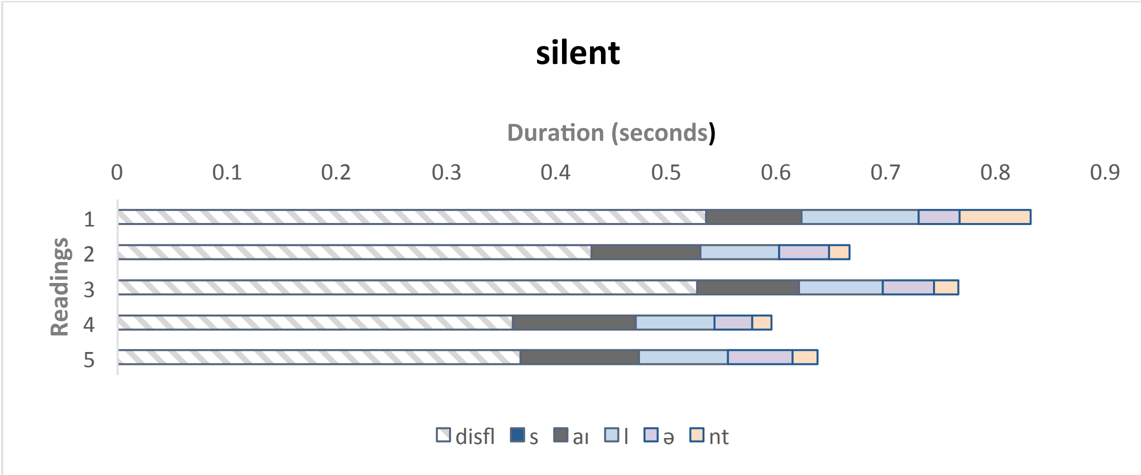
APPENDIX B. Word Analysis Pictures By Participant

Participant 11001





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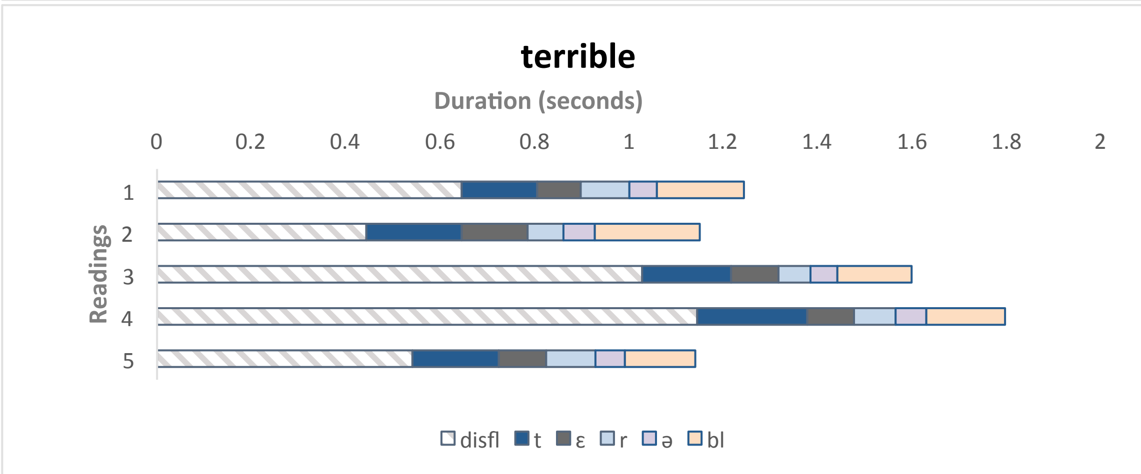
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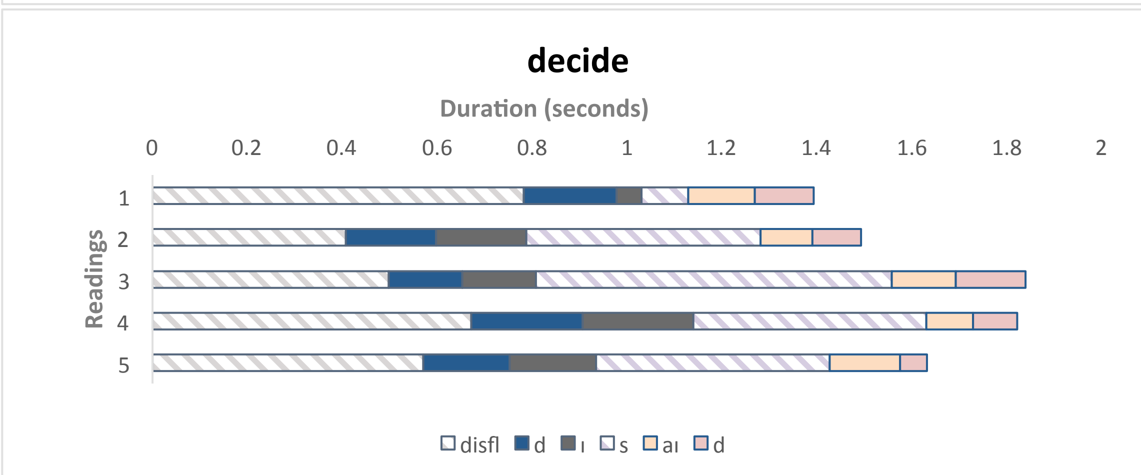
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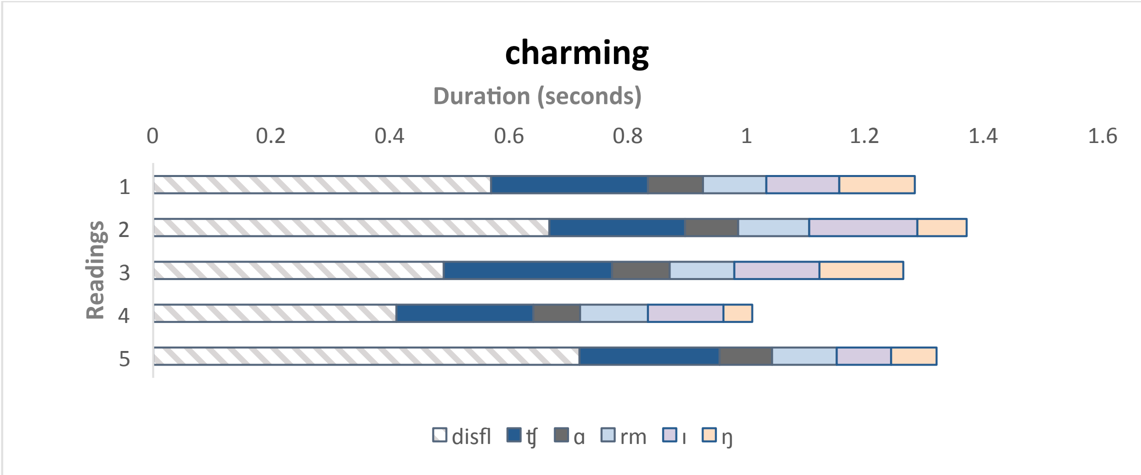
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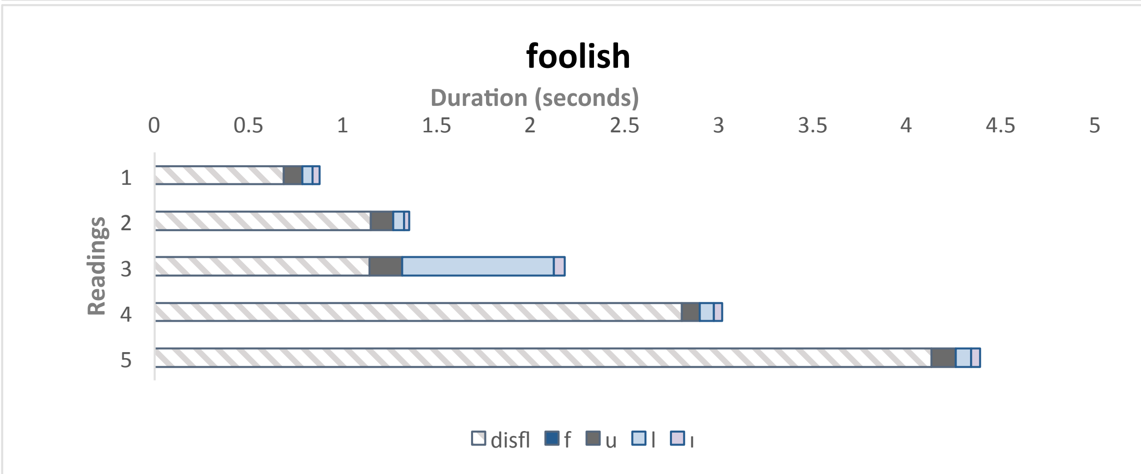
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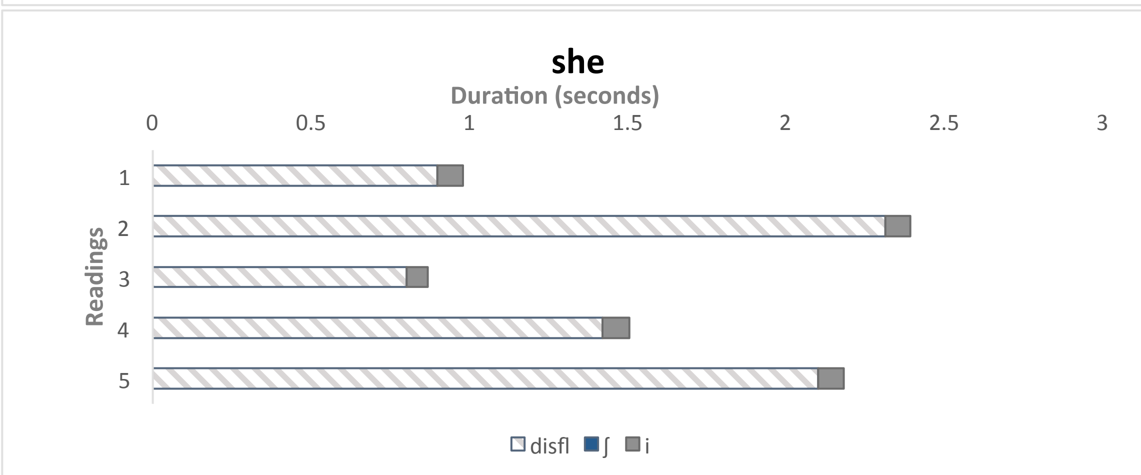
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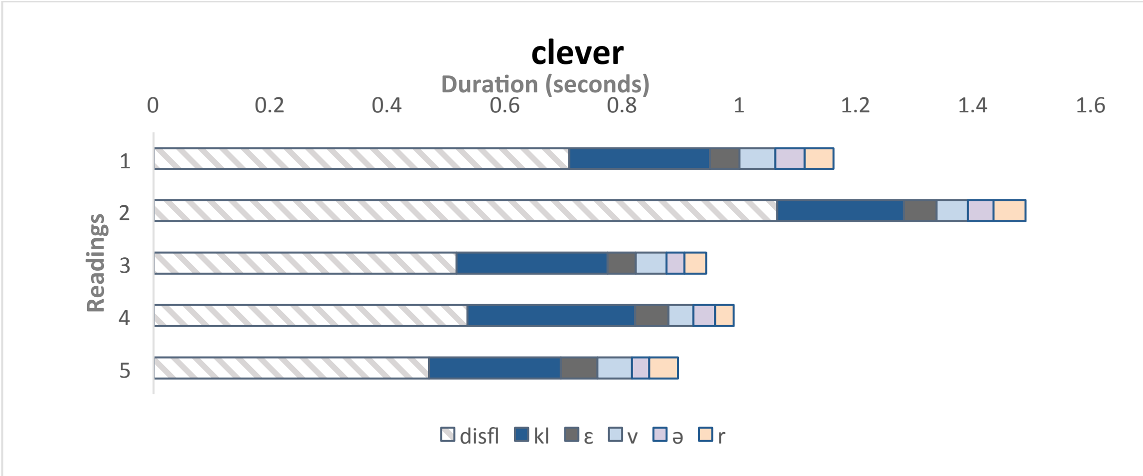
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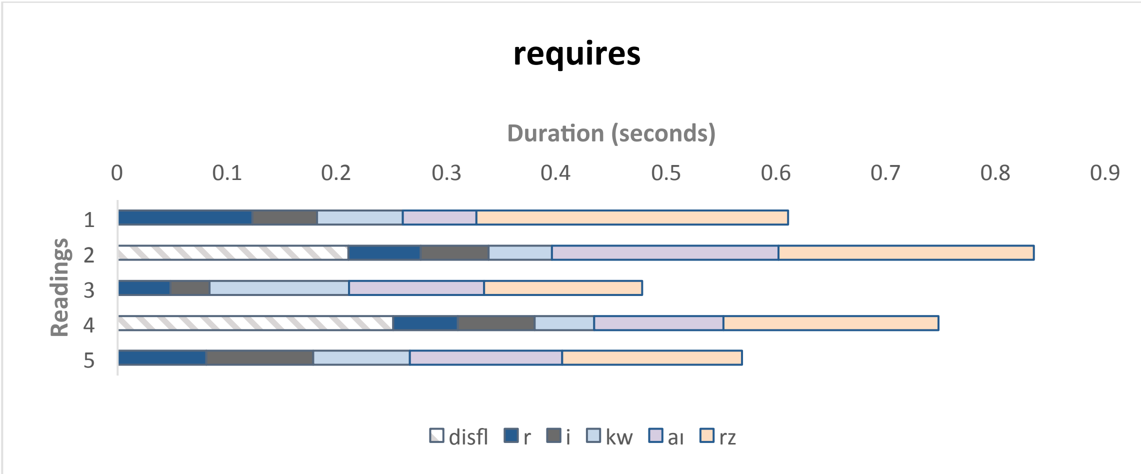
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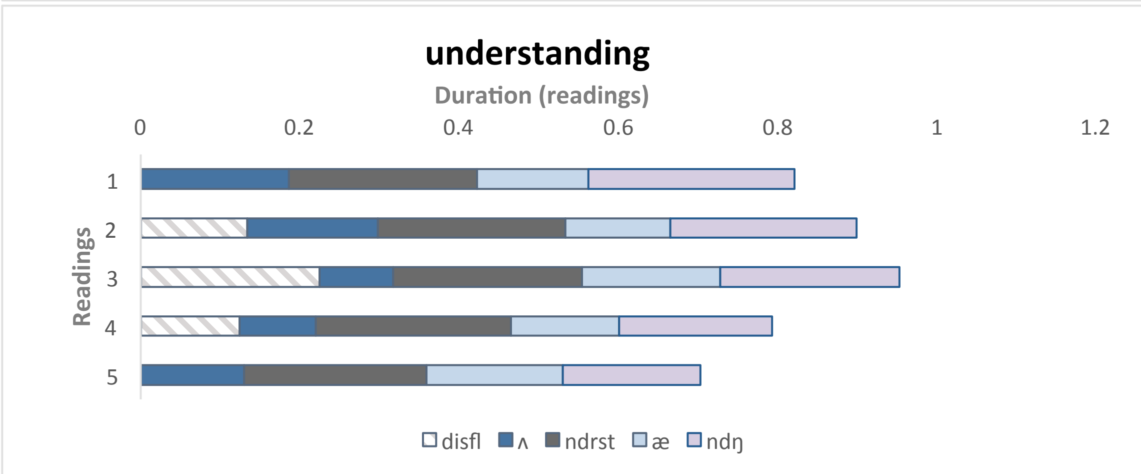
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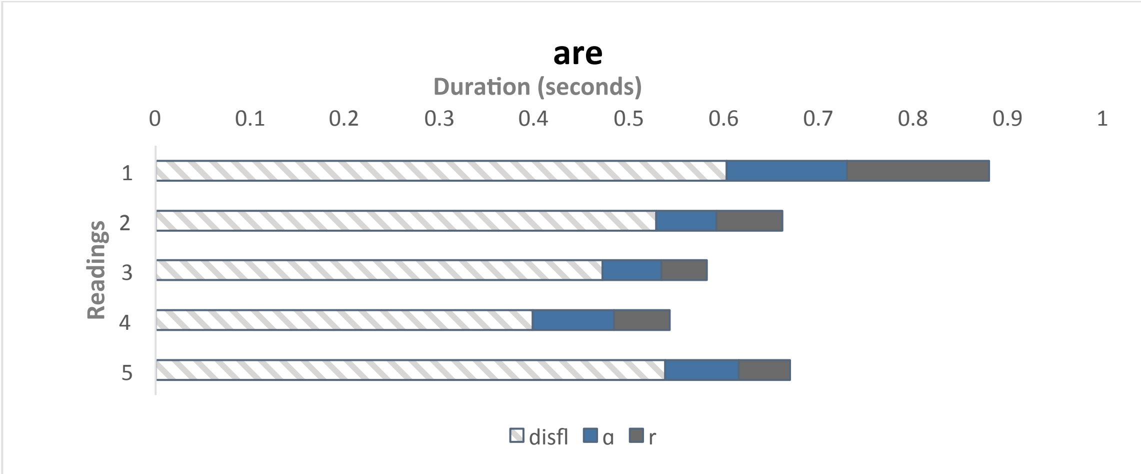
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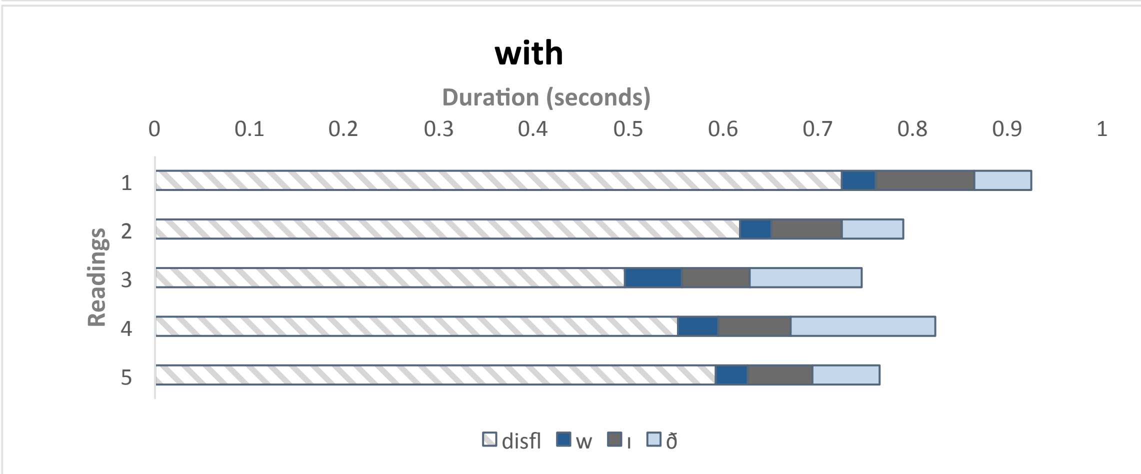
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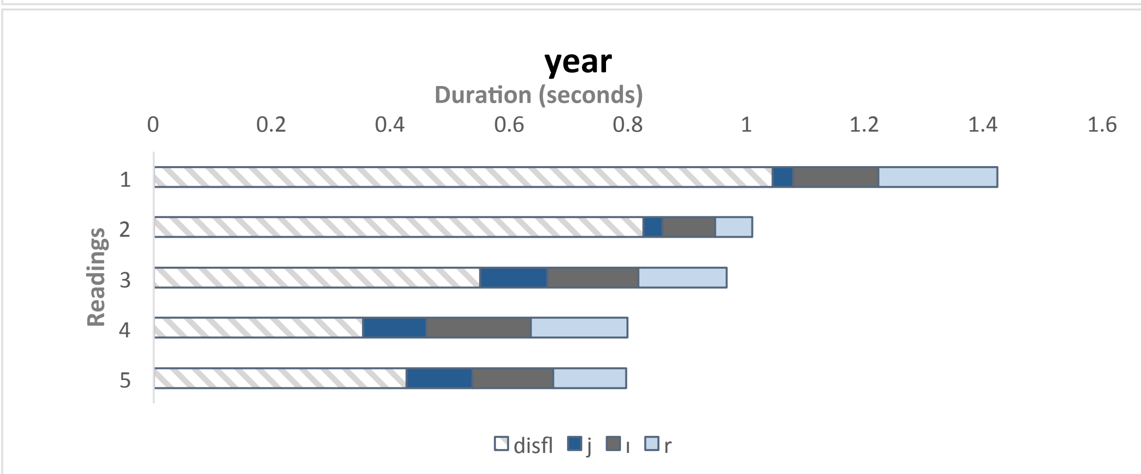
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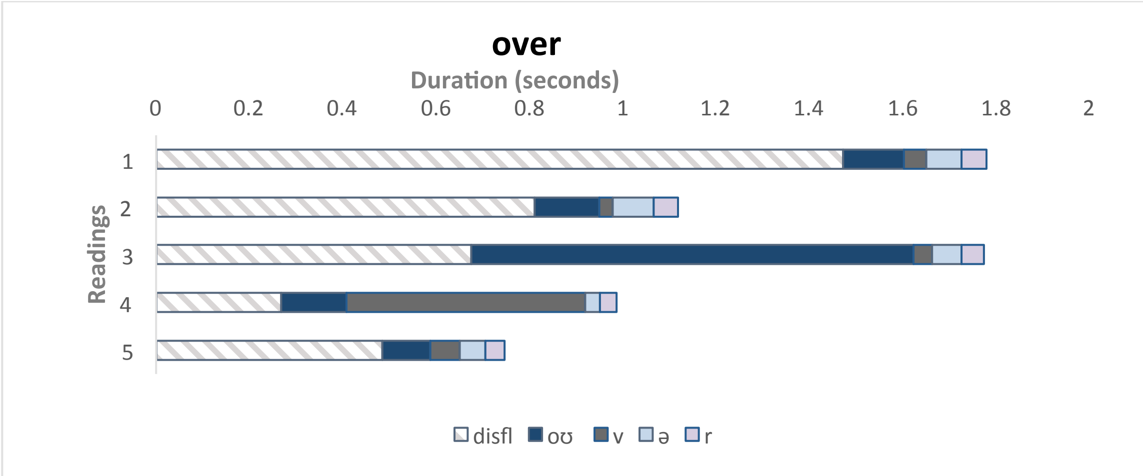
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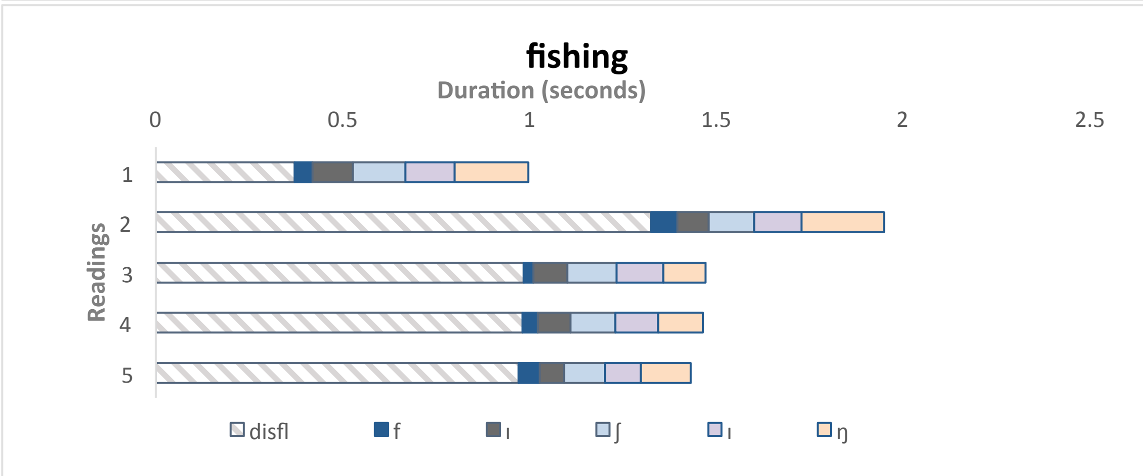
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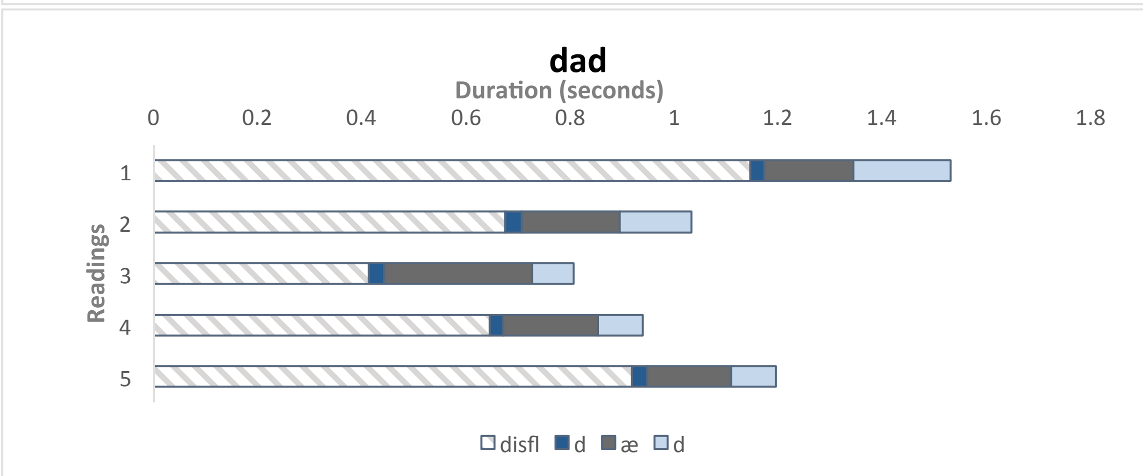
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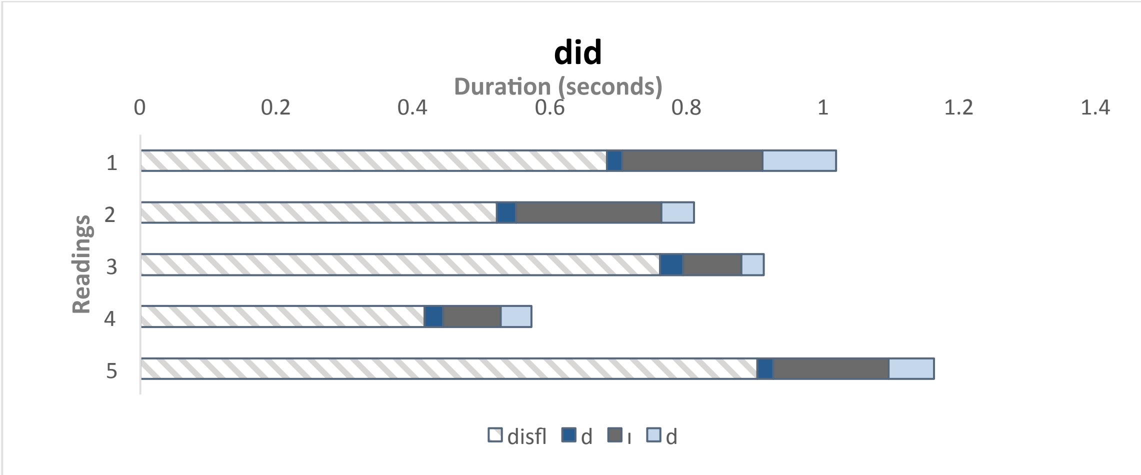
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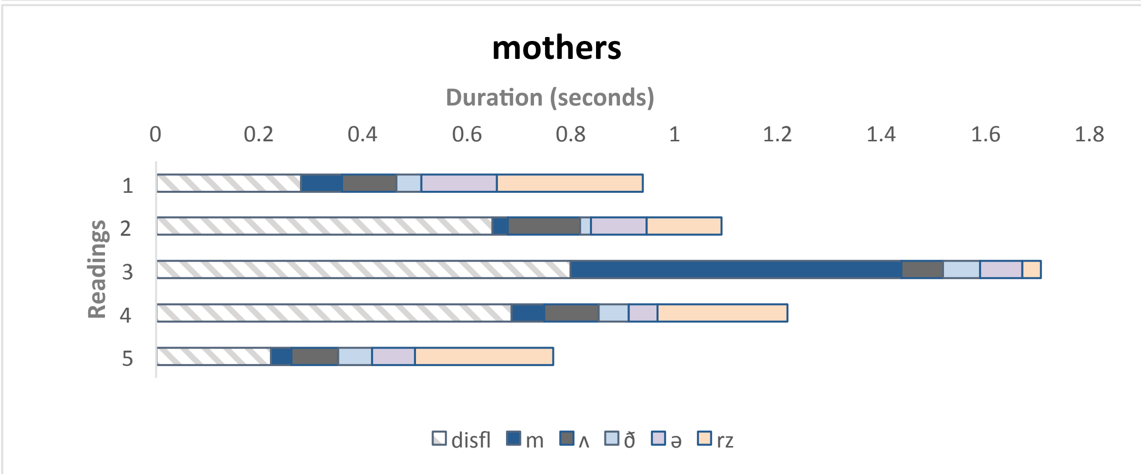
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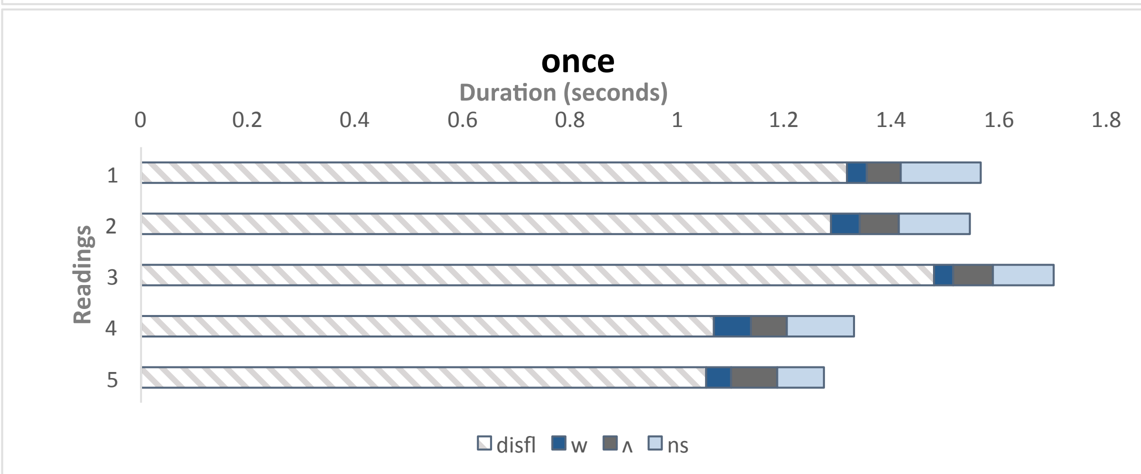
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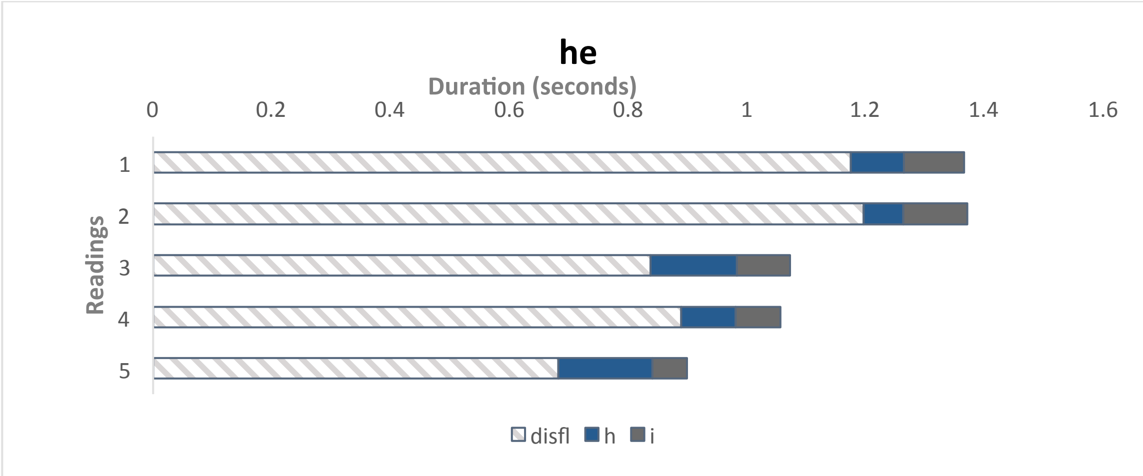
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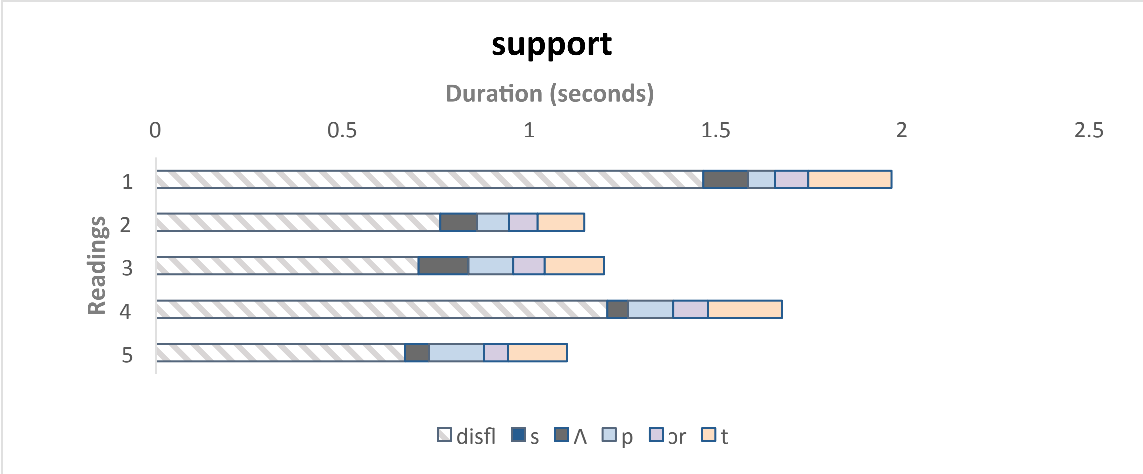
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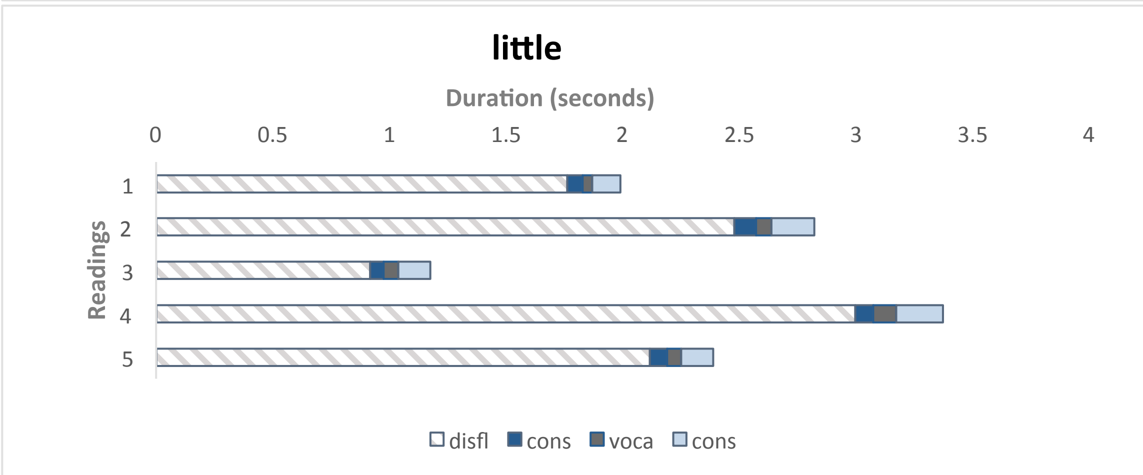
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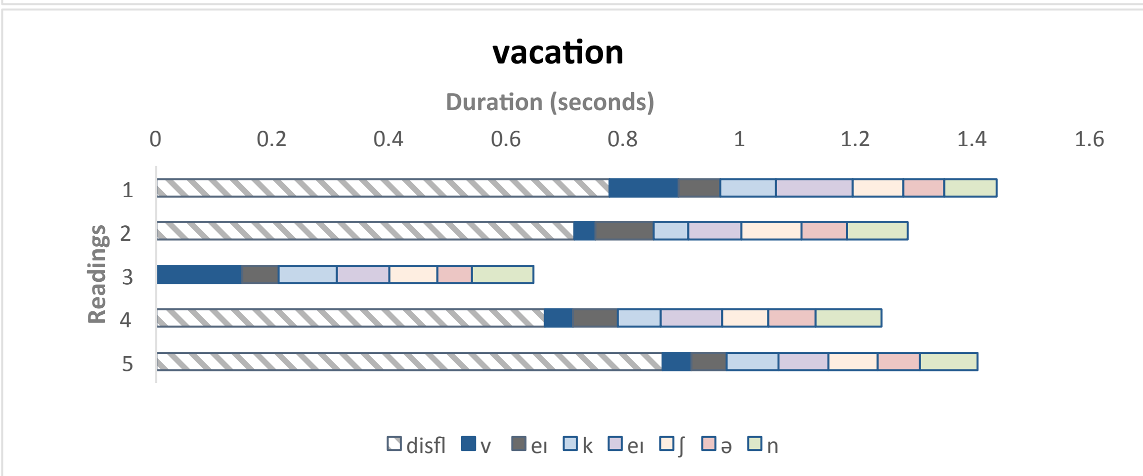
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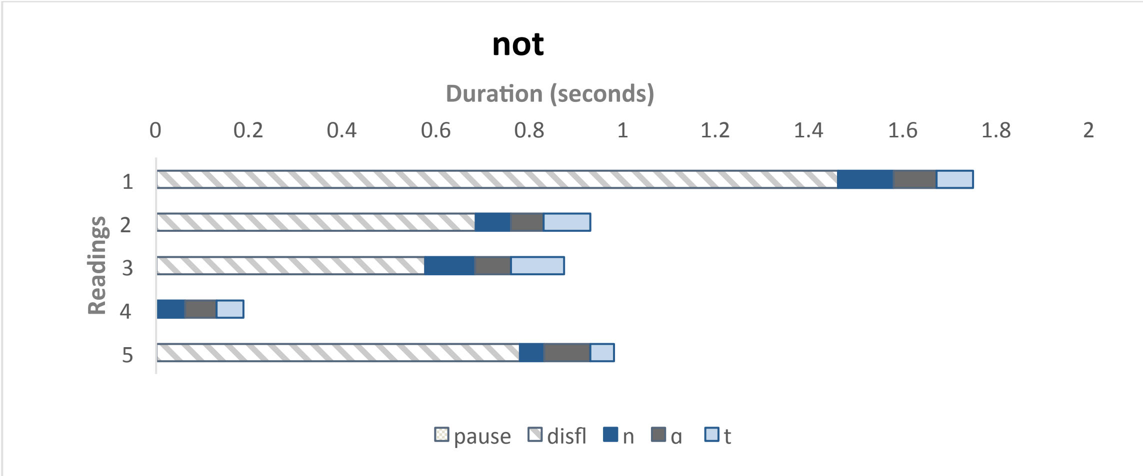
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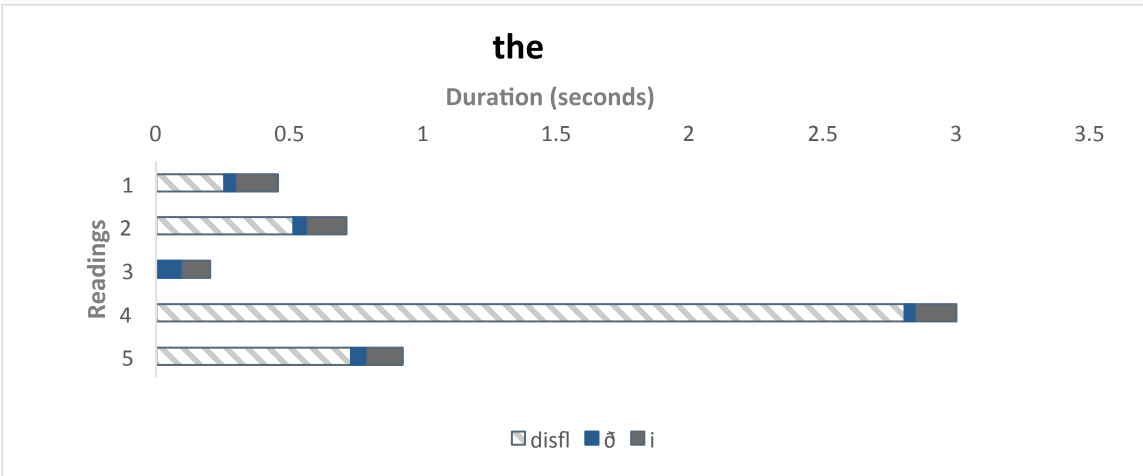
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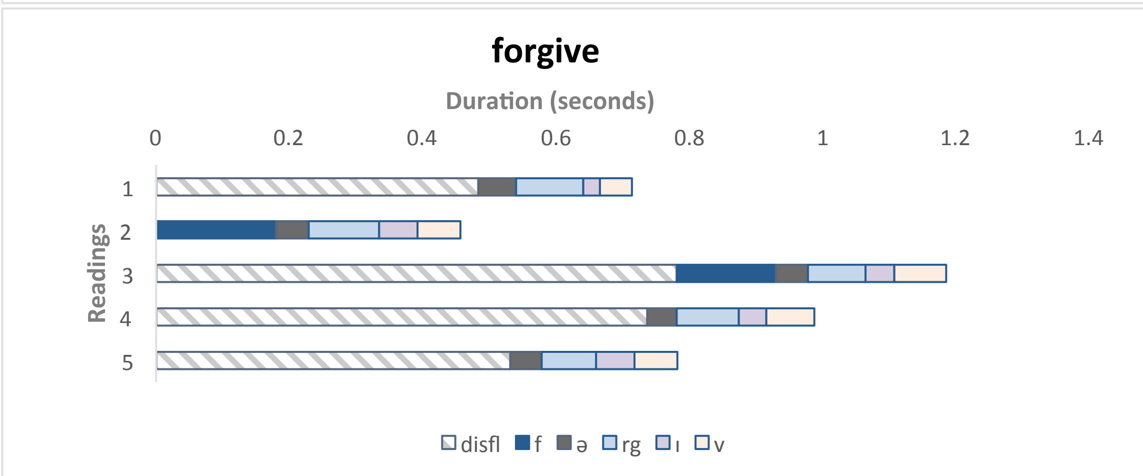
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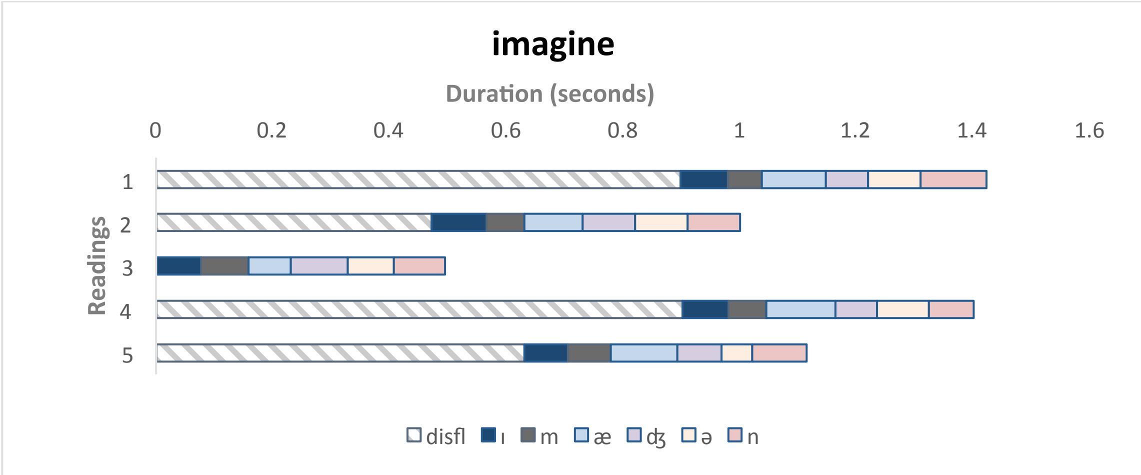
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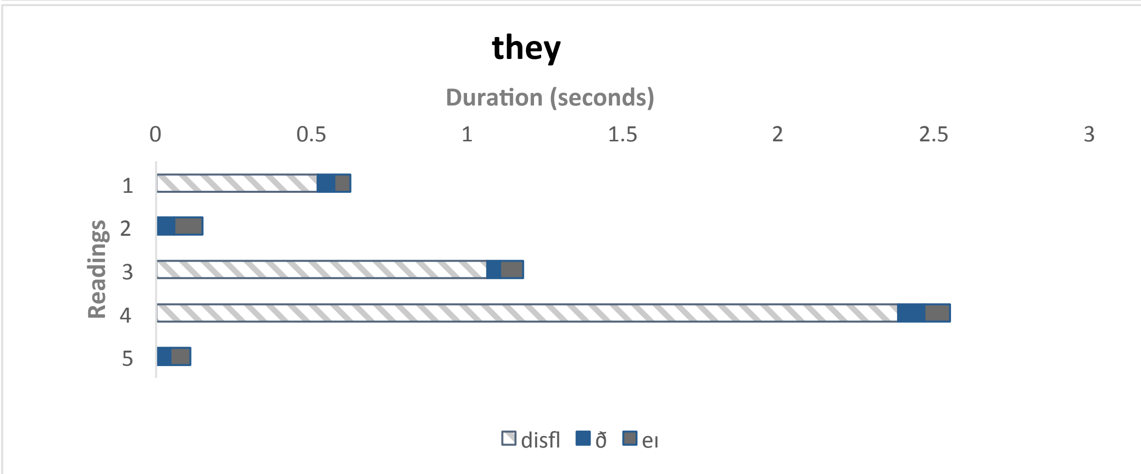
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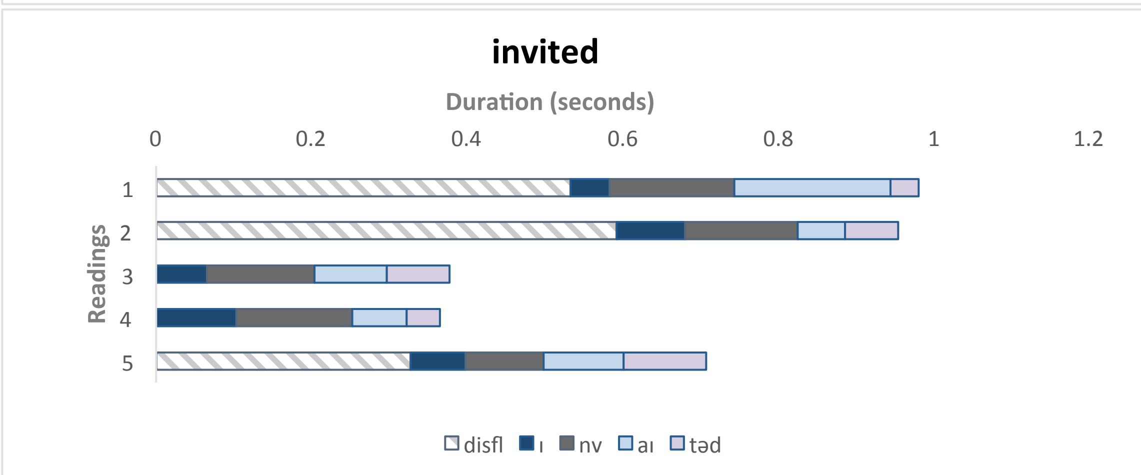
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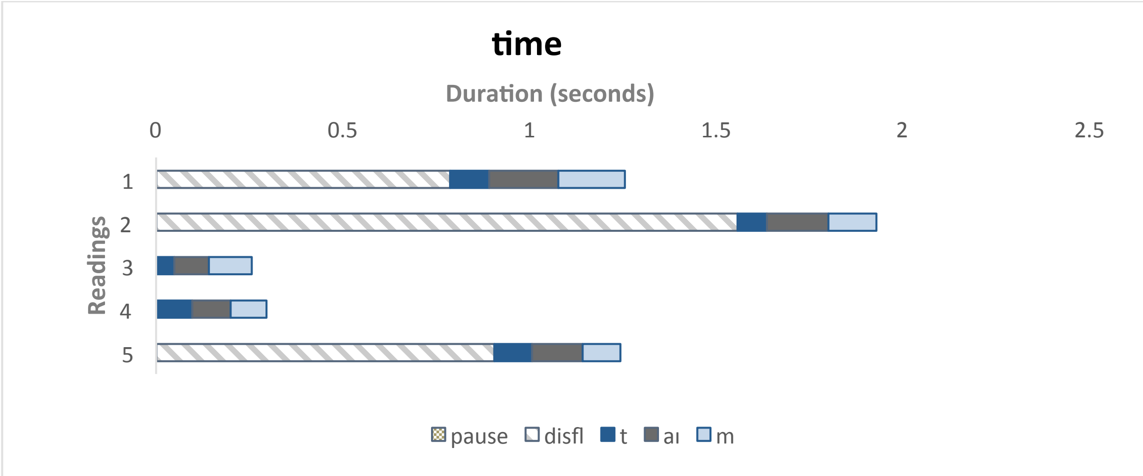
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