CAUSE OR CONSEQUENCE: AN INVESTIGATION OF THE FACTORS DETERMINING THE ONSET AND DEVELOPMENT OF STUTTERING

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ABSTRACT

Current research indicates that the onset, recovery and persistence of stuttering stem from a number of complex factors and their interaction with speech motor control processes. The use of non-speech and quasi-speech tasks have helped to increase the understanding of speech production processes involved with stuttering, however results from such studies are somewhat inconsistent and do not reflect natural speaking contexts. It is often difficult to ascertain the direction of causality of findings.

The aims of the research reported in this thesis were as follows:

- Define speech and language fluency profiles for individuals at different stages of stuttering.
- Compare speech and language fluency profiles for children with and without a family history of stuttering.
- Determine whether the observed changes in speech and language fluency profiles associated with stuttering are a cause or consequence of stuttering.

Speech production measures were gathered through natural and age-appropriate speaking contexts from three age groups to capture different stages of stuttering. The three age groups were of y*oung children* (longitudinal design), *school-aged children*, and *adults*.

To investigate familial history as a risk factor for the onset of stuttering, *young children* with and without positive family history were investigated over a period of nine months with the first data session being prior to any stuttering onset. During the study some children were diagnosed with stuttering. This allowed for further investigation of the relevant risk factors associated with the onset of stuttering, and speech production development associated with and without stuttering.

To explore the way in which speech motor control and linguistic planning processes interact, the set of collected speech measures targeted both processes.

Together, the measures reflect the multidimensional aspect of fluency and dynamic processes of speech production. A novel approach for the investigation of pauses in speech was adopted (Kirsner, Dunn, & Hird, 2003) in conjunction with common measures of speech and language production (Performance Deviations: PD, Brookshire & Nicholas, 1995; Systematic Analysis of Language Transcripts: SALT, Miller, 2008; Correct Information Unit: CIU, Nicholas & Brookshire, 1993).

The impact of stuttered disfluencies on speech production ability of people who stutter was investigated by comparing speech samples containing stuttered disfluencies with perceptually fluent samples. The relationship between stuttered disfluencies and the use of fluency techniques and how they relate to speech production measures for adults who stutter were explored.

The first study of *young children* investigated the onset and developmental aspects of early stuttering across four data sessions. No group differences were found for speech production measures for children with (n = 9) and children without a family history of stuttering (n = 9). Of the typically developing children (n = 18) who participated, five children started stuttering. Four children had a positive family history of stuttering. The likelihood of stuttering onset based on family history was not significant. Syllables Spoken per Second was found to be a significant predictor for stuttering onset but this result could also be explained by group differences in age. Prior to any stuttering onset, the speech production ability of children who started stuttering was comparable to that of children who continued to typically develop. However, soon after stuttering onset, the results showed an early impact of stuttering on speech production. There was a group interaction for Percent Intelligibility (SALT) for data from Session 3 to Session 4. There were also subtle changes to associated speech and language measures for the children who started to stutter compared to typically developing children.

Results for *school-aged children* who stutter (*n* = 13) compared with children who do not stutter (*n* = 13) demonstrated noticeable differences in speech and language functioning between the groups. This reflected the negative impact of stuttering for the ongoing development of speech and language skills. Children who stutter were significantly slower with speech production as indicated by the production of longer *short* and *long* pauses in their perceptually fluent speech. They also had unusual patterns of performance for how some of their speech and language measures related to each other, supporting the use of trade-offs in speech production.

Results for *adults* who stutter (*n* = 12) compared to adults who do not stutter (*n* = 12) demonstrated differences for the timing aspects of speech production. Adults who stutter were slower in speech production than control participants as indicated by longer short pause mean and fewer syllables spoken per second. However these differences were found to be a result of stuttered disfluencies in their speech, rather than from underlying speech planning and execution processes. Adults who stutter did, however, have generally slower speech production processes as indicated by an increased proportion of pause time in their perceptually fluent speech. It is hypothesised that this was due to compensatory techniques employed by the adults who stutter.

A primary finding from the study is that group differences for speech production processes differed at different stages of stuttering. For the young children who started to stutter in Study 1 and for the adults who stutter in Study 3, differences occur as a result of stuttering, rather than a cause of stuttering. For the *school-aged children* of Study 2, the results showed that stuttering was co-developing with ongoing speech and language skills. Discussion of speech production differences are interpreted in light of the accounts of stuttering and of speech motor control. Implications for clinical practice are also presented.

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Finally, the last congratulation - goes to me! To complete this thesis, I counted a total of 38,829 syllables, hand segmented and transcribed 52,213 pause-speech data cycles, transcribed and segmented 10,309 utterances based on communication units, identified and coded 5,717 performance deviations and counted 3,189 correct information units!

DECLARATION

I hereby declare that this submission is my own work, and that to the best of my knowledge and belief this thesis contains no material previously published or written by another person, except where due acknowledgement is made in the text.

This thesis contains no material which has been accepted for the award of any other degree or diploma of a university of other institute of higher learning.

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LIST OF ABBREVIATIONS

The following abbreviations are used throughout the thesis:

SALT	Systematic Analysis of Language Transcripts
CIU	Correct Information Unit
PD	Performance Deviation
MLU	Mean Length of Utterance
NDWR	Number of Different Word Roots
CWS	Children who Stutter
AWS	Adults who Stutter
%SS	Percent Syllables Stuttered
NTU	Number of Total Utterances
ANCOVA	Analysis of Covariance
FPS	Fluency Profile System
WHO	World Health Organization
S1 – S4	Session 1 – Session 4
FT	Fluency Techniques

CHAPTER 1: INTRODUCTION

The importance of speech production for the daily functioning of human beings is something that can easily be taken for granted. As our primary means of communication, this has been described by Messenger, Onslow, Packman, and Menzies, as “the fundamental mechanism underpinning day-to-day interaction with others, around which social networks are established, developed and sustained” (2004, p. 203). For those who live with stuttering, their most basic human needs and wants are often compromised by their difficulty with producing fluent speech.

The psychosocial effects of stuttering are well-documented. The negative consequences of stuttering can take effect from the early stages of stuttering. School-aged children who stutter are more at risk of bullying, being rejected and being neglected, when compared to their peers who do not stutter (Davis, Howell, & Cooke, 2002; Langevin, Bortnick, Hammer, & Wiebe, 1998). Older individuals who stutter, often experience increased anxiety during social interactions, and an overall decreased quality of life (Yaruss, 2010).

The majority (76%) of people who stutter reported that stuttering impacted on their employment choices (J. Klein & Hood, 2004). With a major focus on verbal communication skills in the modern workforce, stuttering contributes to economic cost (Ruben, 2000). Ruben estimated the financial cost of communication disorders combined to be up to 186 billion dollars per year for the US economy. The personal financial cost for a person who stutters is also significant (Blumgart, Tran, & Craig, 2010).

Many researchers have dedicated a lot of time and effort to search for the cause of stuttering. This search has proved challenging. Long-standing challenges include identifying the factors that predispose one to stutter, understanding the factors that perpetuate it and identifying the factors that cause a stutter to persist. In order to have a more accurate and earlier prediction of chronic stuttering (Yairi, Ambrose, Paden, & Throneburg, 1996) and to evaluate why stuttering therapy works or does not work (Bothe, 2004), there is a need to have an increased understanding of the nature of stuttering. The complexity of the disorder is highlighted by converging evidence from studies in the areas of neurological functioning, speech motor control activity and genetics. To investigate factors relevant to the onset and development of stuttering, studies must examine and analyse multiple factors.

Since stuttering manifests in overt speech, it has been extensively studied as a disorder of speech motor control (Peters, Hulstijn, & van Leishout, 2000; Peters & Starkweather, 1990). Although previous work in this area has been comprehensive, traditional approaches of inquiry have not produced definitive results. As such, there is currently no definitive explanation as to how or why the speech production ability of people who stutter, differs from people who do not stutter.

In developing theories on why speech production abilities differ from people who do not stutter, the interpretation of results from previous research has been difficult. The area is plagued with inconsistent and contradictory findings. Questions remain regarding whether differences between people who stutter and people who do not stutter, reflect cause or consequence of stuttering. Questions also remain regarding whether these differences reflect speech motor control processes, linguistic planning processes, or both. One potential reason for the contradictory findings is that the majority of the knowledge of speech motor control processes of stuttering is derived from studies of adults who stutter. There are concerns regarding the application of results from these studies, as these results may have been confounded by individual compensatory techniques and various therapy backgrounds (Armson & Kalinowski, 1994).

A major limitation of speech motor studies in stuttering is the over reliance on manipulated experimental conditions. Whilst decontextualised and unnatural speaking contexts have been targeted to delineate specific speech and language processes they are far from the spontaneous and natural conditions in which stuttering most often occurs. As such, results from studies cannot be generalised to natural speaking situations. There is a lack of detailed investigations that measure multiple aspects of speech production in those who stutter. The majority of tools and speech sampling procedures have an insufficient scope to reflect the dynamic properties of speech production (Hird & Kirsner, 2010).

The current study offers a timely and important contribution to the field, utilising an integrated approach to investigate factors relevant to the onset and development of stuttering. These factors were based on familial history, speech and language fluency profiles, and the individual's developmental stage of stuttering. In order to determine cause and consequence of stuttering, three studies were undertaken. The studies differed by the age of the population studied and the design of the study. The first study was longitudinal and the second and third studies were cross sectional. Importantly, all studies included a naturalistic speech context for data collection. The speech and language fluency profiles for participants were created from these contexts.

1.1 Organisation of Thesis

This thesis has seven chapters. The Introduction and Literature Review make up chapters one and two respectively. Chapter three, General Methods, presents common methodology across studies, and each study chapter (chapters four to six) contain specific aims, hypotheses, methods, results and a discussion for that study. The studies were as follows, *Study 1* - young children with and without a known family history of stuttering, who were all typically developing at the beginning of the study. *Study 2* - school-aged children who stutter and who do not stutter, and *Study 3* - adults who stutter and who do not stutter. General conclusions are presented in the final chapter (seven).

CHAPTER 2: LITERATURE REVIEW

The aim of this chapter is to demonstrate key issues surrounding the complexity and dynamic nature of stuttering. It highlights the need for research to reflect these complexities in order to further increase the understanding of stuttering. This review of the research provides a background and introduction to stuttering, a discussion surrounding the limitations in speech motor investigations of people who stutter and a rationale for the theoretical constructs of the study. The chapter concludes with a description of the study aims, as well as a summary of the three studies undertaken.

2.1 What is Stuttering?

To the ordinary person, stuttering may not seem so hard to identify. However, even after decades of research and discussion, there is still contentious and wide debate about what precisely makes up stuttering, how to define it, and how to measure it (Ham, 1989; Kully & Boberg, 1988; Yairi & Seery, 2011). The general consensus is that stuttering is a disorder that manifests as disruptions in the ongoing production of speech, defined as "... a disorder in the rhythm of speech in which the individual knows precisely what he or she wishes to say, but at the same time may have difficulty saying it because of an involuntary repetition, prolongation, or cessation of sound." (WHO: 1977, p. 202). This definition incorporates both perceptual and introspective aspects. The perceptual aspect involves judgments of the observable characteristics made by listeners to determine presence or absence of stuttering (Perkins, 1990). The introspective component relates to the individual's loss of control in being able to produce fluent speech.

Many descriptors are currently employed for labelling stuttering behaviours, however they are used unreliably and inconsistently (Cordes & Ingham, 1994; Einarsdóttir & Ingham, 2005; Ham, 1989; Packman & Onslow, 1998). The theoretical assumptions underlying typologies are unclear with many descriptors stemming from subjective perceptions of what a particular behaviour is. Repetitions of sounds and syllables, prolongations and blocks have been described as the core verbal behaviours of stuttering (Van Riper, 1971) that interrupt the forward flow of speech. Of these behaviours, production of prolongations and blocks are reported more commonly for those with chronic stuttering, and repetitions for those who are stuttering in the early stages (Guitar, 2006). However, any type of behaviour can be present at any time, and any age with some children at near onset of stuttering displaying signs of tension and force associated with their stuttering (Yairi, 1983).

Stuttering does not only comprise of the core verbal behaviours. It is a multifaceted disorder with implications across physical, affective and cognitive domains (Yairi & Seery, 2011). Secondary and non-verbal behaviours may be present as reactions to the struggle associated with producing fluent speech. For example, accessory non-verbal behaviours include physical aspects such as eye-blinking, facial tremor and head movement. Individuals may also have significant negative feelings, reactions and attitudes as a result of stuttering (Yaruss, 2010).

The *prevalence* of stuttering is reported at approximately 1% of the school-aged population, and less than 1% in adulthood (Andrews et al., 1983). A study conducted in Australia reported a rate of 0.72% for the general population, and approximately 1.4% for school-aged children (Craig, Hancock, Tran, Craig, & Peters, 2002). Historically, stuttering is thought to have existed since humans started speaking. It is speculated that Moses was afflicted with this disorder in 2000BC, and so too was Demosthenes from 384-322BC (Brosch & Pirsig, 2001). Stuttering is believed to be present in all cultures and spoken languages, though the prevalence of stuttering may vary across different cultures (Yairi & Seery, 2011).

The *incidence* of stuttering in children has traditionally been reported to be around 5% (Andrews, et al., 1983; Mansson, 2000), but a more recent study reported an 8.5% incidence (Reilly et al., 2009). The difference between the incidence and prevalence figures supports the notion that most individuals who start to stutter will recover from it. Spontaneous recovery or natural remission is defined as recovery without formal intervention, and its rate has been reported to vary greatly in the literature, ranging from 20% to as high as 80% (Andrews, et al., 1983). Through a longitudinal study of young children who stutter, Ambrose and Yairi (1999) estimated a spontaneous recovery rate of 75%.

Stuttering is a developmental disorder for the majority of people who stutter. The onset is generally within the first two to five years of life (Conture, 1990), with most cases occurring between two and three years of age (Yairi, 1983). This period coincides with the time a child normally starts producing multi-word sentences. A later onset of stuttering is also possible, with cases of acquired stuttering occurring post-brain injury (De Nil, Rochon, & Jokel, 2009; Van Borsel & Taillieu, 2001).

One in five of those who start to stutter in childhood are reported to continue to stutter into their adult lives (Andrews, et al., 1983; Bloodstein, 1995). This is referred to as persistent, advanced, or chronic stuttering, and is most often associated with negative psychosocial consequences. Factors relating to the persistence of stuttering have been a focus of research in more recent years, particularly through longitudinal investigations (e.g., Ambrose, Cox, & Yairi, 1997). However there is still a need for future research to validate the reliability of predictive factors for the persistence of stuttering.

So far, the persistence of stuttering has been linked to male gender and a positive family history of stuttering (Ambrose, et al., 1997). Specifically, children of parents who had stuttered and recovered, have been found to be more likely to recover than that of parents who stuttered but did not recover (Ambrose, et al., 1997; Ambrose, Yairi, & Cox, 1993; Dworzynski, Howell, & Natke, 2003). Compared to children who stutter, there are more males who stutter than females with a ratio of approximately 4:1 for adults who stutter. The proportion of males who stutter increases with age (Kloth, Kraaimaat, Janssen, & Brutten, 1999; Mansson, 2000). This suggests that females start to stutter at a younger age and tend to recover earlier and more frequently than males (Ambrose & Yairi, 1999; Yairi, Ambrose, & Cox, 1996). Females may also be more resistant to developing a stutter, and as mothers, they pass on more genetic susceptibility to their children. This increases the likelihood that their children will develop a stutter.

It is important to note that the extent to which stuttering affects one's life is highly individual and depends on each individual's reactions to stuttering. The magnitude of impact is not necessarily related to the clinical severity of the stutter. That is, individuals with clinically mild stutters can experience a similar or even greater negative impact when compared to individuals who have clinically severe stutters. Early identification and treatment of stuttering is imperative to minimise or prevent persistent stuttering and its adverse effects on one's life (Davis, et al., 2002; Langevin, et al., 1998).

2.2 Theories of Stuttering: Evidence for a complex and dynamic disorder

Theories play an important role in how stuttering is perceived, how it is assessed and managed, and how treatments are evaluated. Based on a review of the literature, many different viewpoints of stuttering highlight the range of factors thought to be involved. Causal theories can explain different aspects of stuttering (Packman & Attanasio, 2004). Shapiro (1999) described factors that ‘cause’ stuttering and collectively referred to them as the three Ps: factors that *predispose*, *precipitate*, and *perpetuate* stuttering. Also, there are specific accounts of stuttering to explain the exact moment of a stuttered disfluency (e.g., Postma & Kolk, 1993).

The field has progressed from psychological and environmental accounts as sole causes of stuttering, to investigations of the biological and physiological functioning of people who stutter. In the 1950s, psychological accounts of stuttering were popular. However, over the years such accounts have failed to be supported with evidence (Andrews, et al., 1983). Psychological accounts of stuttering have long contributed to the common misconception that people who stutter are psychologically inferior to people who do not stutter. It is now generally accepted that negative psychological responses to stuttering come about as consequences of stuttering rather than causing stuttering.

Another influential account was the *Diagnosogenic* theory outlined by Johnson and colleagues (1959). This theory proposed that a child would begin to stutter as a result of his or her parent’s inappropriate reactions to, or incorrect labelling of, normal disfluencies that the child produced in speech (Johnson & Associates, 1959). As a result, the speech difficulty experienced by children who stutter was ignored by their parents. Parents thought that attention brought to the stutter would cause more harm than good. Over 50 years later, there is now evidence to indicate that treatment based on parents’ verbal responses to the speech of children who stutter is efficacious in remediating stuttering (see Lidcombe program, Jones et al., 2005).

Differences have been found between people who stutter and normally fluent speakers in ability to perform a variety of motor tasks. This has provided evidence for stuttering to be a disorder of general aberrant sensorimotor processes. People who stutter have been found to have differences in execution of finger movements as well as speech-related movements compared to control participants (Max, Caruso, & Gracco, 2003; Max & Yudman, 2003; van Leishout, Hulstijn, & Peters, 1996). Whilst such findings indicate general motor deficits to be the possible underlying processes of stuttering, the problem of stuttering is that it is a disorder of speech affecting communication skills.

The investigation of speech processes of people who stutter have been of central interest along with investigations of genetics and brain functioning. Several hypotheses have been proposed to explain the cause of stuttering relating to speech production. This includes theories of deficient auditory processing, sensory-motor feedback, as well as stuttering as a physiological tremor (Max, et al., 2003; Max & Yudman, 2003). There is now agreement that a single cause for stuttering is unlikely, and to achieve a comprehensive understanding of stuttering there is a need for research to integrate principles from various scientific fields (Conture et al., 2006; Smith, 1999).

Stuttered disfluencies manifested through speech involve a complex interplay between genetic, neurological, biological, and environmental factors. This complexity highlights the importance for further investigations into the nature of stuttering, particularly to examine the interaction of the various factors and how they affect speech fluency. The following section reviews, in more detail, areas of current research pertaining to stuttering aetiology including neurological functioning, genetics, the role of the environment and speech motor control.

2.2.1 Neurological Functioning

Questions regarding the role of neurological mechanisms have been discussed since the 1920s, as described in the *Cerebral Dominance Theory* (Orton, 1928; Travis, 1978). However it is the advent of highly sophisticated tools that have allowed for more detailed and accurate investigations. Findings from neurological studies have facilitated an increased understanding of the differences of the brains of those who stutter compared to those who do not stutter. Spatial and temporal differences have been reported. Making sense of inconsistent results across these studies, as well as establishing direction of causality of findings, is a challenging task in itself (Ingham, 2004).

The results of neurological studies have led to stuttering being described as a complex multi-factorial disorder (e.g., De Nil, 1999; Smith, 1999). This is in line with converging evidence from studies of the neurological substrates underpinning normal speech and language processes. The evidence indicates that there is a dynamic and rapid interplay between multiple areas of the brain required for the production of fluent speech (Hickok & Poeppel, 2007). Stuttering is thought to be a dysfunction of this dynamic system (Ludlow & Loucks, 2003).

More specifically, the dysfunction relates to the timing and co-ordination of the brain areas involved, and the interactions between processes required for speech production (Salmelin et al., 1998; Salmelin, Schnitzler, Schmitz, & Freund, 2000). For example, Sommer, Koch, Paulus, Weiller and Buchel (2002) hypothesised that timing and sequential deficits arise in stuttering as a result of a disturbed signal transmission through the left sensorimotor cortex due to atrophy of white matter in certain areas of the brains of adults who stutter.

Research findings indicate that the brains of people who stutter function differently to those of control participants for speech and language tasks. Compared to control participants, people who stutter have over-activation in areas of the right hemisphere and under-activation of some areas in the left hemisphere when performing the same speech tasks (Braun et al., 1997; De Nil, Kroll, Kapur, & Houle, 2000; Fox et al., 1996).

Decreased activations have been reported in extraprimary auditory and temporal areas (Braun, et al., 1997; Fox, et al., 1996; Salmelin, et al., 1998). Hyperactivity has been reported in the premotor and motor areas, the primary motor cortex, anterior cingulate cortex and the supplementary motor area (SMA) (Braun, et al., 1997; De Nil, et al., 2000; Fox, et al., 1996). In addition, such areas of hyperactivity have been found to be unusually lateralised to the right hemisphere. Interestingly, unusual activations observed for people who stutter have been present even when no overt stuttering is produced (De Nil, et al., 2000). Unusual activations have also been observed to be corrected to some degree after treatment (Braun, et al., 1997; De Nil, Kroll, Lafailee, & Houle, 2003; Kell et al., 2009).

Theoretical accounts for the cause of stuttering have been postulated based on the findings of neurological studies of stuttering. Webster (1997) hypothesised that the right hemispheres of adults who stutters causes interference to key areas of the left hemisphere required for fluent speech production, namely the SMA. Packman, Code and Onslow (2007) also proposed that the SMA is disturbed in people who stutter, and that it is this disturbance that results in difficulty of initiation of syllables required for the production of fluent speech.

Recently, studies into other aspects of the nature of the underlying neurological mechanisms of stuttering have emerged. Through such studies an increased understanding of stuttering can be achieved in regards to the development of the brain associated with the different trajectories of stuttering. Kell and colleagues (2009) investigated stuttering persistence and recovery in adult males. They reported that persistence in stuttering is associated with over activations in the right hemisphere, which have been engaged to compensate for deficits originating in the left hemisphere, namely the left inferior frontal region. After a therapy program the adults with persistent stuttering displayed changes to the brain which normalised the areas involved with compensation. For adults who recovered from stuttering without guided therapy, the left Brodmann’s Area 47/12 in the orbitofrontal cortex was observed to have normalised compared to those who were persistent stutterers. The author’s definition of recovery was determined as 1% stuttered syllables or less, unassisted without guided therapy. However, since the diagnosis of stuttering was dependent on the adults’ self-reports, this result requires further validation.

Recently, Jiang, Lu, Peng, Zhu and Howell (2012) scanned the brains of 20 adult males using an event related design to investigate the neurological patterns associated with different types of stuttering disfluencies. The researchers grouped disfluencies as either ‘more typical’ to people who stutter or ‘less typical’, as disfluencies that are observed in both people who stutter and fluent speakers. They found that the brain activity patterns of the two classifications could be identified separately from one another. The more typical disfluencies involved the left inferior frontal cortex and bilateral precuneus, whereas the less typical disfluencies involved the left putamen and right cerebellum.

So far, the clinical applications derived from neurological studies of stuttering are limited. Studies to date have typically been of adults who stutter. There have been some trials of dopamine blockers for the treatment of stuttering based on the observation that excessive dopamine affects the efficiency of speech programming. For example, Olanzapine, a dopamine blocker, was found to significantly reduce the severity of stuttering in adults who stutter compared to those who took a placebo (Maguire et al., 2004). There are currently studies underway of younger participants to investigate predictors for the onset and persistence of stuttering. This could potentially help to unravel longstanding mysteries of the disorder. As knowledge in this area grows there is potential for specific treatments to be developed for people who stutter based on the neurophysiology of stuttering.

2.2.2 Genetics

Currently the role of genetics in the development of stuttering is an area of interest in stuttering research. Earlier findings have impacted on clinical practice in relation to the recovery and persistence of stuttering in childhood (Ambrose & Yairi, 1999; Ambrose, et al., 1993). Evidence supporting a genetic component to stuttering (Wittke-Thompson et al., 2007) comes from research that had found higher concordance rates for stuttering in monozygotic twins (20-90%) than in dizygotic twins (3-19%) (Dworzynski, et al., 2003; Felsenfield et al., 2000; Howie, 1981). Research has also indicated that the incidence of stuttering in first degree relatives is higher than that of the general population (Felsenfield, et al., 2000; Kidd, 1984; Yairi, Ambrose, & Cox, 1996). Approximately 39% of children who stutter also have a relative who stutters in their immediate family, and this percentage increases to 68% when considering relatives in their extended family (Ambrose, et al., 1993; Yairi, Ambrose, & Cox, 1996).

Currently, investigations into the genetics of stuttering are in the area of biological genetics (Wittke-Thompson, et al., 2007). This involves linkage analyses, which are used to identify potential genetic markers on chromosomes implicated for a disorder by analysing saliva and/or blood samples of those affected. Genes are usually examined in family members (pairs of siblings), and analysis can only identify a genetic neighbourhood, not a specific gene causally related to the phenotype.

Linkage analyses conducted for families with a large number of members who stutter have already identified several chromosomal locations as possible sites for genes associated with stuttering. For example, chromosomes 1, 2, 5, 7, 9, 12, and 13 have been found to be possibly linked to stuttering (Wittke-Thompson, et al., 2007). Additionally studies are continuing to examine the genes associated with the persistence of stuttering, and the gender differences in stuttering (Suresh et al., 2006).

It has been speculated that a genetic predisposition to stuttering can lead to a more unstable speech system which precedes stuttering manifestation (e.g., Packman, Onslow, Richard, & Van Doorn, 1996). But exactly what an unstable speech system means is yet to be clarified. There have been no studies which directly compare the speech and language skills of children with and without a genetic predisposition to stuttering.

Genetic predisposition is thought to increase the likelihood of observing the onset of stuttering in young children (e.g., Kloth, et al., 1999). However it is unknown if a genetic predisposition actually translates into differences in the phenotype of a child’s speech and language skills, or if it impacts on how the child’s speech system holds up during periods of rapid speech and language development. Perhaps children with genetic predisposition may not be as successful at recovering from fluency breakdown that occurs during the time at which there is a surge in language skills (Bloodstein, 2002); this time period coincides with the usual time of the onset of stuttering in young children. Investigations that examine genetic factors with relevant environmental and psychosocial factors could potentially solve questions surrounding the onset and persistence of stuttering.

2.2.3 Genetics and Environment

There is a general belief that environmental factors (i.e., psychosocial factors) are necessary for the development of stuttering, and that these factors affect changes in the expression and development of a stutter (Conture, et al., 2006). However studies have not found such environmental factors to be different between children who stutter compared to those who do not stutter (e.g., Reilly, et al., 2009). The search to identify relevant factors and the role that they play in the onset and persistence of stuttering remains a pressing issue (Suresh, et al., 2006).

There is still much to learn about what genes actually do and how they interact with environmental factors for the manifestation and maintenance of a stutter. Conture et al. (2006, p. 25) notes this succinctly, stating that "it is still not understood what speech-language abilities are inherited and/or what environmental (internal or external) factors influence the expression of what is inherited."

In the area of psychology, models based on Genetics x Environment (G x E) interactions have existed for some time. For example, diathesis-stress models for the explanation of psychiatric disorder such as schizophrenia were proposed in the 1960s (Monroe & Simons, 1991). A diathesis-stress model attempts to explain how predisposition factors, such as genetic, biological, or possibly even psychological factors, interact with stress for certain psychopathologies (Ingram & Luxton, 2005).

There have been very few G x E studies in the area of speech pathology. McGrath et al. (2009) found evidence for G x E interaction for the genes associated with speech sound disorders and reading disability with environmental factors. The environmental factors they found to interact with genes were home language/literacy environment and the total number of ear infections that a child has had. There are yet to be studies looking specifically at G x E interactions in the area of stuttering.

2.3 Speech Motor Control: A contemporary view of stuttering

2.3.1 Speech Motor Control Processes

Prior to describing how people who stutter differ in their speech motor control processes, a background to what the concept entails is warranted. Kent (2000, p. 391) describes speech motor control as the "systems and strategies that regulate the production of speech, including the planning and preparation of movements and the execution of movement plans to result in muscle contractions and structural displacements."

A widely cited and influential account of speech production is Levelt's (1989) model of speech production. Levelt refers to the major components in his model as 'stages', operating in a serial manner. In this model, speech production begins with a communicative intent, the macro-structure of which is planned in the *conceptualiser* stage. The linguistic form of the preverbal plan is then prepared by the *formulator* stage where grammatical, phonological and phonetic encoding is completed before execution occurs at the *articulator* stage. The model also describes a self-monitoring system, and a speech comprehension system for decoding speech input. Speech motor control processes correlate mainly with Levelt's (1989) articulator stage where the motor execution of speech occurs. Since motor plans are computed and/or retrieved at the end of formulation during phonetic encoding, the end of the formulator stage is likely to be implicated in stuttering.

Levelt's model is a modular account of speech production, describing components of a system that are relatively autonomous. The model does not sufficiently differentiate the motor planning and programming stages of speech production. The *motor planning* phase is where the transformation of symbolic units takes place to develop an articulatory plan, whereas the *motor programming* phase is where muscle-specific goals are determined.

An alternate model which encompasses these aspects is van Der Merwe's (2009) Speech Sensorimotor Control Theory. The model describes a four 'phase' neurophysiological model of speech motor control: (a) linguistic-symbolic, (b) motor planning, (c) motor programming, and (d) execution.

The model describes speech motor control as a fine sensorimotor, goal-directed and afferent-guided skill. Sensory feedback, including auditory, tactile and proprioceptive feedback, contribute to the ongoing coordination of speech movements, for the correction of errors in individual movements, and for making adjustments among the multiple movements involved in a given articulatory gesture. The model also accentuates the relationships between phases with both feedback and feed-forward interactions. For example, the linguistic-symbolic phase feeds directly into the highest motor planning phase, so difficulties with language formulation can affect speech motor control and vice versa.

The *linguistic-symbolic* phase is a premotor language planning phase with neural involvement from the temporal-parietal area, and Broca's area. The *motor planning* phase achieves an articulatory plan, and has involvement from neural regions including Broca's, Wernicke's, prefrontal cortex, supplementary motor area, and parietal areas. The *motor programming* phase involves the supplementary motor area, basal ganglia, the lateral cerebellum, the fronto-limbic system, and the motor cortex. Lastly, the *execution* phase results in the acoustic signal of speech which involves the supplementary motor area, the cerebellum, basal ganglia, the motor cortex, the thalamus and the brainstem. It can be seen here that there is overlap with brain areas implicated in specific functions of speech motor control to the ones implicated in neurological studies of stuttering discussed previously.

2.3.2 Development of Speech Motor Control

Whilst knowledge of the processes underlying speech production has advanced over the past century, speech motor control development in young children is still in its infancy. It is yet to be established how it is that children develop the skills required for adult-like speech production, as well as which factors facilitate or hinder this. There is also a need to ascertain valid and reliable measures to indicate changes in speech motor development.

Smith and colleagues, through a series of studies which examined the speech motor variability of participants, found that children are slower and more variable in their articulatory patterns than adult speakers. From approximately 14 to 16 years onwards, articulatory patterns stabilise (Smith, 2006).

Specifically, early speech motor development has been conceptualised as an interaction between the child's central nervous system and their internal and external factors. Internal factors are cognitive or neural, and external factors are environmental. Speech fluency develops as language learning becomes more automatic in terms of temporal planning and language formulation (Strand, 1992).

Green and Nip (2010), posit a framework based on a 'motor adaption.' Motor adaptions are "...young children's solution for achieving some level of speech proficiency despite their immature articulatory abilities," (p. 175). A motor adaption is influenced by factors which can be stimulated by 'catalysts' or limited by 'production constraints.' Catalysts and production constraints can be biomechanic, perceptual, cognitive, neural and environmental in nature. Green and Nip's view of speech motor development is one that does not necessarily unfold in a linear progression, stating that accelerations, decelerations, plateaus and regressions in performance are possible.

A common thread among studies is the emphasis placed on speech motor skill as a product of the child's simultaneous integration of a number of factors, all of which interact in a dynamic fashion. The relationships of relevant factors need to be considered over time to gain an increased understanding of the co-emergence of speech motor, language and cognitive development for the understanding of speech disorder and impairment (Kelly, 2000; Nip, Green, & Marx, 2011).

2.3.3 Speech Motor Abilities in People who Stutter

Over the past 40 years, investigations into the speech processing and speech motor control abilities in people who stutter have evolved to explain physiologic aspects related to stuttering. Investigations of speech motor control aim to understand the mechanisms that underlie the disorder and the stuttering moment. Specifically, how does the speech motor control system interact with linguistic, cognitive, emotional and metabolic factors for stuttering (Kent, 2000), and following on from this, how do treatment approaches for stuttering work?

The use of several different assessment measures has led to the discovery of how the speech systems of people who stutter differ from those who do not stutter. These include acoustic and kinematic measures of speech production. As a result, differences have been reported involving each of the speech motor phases of van der Merwe's (2009) model. These include a delay in speech production, a limited range of movement in speech articulators, and a lack of coordination between articulators and the larynx. Importantly, differences have been found in the *disfluent* speech of people who stutter as well as in their *fluent* speech, when there is no discernible overt stuttering. This has been interpreted to indicate impaired or disrupted neuromotor processes (Caruso, Max, & McClowry, 1999; Peters, et al., 2000).

A motoric view of stuttering, involving the motor programming and/or execution phases (van der Merwe, 2009), implies that stuttering is a result of dysfunction across the subsystems of speech, such as phonation, articulation, and respiration. It has been suggested that the disruption in the timing and coordination of these subsystems is the cause of stuttering (Max & Yudman, 2003; Peters, et al., 2000). Earlier studies reported that people who stutter have longer voice onset times (Zimmerman, 1980), as well as an unusual build-up of subglottal pressure in phonation (Peter & Boves, 1988). Reaction time, acoustic and kinematic measures have also indicated that adults who stutter have slower initiation times for speech movements (Logan, 2003), and increased variability of some speech apparatuses such as the movement of the lips, when compared to control participants (Kleinow & Smith, 2000).

2.4 Stuttering and Linguistic Processes

Researchers continue to debate whether there is an exclusive motor base to stuttering or if there are contributions from higher level language formulation processes, such as the linguistic-symbolic phase of van der Merwe's model. Researchers are faced with the challenges of elucidating the contribution of linguistic processes and how they relate to stuttering, with equivocal findings in the literature.

Kent (2000), states that speech motor control should be viewed in relation to the whole communication system with complex interactions between processes. However, the inherent complexity of the interactions between language planning and speech motor processes makes it difficult to separate and quantify the processes. The phonological representation of language (such as phonological encoding) is the input for the motor planning phase of speech motor control, and as such, deficiencies here can have a flow down effect to disrupt speech motor control processes. Influence in the opposite direction is also possible (van der Merwe, 2009).

Generally, there is no evidence in the literature to indicate that adults who stutter have difficulty with early processes of the linguistic-symbolic phase (i.e., communicative intent, semantic construction of the message). The consensus is that people who stutter know exactly what they want to say, such that it is reflected in the WHO stuttering definition (e.g., WHO stuttering definition, 1977).

It has been postulated that people who stutter have deficits in self-monitoring and auditory processing of speech (Fairbanks, 1954) that may stem from the error repair activities that a speaker uses. It is thought that the use of external devices for the amelioration of stuttering, such as delayed auditory feedback and altered auditory feedback, help to correct these deficits to reduce or eliminate stuttering.

The role of processes to do with syntactic, lexical, morphological and phonological planning, and how they impact on speech motor control processes at the time of a stuttering moment, is less clear. Such linguistic processes have been commonly investigated through reaction time tasks (i.e., semantic and phonological priming lexical retrieval tasks). There are some studies that suggest stuttered disfluencies originate from deficits in linguistic processes that interfere with speech motor processes (Logan, 2003; Prins, Main, & Wampler, 1997), while other studies have reported evidence to the contrary (e.g., Hennessey, Nang, & Beilby, 2008; Melnick, Conture, & Ohde, 2003).

There are accounts purporting that stuttered disfluencies are a result of deficient language planning processes as their central premise. Perkins, Kent and Curlee (1991) describe the *Neuropsycholinguistic Theory of Stuttering* whereby stuttering results from asynchrony of linguistic and paralinguistic processes of speech production. *The Covert Repair Hypothesis* (Postma & Kolk, 1993) postulates that stuttering stems from a deficit originating from phonological encoding processes. Deficient phonological encoding leads to inefficient phonetic plans required for production of continuous speech, and as a result stuttered disfluencies arise from covert repair of these inefficient plans. The *EXPLAN* model (Howell & Au-Yeung, 2002), on the other hand, emphasises that it is the difficulty with the coordination and timing of linguistic and motor planning processes that results in stuttered disfluencies.

Common features among these theoretical accounts are that the nature of the deficit is a temporal one, and that stuttered disfluencies occur under conditions of time pressure. The models predict that a reduction in speech rate helps to compensate for the deficiencies by providing extra time required for aberrant processes to reduce the frequency of stuttered disfluencies in speech. Furthermore, the models also predict that stuttered disfluencies are more frequent for contexts where linguistically complex material is produced.

2.4.1 Nature of Stuttering and Links with Linguistic Factors

Some observations regarding the nature of stuttering provide a link between stuttering and linguistic factors. Linguistic factors are known to affect variability observed in the characteristics of stuttering. Changes in stuttering frequency can be described in linguistic terms (Zackheim & Conture, 2003), and a reduction in linguistic stress can reduce stuttering frequency (Packman, et al., 1996).

There is a greater tendency for stuttering to increase during (a) spontaneous speech, (b) in complex sentences, (c) on initial words of syntactic units, (d) when the sentence length and/or complexity increases, (e) at initial clause positions, (f) on stressed syllables compared to unstressed syllables (Packman, et al., 1996), (g) on low frequency words compared to high frequency words, and (h) at major clause boundaries (Dworzynski, et al., 2003; Peters & Starkweather, 1990; Watson et al., 1991).

It has been suggested that the onset, development and occurrence of stuttering in young children are related to the demands that language places on a child to appropriately plan and execute speech. The syllable initiation theory proposed by Packman and colleagues (2007) hypothesise that this specifically affects the child's ability to initiate speech motor programs for the production of syllables. There is little evidence to support an onset of stuttering for children producing speech at one or two word levels (Karniol, 1995). Instead, the onset of stuttering, especially between 2 ½ and 3 ½ years of age (Yairi & Ambrose, 2004) coincides with a time period hypothesised to be important in acquisition of major linguistic aspects of language (Locke, 1997).

This time period falls within the analytical and computational phase of Locke's (1997) neurolinguistic model, which refers to the time a child begins to acquire syntax to produce longer and more complex sentences. The need to coordinate what is being learned during this period, places additional demands on children acquiring language (Bloodstein, 2002, 2006). For children who are susceptible to stuttering (e.g., possibly from genetic factors), this period may be especially problematic, and stuttering may manifest as speech motor dysfunction (Packman & Onslow, 1998).

Stuttering may also be attributed to language delay or ongoing difficulties with acquiring and coordinating the surge in growth of language skills (Bloodstein, 2002). This correlates with the integrative and elaborative phase of Locke's (1997) neurolinguistic model, where large volume acquisition is accomplished by a fully integrated, automatic system. From approximately three years of age and onwards, a child continues to learn lexical items and irregular syntactic forms, along with further aspects of language and linguistic communication. For some children whose stutters persist, this phase may be impacted by their stutter and they may display concomitant speech and/or language disorder, with articulation and phonological disorders as the most common co-occurring speech disorders of children who stutter (Arndt & Healey, 2001; Blood, Ridenour, Qualls, & Hammer, 2003).

There have been numerous investigations into the language abilities of children who stutter. However, the results are inconclusive and extensive reviews have been conducted in an endeavour to make sense of the findings (Nippold, 1990, 2012; Ntourou, Conture, & Lipsey, 2011; Ratner, 1997). Over recent years, with more advanced methods of examining speech and language skills, evidence suggests that children who stutter do indeed have depressed language skills. This seems to be especially the case when detailed and more specific aspects of language, such as lexical diversity are examined (e.g., Silverman & Berstein Ratner, 2002).

A meta-analysis of the language skills of children who stutter aged 2;0 to 8;0 years of age by Ntourou, Conture, and Lipsey (2011) concluded that the language skills of children who stutter are inferior to children who do not stutter in the areas of overall language, receptive vocabulary, expressive vocabulary and mean length of utterance. Contrary to this, Nippold (2012) recently concluded through a review of the literature that there is lack of evidence to support that language deficits are associated with the onset and persistence of stuttering in children. She concluded that stuttering has little or no impact on language development.

2.5 Speech Motor Control Research: Addressing the limitations and challenges

One may ask what it is that can be derived from studies of speech motor control for furthering the understanding of stuttering and its management. Understanding the mechanisms of normal speech motor control processes and how these processes differ for people who stutter may help clinicians explain the episode of stuttering to clients, describe what is happening at the level of speech motor control and facilitate the ongoing development of treatment strategies. Knowledge of speech motor processes may be used to facilitate the teaching of speech restructuring techniques that require manipulation and adjustment of fine motor movements. In addition, knowledge of linguistic environments and how they affect the frequency of stuttering may assist in the planning of more appropriate treatment plans. For example, it may be appropriate to target speaking tasks of different levels of complexity at different stages of a therapy program.

Unfortunately, the findings from speech motor control studies have been criticised for not being useful in providing a solid theoretical background of the disorder, or for guiding clinicians in assessment and treatment (Ingham, 1998). Many aspects of research design and methodology contribute significantly to the inconclusive nature of research for the understanding of stuttering. The stuttering conundrum is that it is overt speech that can be investigated, but at the same time this has dilemmas because overt speech is the product of a number of complex processes, many of which are invisible. The challenges associated with investigation of speech production processes of people who stutter are not exclusive to the stuttering world. In particular, research findings in the area of speech motor abilities have been limited in their applicability to children who stutter (Conture, 1991).

What is known about speech motor control processes and stuttering derives largely from investigations of adult speakers. However, adults possess highly individual traits of stuttering that can impact on speech measures. This includes the severity and type of stuttered disfluencies produced, where the stutters occur in speech, the variability of stuttering in different situations, and any unique coping strategies an adult has developed.

Attempts to gain insights into the speech motor control processes of younger individuals who stutter have had limited success (Ingham, 1998). This is because differences noted in adults who stutter compared to controls have not been commonly seen in children who stutter (Zebrowski, Conture, & Cudahy, 1985). Differences that have been observed for children who stutter are reported to be inconclusive, unreliable, and non-informative (Ingham, 1998; Kloth, Janssen, Kraaimaat, & Brutten, 1995; Rosenthal, Curlee, & Qi, 1998).

This position was earlier emphasised by Conture (1991, p. 378) who stated that "no-one has been able to show that young stutterers' speech production abilities and behaviours are useful, objective or observer-independent criteria." Conture goes on to say that speech production measures cannot be used to make the following distinctions: "(a) children's stuttered and non-stuttered disfluencies, (b) children who are or are not stutterers, and (c) those young stutterers who will or will not continue to stutter as adults…"

2.5.1 The Perceptually Fluent Speech of People who Stutter

Differences found in the perceptually fluent speech samples of people who stutter support the notion of disrupted neuromotor systems in people who stutter. The fact that listeners can distinguish the perceptually fluent speech of people who stutter from the samples of normally fluent speakers (e.g., Howell & Wingfield, 1990; Wendahl & Cole, 1961), highlights the presence of 'something' in the speech of people who stutter that is different to those who do not stutter. But to eliminate or reduce stuttered disfluencies in the speech samples of those who stutter, controlled experimental tasks using speech tasks with decreased complexity are necessary. This leads into another problem that is pertinent to older individuals who stutter – they are likely to implement compensatory strategies to avoid stuttered disfluencies (Bloodstein & Bernstein Ratner, 2008; Ingham, 1998). The use of compensatory techniques can then become another confounding variable.

Specifically, the use of therapy techniques can confound experimental findings as they aim to change the speech motor pattern and acoustic characteristics of a speaker (Armson & Kalinowski, 1994). Also known as speech restructuring techniques, changes that commonly occur include speech produced at a slower articulatory rate, with increased airflow, with softer articulatory contacts, with increased duration of vowels, and/or with speech produced using a monotonous voice (see also, Onslow, 1996). Using altered speech patterns to maintain fluent speech will result in speech patterns different to those of people who do not stutter, potentially masking the impact of stuttering on the speech system.

Without a delineation of how the use of compensatory techniques impact on speech measures, it is uncertain if the differences found in studies of speech motor control are due to underlying differences and/or to compensatory techniques employed. In order to address this challenge a reliable method of measuring the quality and quantity of the use of compensatory and therapeutic techniques in adults who stutter is required.

2.5.2 Insights from Younger Participants and Longitudinal Studies

Investigations of individuals who have been stuttering for less time may be particularly informative as they generally have had less time to develop compensatory mechanisms. Differences found in children who stutter may be a more valid reflection of the underlying differences between people who do and do not stutter. This approach is currently being adopted for brain imaging studies of developmental speech disorders.

Such studies also have the challenge of distinguishing differences in brain activity due to compensatory mechanisms or from underlying causes of a speech disorder. Chang and Ludlow (2010), recommended studies that are as close to the onset of symptom presentation, in addition to longitudinal investigation, to increase the understanding of speech development disorders.

Investigating the speech and language skills of children before, during and after stuttering could potentially lead to more informed clinical management, earlier identification and more accurate prediction of chronic stuttering (Adams & Webster, 1989; Bloodstein, 1995). The ultimate outcome would be to implement intervention when it is necessary to prevent, eliminate or minimise the adverse psychological and social effects commonly reported to be associated with chronic stuttering.

While longitudinal investigations have yielded theoretically and clinically important findings, the relevant scientific data are still sparse, and there are not enough data to derive a prognosis (Suresh, et al., 2006). Valid verification can only come from increased and thorough longitudinal follow-ups (Yairi, Ambrose, Paden, et al., 1996).

Many previous longitudinal studies that have focussed on factors informing the persistence and recovery of stuttering in childhood have collected data only after stuttering onset and used pre- and post- outcome measures. To examine how speech and language ability change over time and how this development differs in the course of a child who stutters, it is necessary to collect and analyse data before stuttering begins (Chang & Ludlow, 2010) and at different points of development.

In the past decade there have been several studies into the developmental nature of stuttering (e.g., Ambrose & Yairi, 1999), with a particular interest in the investigation of factors for persistence of stuttering. Yairi and colleagues found that for children whose stuttering persisted (n = 10), they had restricted movements of their articulators compared to those who recovered (n = 10) (Subramanian, Yairi, & Amir, 2003).

Difficulty with expressive language skills gathered from spontaneous language samples was not found to be a factor for the persistence of stuttering (Watkins & Yairi, 1997; Watkins, Yairi, & Ambrose, 1999).

Kloth et al. (1999) followed a group of 93 preschool children to investigate factors for the persistence and recovery of stuttering. Their study is one of the very few to have collected data *prior* to the onset of stuttering. Speech and language data were gathered for children with a positive family history of stuttering from standardised tests as well as from conversational play samples of mothers and their children. They found that for children whose stutters persisted (*n* = 7) there was more variability in their articulation rates, and that their mothers had more complex language production measured as mean length of utterance, than that of children whose stutters did not persist (*n* = 16). At the time of stuttering onset, the articulation rates of children who persisted in stuttering were faster than those of children who recovered (Kloth, et al., 1995).

A more recent study by Reilly and colleagues (2009) adds important insights to the potential risk factors for the onset of stuttering. They conducted a large scale epidemiological study of children aged up to three- years to identify risk factors of stuttering. The study followed children prior to the onset of stuttering and gathered information on a number of variables from 1619 families of young children. It was later confirmed that 137 children started to stutter. The onset of stuttering was not found to be associated with language delay, social and environmental factors, or pre-onset shyness/withdrawal. The four predictor measures that were found to be associated with the onset of stuttering for children up to three- years of age included, being male, having twin birth status, having higher maternal education, and having higher vocabulary scores at the age of two- years old. Vocabulary scores were gathered through the

MacArthur-Bates Communicative Development Inventories, when the children were two- years of age.

In summary, the literature base requires further investigation of younger individuals who stutter to avoid the challenges associated with the investigation of adult participants. Longitudinal studies of speech and language development over time are required to determine how such factors interact for the different pathways of childhood stuttering (Wagovich, Hall, & Clifford, 2009).

2.5.3 The Need for Naturalistic Speaking Tasks

"The study of spontaneous speech is essential if the aim of the enquiry is to gain an understanding of the generative processes involved in speech production" (Goldman-Eisler, 1968, p. 9).

Experimentation to identify and differentiate speech processes has been challenging. This is not surprising given that speech production involves complex and dynamic processes at the cognitive, neuromotor and acoustic levels (Gracco, 1990) in order to progress from higher level processes, through to producing the acoustic events that we can hear. The processes involved form highly interdependent relationships with each other, and are largely invisible. The nature of this complexity is mirrored in recent studies of the neurological correlates of speech production, which have confirmed that the underlying distributed network for speech production is highly complex and dynamic (for a discussion, see Ross, 2010).

To assist with the clarification of the processes that are under investigation in stuttering, the use of simplified tasks has been adopted. Such tasks include single word productions, modelled speech, and/or tasks requiring rapid responses to measure reaction time. The use of such tasks has contributed much to the understanding of specific speech and language processes in stuttering. However, studies have also relied heavily on decontextualised and quasi-speech tasks to target specific processes and to reduce the occurrence of overt stuttered disfluencies. While some tasks have established reliability and validity, they have limited generalisability.

Decontextualised and quasi-speech tasks work on the assumption that speech production is the sum of the function of individual speech and language processes, and as such, these processes can be separated out for individual examination in a static manner. According to constraint accounts of coordination (e.g., Turvey, 1990), they do this by de-emphasising the movement dynamics required to produce connected speech. Therefore, they do not reflect the interactive processes required to produce speech in its natural form. As such, relationships between different factors and how they affect overall performance may not be considered. This results in findings that cannot be readily generalised to natural settings (Bornstein, Painter, & Park, 2002).

The use of decontextualised tasks adds to another dilemma in the area of stuttering. It is known that stuttering behaviours most often occur in connected speech, and even more so in the production of unplanned spontaneous speech. It is thought that the lack of language processing and/or the simplification of speech production constraints contribute to reduced stuttering events (Ludlow, 1999). This concept of speech and language 'trade-off' has also been previously described in children who do and do not stutter. For example, it has been observed that an attempt to speak with more complex language forms result in increased disfluencies in speech (Anderson, Pellowski, & Conture, 2005). Therefore, decontextualised speaking tasks do not capture the complete picture of what normally happens when an individual who stutters has difficulty with the ongoing production of speech.

It is possible that a lack of differences found in speech motor control studies, particularly in children who stutter, are due to the use of decontextualised tasks that do not have the sensitivity to detect differences. There is a need for studies to investigate stuttering in natural speaking contexts and to gather more comprehensive measures of speech and language to reflect the dynamic properties of speech more appropriately. However, the use of natural speaking tasks can be problematic as it can be challenging and time consuming to analyse and interpret data from such tasks. With appropriate data analysis methodology it is possible to quantify the relative contributions of factors impacting on speech production in natural contexts. The use of more ecologically valid speaking tasks can be adopted to investigate the relationship of speech and language measures to stuttering and how such relationships may change over the course of stuttering development.

2.5.4 Verbal Fluency: A multidimensional concept

'Fluent' is the common adjective used to indicate a speaker's success with producing speech with effective and efficient communication as the goal. It is a complex and multidimensional concept consisting of a multitude of processes associated with the delivery, timing and content of speech.

The specific factors a listener uses to make fluency judgments within spontaneous speech are not well understood. However, it is likely to be a largely subjective process determined by cultural and socio-linguistic factors and interpretation of the context or purpose of the speaking situation. Measures of speech motor ability and language ability are thought to be considered at a holistic level. This includes speech rate, number of speech errors or disfluencies (including filled pauses), degree of lexical variation, accuracy and informativeness (i.e., Correct Information Units, Nicholas & Brookshire, 1993), intelligibility, accurate use of syntactic structures and the appropriate use of pauses in speech. It has been suggested that the temporal aspects of speech production are particularly salient features of fluency – pauses, rhythm, intonation, stress, rate and the rate of information flow (Starkweather, 1987).

Many fluency aspects have been explored in people who stutter across studies but not normally within single studies. There has been particular interest in the investigation of the defining characteristics of stuttering (e.g., Teesson, Packman, & Onslow, 2003). The characterisation of the core verbal behaviours that interrupt the flow of speech, however, is still problematic without much agreement amongst researchers (Cordes & Ingham, 1994; Einarsdóttir & Ingham, 2005).

In order to profile a speaker's fluency ability and to provide information on the functioning of the whole speech production system, it is necessary to gather a range of measures to reflect its multidimensional quality. The dynamic processes of speech production need to be considered. Speech motor processes, as well as language planning processes can be gathered. It is noted that while measures can be considered either primarily language-based or reflect speech motor ability, many measures of speech and language output are essentially a product of both. Therefore, measures need to be examined in relation to each other within the system to potentially provide critical insights into their role for the onset, recovery, and development of stuttering.

2.6 Key Speech Processes Under Investigation: Defining speech and language fluency profiles

It has been argued so far that for the field of stuttering to move forward there is a need to (a) integrate principles from different scientific areas for the investigation of how relevant factors interact in stuttering, (b) conduct studies with a developmental focus, and (c) to investigate stuttering under natural speaking contexts with measures to reflect the dynamic processes of speech production and of fluency. This research adopts an integrated approach in order to address the major limitations and challenges of speech motor control research described previously.

The following section presents information on the rationales for the specific measures that can be readily gathered from samples gained in natural speaking contexts. In order to define speech and language fluency profiles for speakers, measures reflecting the multi-dimensional concept of fluency are required.

2.6.1 Articulation Rate

Articulation rate and speech rate are measures of speech motor output and verbal efficiency that provide information on multiple aspects of speech production. *Speech rate*, which is calculated with pauses and disfluencies in speech samples, is linked to processes of conceptualisation and formulation of speech in addition to processes of articulation (see also, Levelt, 1989). In contrast, *articulation rate*, which is calculated without the inclusion of silent pauses and disfluencies is mainly used to target speech motor control processes, and it is commonly expressed as *Syllables Spoken per Second* (Robb, Maclagan, & Chen, 2004). The common criterion used for silent pauses is 250 milliseconds (Goldman-Eisler, 1968).

There is a general agreement that reducing speech rate and/or articulation rate will typically result in a reduction of stuttered disfluencies for people who stutter (Blomgren & Goberman, 2008; Costello & Ingham, 1984; Logan, Byrd, Mazzocchi, & Gillam, 2011). It is, therefore, unsurprising that speaking at a slower rate is often a target technique in the treatment for both children and adults who stutter. In adults who stutter, this is a marked feature of restructuring techniques, such as prolonged speech, but it often comes at the cost of reduced speech naturalness (Onslow, Costa, Andrews, Harrison, & Packman, 1996).

The role of speaking rate has been implicated in theoretical accounts of stuttering. For example, Postma and Kolk's (1993) *Covert Repair Hypothesis* postulates that stuttering behaviours are due to delayed phonological encoding processes, and that this delay is corrected by a reduction in speech rate. The effects of speech rate on the frequency of stuttering behaviours, also supports the viewpoint of stuttering as a disorder of the timing of speech (Blomgren & Goberman, 2008).

Studies investigating both speech and articulation rate in stuttering have had conflicting results. Generally, it is reported that people who stutter speak with a slower rate than people who do not stutter (e.g., Bloodstein, 1944), but there are also reports of no differences (e.g., Hall, Amir, & Yairi, 1999).

2.6.2 Language-Based Measures

As previously discussed, language factors are important for understanding stuttering. However, the literature reports equivocal findings. It is important to gather age-appropriate language measures, in addition to measures of speech motor control, to examine a system holistically. Given that the frequency and likelihood of stuttering has been described to be affected by linguistic complexity people who stutter may 'trade-off' aspects of their speech and language production in order to decrease noticeable stuttering behaviours.

2.6.2.1 Language-Based Measures for Children

In children, information about language use, content and development has been widely investigated using Systematic Analysis of Language Transcripts (SALT: Miller, 2008). As a result, research literature contains normative data for the specific measures produced by SALT upon which comparisons can be made. Global measures of language performance from SALT can inform about different aspects of speech and language production and are robust indicators of language impairment (Heilmann, Nockerts, & Miller, 2010).

More specifically, the *Number of Different Word Roots* has been demonstrated to be a robust indicator of vocabulary skills. The *Mean Length of Utterance in Morphemes*, a measure of morphological and syntactic skills in young children, has been found to be one of the most reliable and robust indicators of language impairment (Brown, 1973). A minimum sample size of 50 utterances is recommended as there is reduced reliability for these measures for short speech samples. The *Number of Total Utterances* produced by a child has been found to be a reliability indicator of chronological age in a cross-sectional sample of three- to 13- year olds and is a reliable measure for short speech samples (Tilstra & McMaster, 2007).

In addition, the *Percent Intelligibility* and *Percent Mazes* are potentially useful measures to compare typical and atypical development. However, they have not been found to be reliable indicators of typical speech and language development (Miller, 2008).

Percent Intelligibility is defined as how understandable an individual's speech is, and though there are many factors that contribute to this, the most common factors are phonological ability, and speech motor control ability (i.e., speech rate, use of intonation, prosody) (E. Klein & Flint, 2006). As such, this measure is largely a measure of speech motor ability.

Mazes are considered to be disfluencies that do not contribute meaning to ongoing flow of language (Loban, 1976; Miller, 2008). They are typically described as filled pauses, repetitions and revisions that may implicate difficulty in language planning as well as speech motor control difficulty. For children who stutter, *Percent Mazes* may also include stuttered disfluencies depending on whether these disfluencies carry linguistic content or not.

2.6.2.2 Language-Based Measures for Adults

For adult speakers, it is important to measure communicative effectiveness. The *Correct Information Unit* (CIU: Nicholas & Brookshire, 1993), and *Performance Deviation* (PD: Brookshire & Nicholas, 1995) analyses, have been demonstrated to have acceptable reliability for use with adult speakers with and without speech and language impairment after brain injury (aphasia). Both measures focus on spoken language content informativeness and efficiency rather than the use and content of language forms and adherence to grammatical rules.

CIU measures reflect the degree of accuracy and informativeness of speech production for a given context hence it is a measure of language production (Nicholas & Brookshire, 1993). PD analysis is an extension to CIU analysis. The measures inform about the frequency, rate and type of errors each participant produced. The PD analysis gives insight into the types of errors produced by a speaker by categorising the productions that did not qualify as a ‘word’ and the productions that did not qualify as a ‘Correct Information Unit’ (Brookshire & Nicholas, 1995). Therefore, it is a measure that can provide information on speech motor control processes as well as language planning processes.

2.6.3 Production of Pauses in Speech

An aspect of fluency that can be investigated under natural speaking conditions is the production of pauses in speech. The 'Fluency Profiling System' is a novel approach for the analysis of pauses in speech as a whole for both normal and disordered speech (Kirsner, Dunn, Hird, & Hennessey, 2003; Little, Oehmen, Dunn, Hird, & Kirsner, 2012). The system focuses on analysing the distribution of pause durations, as well as the distribution of speech segment durations. Coupled with the measurement of other related aspects of fluency, the pause measures provide a comprehensive analysis of speech fluency.

A background to pauses in speech is given in the following section before presenting a background to the Fluency Profiling System described by Kirsner and colleagues.

2.6.3.1 The Significance of Silence

Spontaneous speech contains intervals that are silent and intervals that are perceivable as 'noise'. Noise can encompass vocalised productions that carry lexical information (speech) or non-speech sounds, such as grunts, tuts, or laughter. The latter of these does not necessarily mean it is devoid of communicative information. The 'silences' of the system or pauses, are essential components of the speech stream for both the speaker and the listener. Pauses are thought to be an integral part of continuous speech segmentation that leads to the effective analysis of the speech stream. They have been found to occupy approximately forty to fifty percent of the total speaking time for adults (Goldman-Eisler, 1968).

It is physically impossible to produce speech without pauses, because many components of the speech system require time to do 'something'. It is also highly challenging, if not impossible, for listeners to understand speech that contains 'no' pauses. This has been found in the speech of people with schizophrenia whose incoherent speech was related to a reduced frequency of pauses (Spitzer et al., 1994).

Pauses in speech are related to a myriad of communicative functions ranging from marking important information to signalling anxiety (Esposito, Stejskal, Smekal, & Bourbakis, 2007). Esposito and colleagues, described the use of pauses in speech as a multi-determined phenomenon, stating that pausing behaviour is not only related to physical mechanisms of speech production (e.g., breathing and articulation) but also to the socio-psychological, linguistic and cognitive factors associated with speech production and communication.

More recently, there has been interest in pauses for the application of automatic speech recognition systems (Esposito, et al., 2007; Little, et al., 2012). These systems depend on accurate detection of word, clause and paragraph boundaries for speech recognition efficiency. Pause detection has been identified as a crucial factor for this. There has also been advances in the investigation of pauses using functional magnetic resonance imaging to discover the neural correlates of pauses (Kircher, Brammer, Levelt, Bartels, & Mc Guire, 2004).

Pauses have been found to relate to the specific speech production processes of word retrieval, changing prosody, stress marking, error detection and/or repair, and to the development of new speech acts. They are also a product of the temporal and spatial coordination of independent movements required for the production of speech (Kirsner, Dunn, Hird, et al., 2003).

Seminal work conducted in the 1960s by cognitive psychologist Goldman-Eisler (1968) investigated cognitive pauses that reflect speech planning and conceptualisation (Levelt, 1989). Goldman-Eisler described three general reasons for the halt of articulatory movement: (a) the discontinuity of phonation due to articulatory shifts, which is the product of speech sounds adjacent to each other requiring movement of the articulators, (b) the discontinuity of phonation relating to hesitation, and (c) when expiration comes to an end and a new breath occurs.

Goldman-Eisler (1968) was particularly interested in hesitation pauses. For normal speakers, she found that it was the production of hesitation pauses that played a major role in determining speech rate rather than articulation rate. As such, she proposed that hesitation pauses reflect a speaker's *uncertainty* in speech production. 'Uncertainty' is generally associated with the general outline of what the speaker wants to say, the syntactic structure in which to say this, and lexical selection based on the syntactic framework. Therefore, hesitation pauses reflect linguistic-symbolic processes, as well as the conceptualiser and formulator processes, of van der Merwe's, and Levelt's (1989) models respectively.

Evidence for the role of hesitation pauses in planning processes comes from the investigation of speech planning processes and cognitive processes required for speech production, for example, attention and working memory (Butterworth, 1979; Goldman-Eisler, 1968). Goldman-Eisler (1968) found that tasks requiring increased cognitive demand resulted in longer and more frequent pauses. Specifically, cartoons were presented to participants and they were asked to provide an *interpretation* of the cartoon. This interpretation was found to have twice the amount of pausing time compared to when participants were asked to *describe* the content of cartoons. Pause production also varied with different degrees of spontaneity. Goldman-Eisler found that a reduction in pause time was observed for tasks that were repeated with more trials and were less spontaneous.

Hesitation pauses are also thought to be related to an increase in information processing and to reflect the degree of uncertainty involved in lexical selection. Butterworth (1979) found that hesitation pauses frequently followed neologisms for a participant with aphasia, and had interpreted this as a reflection of the pauses being indicative of lexical function, namely word finding difficulty. It has also been suggested that pauses that occur *between* clauses (i.e., grammatical junctions) reflect planning of the following clause, whereas pauses occurring *within* clauses generally reflect lexical retrieval processes (Levelt, 1989).

To date there has not been a lot of interest in the investigation of the other types of pauses described by Goldman-Eisler. That is, articulatory pauses and breathing pauses. Goldman-Eisler was essentially only interested in the hesitation pause and consciously separated out articulatory 'gaps' from hesitation pauses, the former of which was identified as breaks in phonation of less than a 250-millisecond duration. This means that essentially she separated out *short* pauses from *long* ones, and deleted all the short ones from her analyses. She expressed that "this might mean loss of some data, but it ensures the clear separation of hesitation pauses from phonetic stoppages" (1968, p. 12). This practise essentially deleted important aspects of how an individual coordinates processes required for speech production. This issue is discussed in more detail later in this chapter.

2.6.3.2 Pauses in Children

There is a paucity of data regarding pause production and its development in children. The specific role of pauses in children's speech and how the properties of pauses may change with speech and language development is unknown. It is possible that the frequency and duration of pauses may decrease with speech and language development. Kowal, O'Connell, and Sabin (1975) found that when completing a story telling task, the frequency and duration of pauses used decreased as children became older. It is possible that newly acquired syntactic structures play a role in this reduction of pauses with age (Rispoli & Hadley, 2001). Pauses in the speech of school-aged children were also found to reflect cognitive demand. Children used more pauses, hesitations, longer pauses, and had a slower speech rate for a task requiring an explanation as opposed to a task requiring a description (Levin, Silverman, & Ford, 1967).

2.6.3.3 Insights for Impaired Speech and Language Functioning

While the investigation of pauses in speech has potential to provide information on speech and language impairment, the utility of pause analysis procedures has been problematic. As a result, it has not been commonly used for the investigation of normal and disordered speech and language processes in comparison to other measures, such as lexical decision tasks and reaction time tasks.

Limited research has addressed the production of pauses in children and the impact of development on pausing. Even so, there are some studies that have found that children with Specific Language Impairment (SLI) produce more pauses in speech than children with typically developing language (e.g., Boscolo & Rescorla, 2002). This is possibly due to difficulties with formulator processes for the children with SLI. However there are also studies that have reported no group differences for children with SLI and typically developing children (e.g., Smith, Hall, Tan, & Farrell, 2011).

Thurber and Tager-Flusberg (1993) found that children with Autism (n = 10 with a mean age of 12;1 years) compared to typically developing children (n = 10 with a mean age of 7;9 years) used fewer pauses within phrases (non-grammatical pauses) when telling stories. The authors interpreted this finding to be indicative of the reduced cognitive complexity of the stories told by children with Autism.

2.6.4 Production of Pauses in People who Stutter

Studies of pauses in stuttering are limited. This is despite stuttering being classified as a disorder of fluency (Wingate, 1964) with pausal elements commonly implicated (Silliman & Leslie, 1983). People who stutter have been described as having an increased number of hesitations and breaks in the flow of speech (Logan, 2003). As an illustrative example, Leung and Robson (1990, p. 498) defined stuttering as "…a speech fluency disorder characterized by frequent repetitions, prolongations, hesitations, or *pauses* [emphasis added] that disrupt the rhythmic flow of speech." Another indication of pausal elements in stuttering is from Prasse and Kikano (2008, p. 1271) stating that "...usually, stuttering manifests as repetitions of sounds, syllables, or words or as speech blocks or prolonged *pauses* [emphasis added] between sounds and words."

It has been found that the higher frequency of pauses in the speech of people who stutter, along with a slower speech rate, are important perceptual cues for discriminating between the speech of people who do and do not stutter (Prosek & Runyan, 1982). The production of pauses in speech has been found to contribute to the overall judgment of fluency in people who stutter. A recent study by Tiling (2011) found that out of three different disfluency types – stuttered, hesitant, and prolonged – it was hesitant speech that was associated more with negative evaluations from listeners. Tiling (2011) defined hesitant speech to consist of interjections, which are starters and fillers, revisions, incomplete phrases, and *pauses*.

An earlier study by Love and Jeffress (1971) found that adults who stutter (n = 25) produced significantly more 'brief' pauses (150 milliseconds to 200 milliseconds) in their perceptually fluent and repeated readings of the same passage compared to people who do not stutter (n = 25). They concluded that these brief pauses were associated with a stuttering speaker's attempt at controlling stuttering in speech saying that "the stutterer continues to do something different from the normal, even when he is not stuttering," (p.239).

In contrast, an acoustic analysis study conducted by Howell and Wingfield (1990) did not show differences in duration, rate or the number of pauses for adults who stuttered compared to controls. However, the inconsistent results for this study compared to Love and Jefress' study may be due to the speech stimuli used for analyses. Howell and Wingfield (1990) used single clauses, each approximately two seconds in duration. They compared clauses that contained one stutter to clauses with no overt stutters. The authors reported that the number of pauses available for analysis were insufficient for significance testing.

A recent study by Beltrame et al. (2011) is the only study that has examined pauses in children who stutter (n = 10). The children had a mean age of 10 years old. The study measured pauses in the narratives of children who stutter and compared them to the narratives of children with Asperger syndrome (n = 4). No group differences were found for the number of pauses produced that were over 250 milliseconds in duration. There was no control group in this study comprised of children without speech and language difficulty. The authors described that children with *moderately severe* stutters (using the Stuttering Severity Index by Riley, 1994), produced more pauses in speech than children with *mild* and *severe* stutters. But no statistical analyses were conducted to determine the significance of this.

2.6.5 The Fluency Profiling System: Pause analysis

The following section describes in more detail some limitations of pause analysis procedures and a novel approach to addressing such limitations - *The Fluency Profiling System* (Kirsner, Dunn, Hird, et al., 2003). Analysis of pauses using this procedure demonstrates that pause durations in speech reveal two lognormal distributions, one of shorter duration than the other but with a degree of overlap between them. The short and long pause duration distributions are hypothesised to reflect contributions from linguistic-symbolic phase of speech production and from motor control processes, respectively, and can be examined in a single system.

The Fluency Profiling System allows for the investigation of speech in a real-time and temporally defined system to provide insight into the adaptive nature of processes that have occurred as a result of speech and/or language impairment. Conducive to the application of the dynamic systems theory to cognitive processing, natural speech and language samples are fundamental to this approach (Hird & Kirsner, 2010). There is an emphasis on the importance of the interaction of cognitive processes required for functional speech production, as opposed to decontextualised tasks which examine the isolated and autonomous processes of a system.

Pause durations examined using lognormal distributions have been demonstrated to be sensitive to speech and language impairment for participants with Broca's aphasia. Participants with Broca's aphasia had ultra-long pause durations compared to controls (Hird & Kirsner, 2010; Kirsner, Dunn, Hird, et al., 2003). Speakers with Friedreich's Ataxia of Speech were also found to have longer short and long pause means than that of controls (Rosen et al., 2010).

2.6.5.1 Identifying and Measuring Pauses

Many of the difficulties of analysing pauses can be attributed to challenges regarding the identification of pauses and defining their roles in planning and executing of speech. There are a wide range of reasons as to why a speaker may pause in speech, and identifying the role of pauses is open to interpretation. There are also methodological and statistical challenges associated with pause analysis procedures.

Difficulties with pause analysis procedures may reflect the use of weak procedures in measuring and examining pause data. Solutions to these challenges are needed in order to improve the utility of pause procedures.

Technological advances in the past century have contributed to more efficient and accurate ways to gather, store and disseminate data. For the investigation of pauses in speech, identifying and measuring pauses have come a long way since Goldman-Eisler's time in the 1950s and '60s when the humble tape recorder was utilised as the main tool for recording speech. Goldman-Eisler's methodology allowed pauses to be marked to 100 milliseconds, using a pen-oscillograph to mark out pulses caused by a signal detector, which was then converted onto magnetic tape for a visual record. Researchers can now operate in a fully digital manner to record pauses. The use of technology and the spectrogram from acoustic analysis programs, such as PRAAT software (Boersma & Weenink, 2010), can be used to assist in providing a more objective identification and accurate measurement of pauses.

2.6.5.2 Making Sense of Pause Data

Procedures used for examining and interpreting pause data have been criticised for not readily taking into account (a) the counting of all pause duration data, (b) the skewness of pause distributions, (c) the need to separate the short and long pause distributions using a threshold procedure, and (d) the need to obtain separate measures of each distribution (Kirsner, Dunn, Hird, Parkin, & Clark, 2002).

First, not all valid pause duration data were included for analyses. Many researchers followed the methodology of Goldman-Eisler using a 250- millisecond criterion to discard articulatory pauses. As the researchers were essentially only interested in hesitation pauses, this practice may have seemed appropriate. However, the

250 millisecond criterion was an arbitrary cut-off with no convincing evidence for its validity.

Deleting articulatory pauses less than 250 milliseconds also removed a significant number of the total pauses produced in speech by a speaker. This can be seen when the frequency and duration of pauses in a normal speaker producing a monologue is plotted visually (see Figure 2.1), where the majority of pauses are ‘shorter’ in duration. Since the temporal and spatial coordination of individual speech movements are essential to the overarching goal of producing an efficient message for the listener (Gracco & Abbs, 1986), it is argued that the deletion of articulatory pauses resulted in the removal of important aspects of a speaker’s ability to coordinate and integrate the processes required for producing speech in real-time.

The 250 millisecond cut-off not only meant a loss of data but it also resulted in an assumption that all speakers, in any speaking context, possess the same articulatory-hesitation threshold. As there are many speaker styles, languages and situational contexts, the likelihood of a universal criterion is questionable.

Figure 2.1 shows that pause duration distribution is highly skewed (positively), with most pauses being 100 milliseconds duration or shorter. This skewness is due to the unit of measurement for pause durations as time, and it is a problem for statistical methods that favour the normal distribution. The distribution of pauses is comprised of a large number of shorter pauses in the system, which tail off to less frequent but longer pauses. In fact, the maximum duration of a pause is theoretically undefined. However, practically, it is bound by linguistic and social rules. As spontaneous speech is a temporally- defined system, listeners and speakers have a biological and conscious threshold for maximum pause duration. It would be ecologically invalid to pause too long in conversation. However, ‘how long is too long’ can be dependent on different contexts and purposes for which communication is produced.

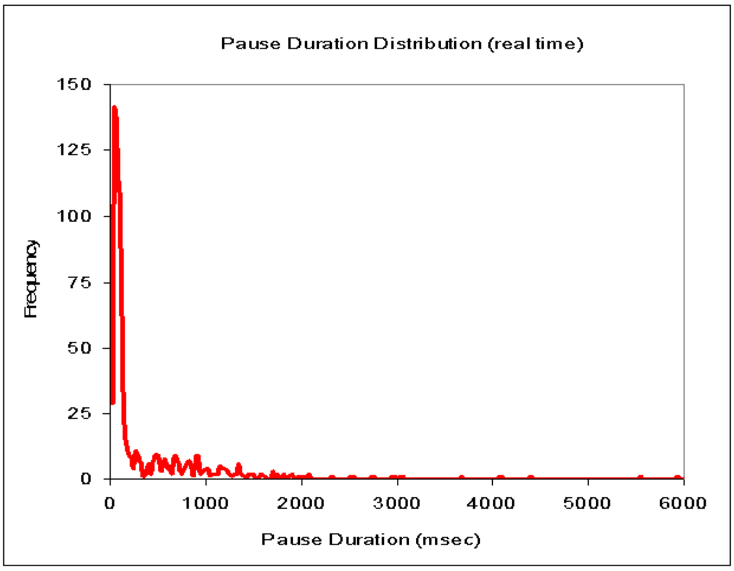


Figure 2.1: Frequency of pauses plotted in real time

(Kirsner, Dunn, Hird, et al., 2003)

2.6.5.3 Lognormal Pause Distributions

A solution to the skewness problem was implemented by Kirsner and colleagues (Kirsner, Dunn, Hird, et al., 2003; Kirsner, et al., 2002). Raw pause duration and speech segment duration data (milliseconds) were collated and subjected to a logarithmic transformation. The transformation revealed one lognormal distribution for *speech* segments, and two lognormal *pause* duration distributions. Figure 2.2 shows the two lognormal pause duration distributions. On this figure, the *pause* duration distribution on the left can be characterised as containing pauses that are shorter in duration, but the frequency of those shorter pauses is higher than the distribution on the right. The distribution on the right contains pauses that are longer in duration but of fewer numbers than the shorter pauses. These two distinct pause duration distributions, short and long, reflect the multifunction of pauses in speech, with both considered equally important for the production of speech. Campione and Veronis (2002) also applied a logarithmic conversion to pause data and published their findings at about the same time.

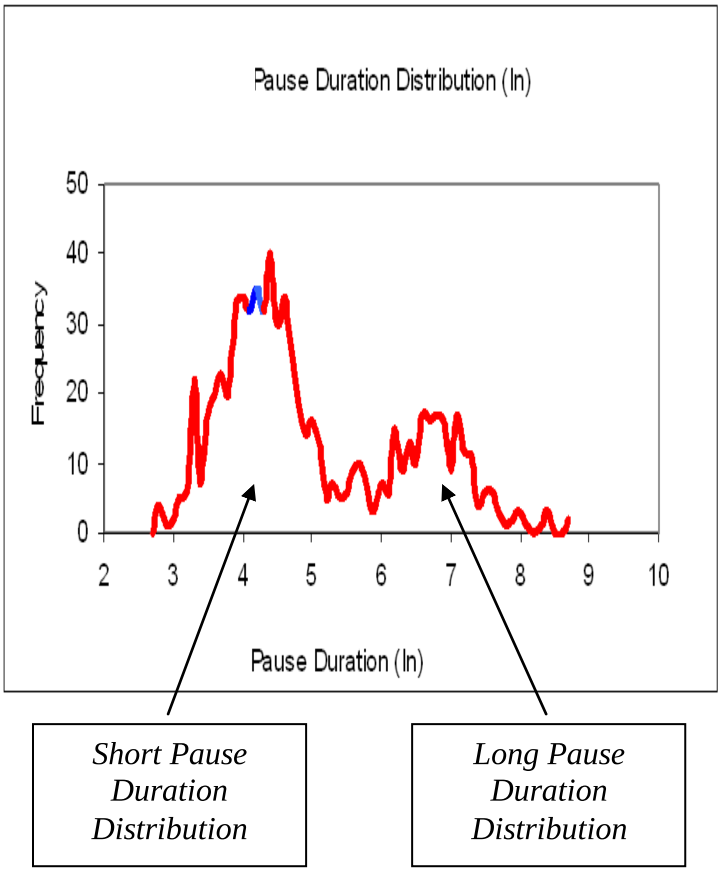


Figure 2.2: Frequency of pauses plotted after logarithmic transformation (Kirsner, Dunn, Hird, et al., 2003)

The significance of the lognormal distribution is symmetrical, and therefore statistically more robust than other distributions (Rosen, Kent, & Duffy, 2003). It has also been found in many naturally occurring complex systems, such as the occurrence of insect species in a particular ecosystem (Halloy & Whigham, 2004). Halloy and Whigham (2004) describe properties of the lognormal system as one that consists of 'agents'. Agents are analogous to species, and they attract and compete for resources to survive. Resource attraction and competition drive interaction between the agents.

Importantly, in the context of speech production it is argued that the existence of the lognormal distributions in speech production are hypothesised to reflect a system that involves the interactive and multiplicative effects of a number of processes, rather than of individual and additive processes (Kirsner, Dunn, Hird, et al., 2003). The system dynamically integrates information from a diverse range of processes and factors (Hird & Kirsner, 2010). Such factors are linked to a speaker's ability to integrate, coordinate and temporarily store information in order to generate speech in real time and to deliver an efficient message.

Kirsner and colleagues used PRAAT acoustic analysis software (Boersma & Weenink, 2010) to visually and acoustically assist in identifying and measuring pauses. Specifically this involves the identification of periods of 'silence' from periods of 'noise', that is, pauses in spontaneous speech from speech segments. The lower limit pause boundary threshold adopted was 20 milliseconds, with no upper limit set. Speech segment durations had no lower or upper limit.

Estimates of the means and variances of the lognormal distributions were computed by applying the Expectation Maximisation algorithm (McLachlan & Peel, 2000). Signal detection theory was used to separate short from long pauses (see Figure 2.2), and one distribution of speech segment duration data. The speech segment duration distribution is bound by long pauses, within which short pauses are folded.

The Fluency Profiling System calculates measures derived from the Expectation Maximisation algorithm by taking into account all pauses produced by a speaker. There is no need to adopt an arbitrary pause criterion to be able to categorise whether a pause is a short or long pause. Instead, the threshold for short and long pauses is calculated uniquely for each speaker.

Common measures from the Expectation Maximisation algorithm include the means and standard deviations for short pause, long pause and speech segment duration distributions. The relative contributions of pauses to speech produced can also be gathered as a proportion of pause time. Additional measures computed from the short and long pause properties include the misclassification rate, which is the degree of overlap of the two pause duration distributions, and the *distribution threshold* (see Figure 2.3), which is the point at which the two distributions intersect.

Each of the two lognormal pause distributions, the *short* and *long* pause duration distribution, is hypothesised to consist of a particular group of processes that are primary to that pause distribution (see Figure 2.3). *Long* pauses are hypothesised to reflect processes primarily involved in breathing and speech planning as described by Levelt (1989), such as conceptualisation and formulation processes. Conceptualisation includes intention, attention and self-monitoring. Formulation includes lexical retrieval, grammatical planning, and prosodic marking.

Short pauses are hypothesised to consist of processes relating to speech motor control and execution processes, including articulation to reflect articulatory configurations such as production of voiceless transitions, voice onset times and stop gaps. It takes about 100 milliseconds for the vocal cords to move inward from their open or neutral position (Soron & Lieberman, 1963). For children who are normally fluent, they produced stop gaps that were on average 123 to 127 milliseconds for words beginning with /b/ and /p/ respectively (Zebrowski, et al., 1985).

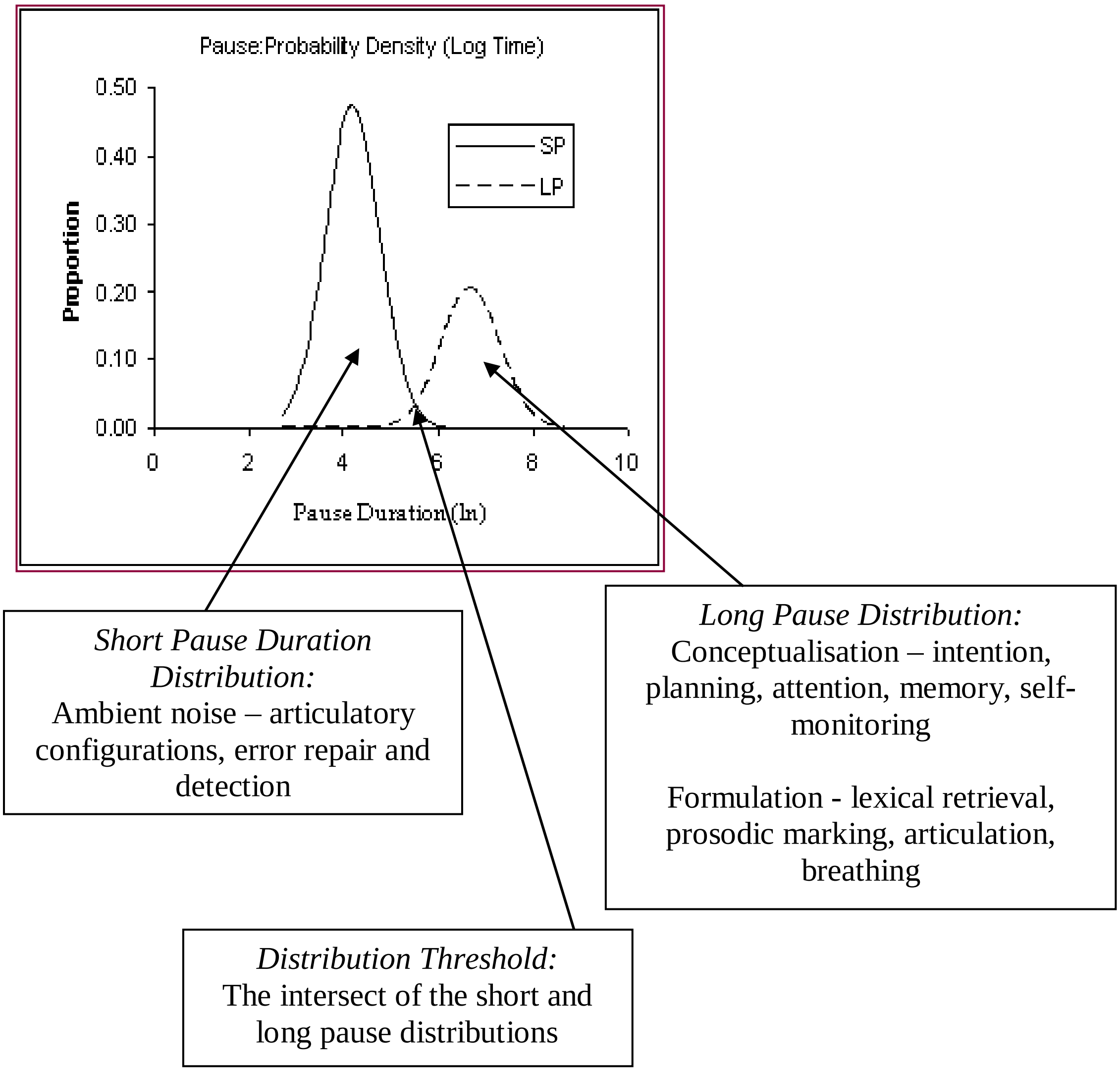


Figure 2.3: Long and short pause duration distributions, and hypothesised corresponding parameters

(Adapted from Kirsner, Dunn, Hird, et al., 2003)

In addition to the processes related to articulation, longer *short* pauses can also be related to language, error repair and detection, and social functions. A study conducted by Hieke, Kowal and O'Connell (1983) found that in political speeches and readings of poetry that over 90% of pauses between 130 to 250 milliseconds related to error repair and marking for emphasis. It is possible for error repair to be executed via the auditory loop 200 milliseconds after production of the error (Levelt, 1989).

Shorter *short* pauses between 50 and 100 milliseconds can be inter- word pauses. As such, these short pauses could also play a role in word retrieval processes. The identification of shorter short pauses requires special attention to identify real speech from ‘noise’ that can appear to be speech in a spectrographic analysis. It is possible that some short pauses cannot be distinguished from ambient noise.

In summary, the presence of lognormal distributions and their related processes can assist in clearer interpretations of the contributions of language, as well as a clearer understanding of the speech motor control processes in stuttering. Pause distribution measures can be conducted for systematic and quantitative analyses throughout the development of speech fluency. This could potentially provide critical insights into the developmental progression of stuttering, assist in early identification of those who stutter, and better predict which children could continue to stutter into adulthood.

There are added advantages to the Fluency Profiling System procedure as it is appropriate for all ages. Also, it is possible to examine pauses independently from linguistic content produced by a speaker. This provides a unique opportunity to examine the impact of stuttered disfluencies on the spontaneous speech of people who stutter. The lines of pause and speech data that are identified as part of a stuttered disfluency can be separated and comparatively examined.

To date, an investigation of pauses in the connected spontaneous speech of people who stutter, as well as the use of lognormal distributions, have yet to be performed. This procedure has not been used to directly investigate the pausing characteristics in children who stutter. Pause analysis adds informative and complementary information to the commonly used fluency measures of articulation rate and spoken language measures.

2.7 Summary of Present Research

The overall aim of this thesis was to define and compare the speech and language profiles for children with and without a family history of stuttering, together with comparing school-aged children and adults who stutter to controls. This was done in order to ascertain whether differences in measures of speech language production are a reflection of the cause or a consequence of stuttering.

The three groups of participants were targeted to investigate potential markers for the onset of stuttering and to track the development of stuttering. Articulation rate and age-appropriate language measures were gathered in conjunction with pause measures from The Fluency Profiling System (Kirsner, Dunn, Hird, et al., 2003; Kirsner, et al., 2002). All speech and language measures were gathered from natural speaking contexts – conversation and play (Study 1), and structured monologues (Experiments 2 & 3).

To further help with clarifying cause from consequence, perceptually fluent speech samples of children and adults who stutter were compared to their speech samples containing stuttered disfluencies. Between-groups differences were investigated for the absolute means of speech and language measures and for the way speech and language measures relate to each other. Clinical stuttering measures were gathered and analysed to explore associations with speech and language measures. Information about the use and practise of fluency techniques for adults who stutter was also gathered through questionnaires.

2.8 General Hypotheses

The following section presents some general hypotheses for this study. Individual study chapters provide more specific hypotheses for the population studied. Table 2.1 provides a summary of the evidence for cause and for consequence of stuttering across the studies of the present study.

2.8.1.1 Familial History as a Cause of Stuttering

To support a familial history of stuttering as a cause, it was predicted that there would be group differences in speech and language profiles between children with and without a family history of stuttering. Also, it was predicted that a greater number of children from the familial group would start stuttering than those in the non-familial group.

2.8.1.2 Differences in Speech and Language Fluency Profiles as Cause of Stuttering

If group differences in speech and language fluency profiles are indicative of the underlying causes of stuttering, there would be differences in the speech and language fluency profiles of young children *before* the onset of stuttering. That is, predictor variables for the onset of stuttering would exist. It can also be expected that differences would exist between the perceptually fluent speech of those who stutter, and the speech of those who do not stutter.

2.8.1.3 Differences in Speech and Language Fluency Profiles as Consequence of Stuttering

If differences in speech and language fluency profiles are a consequence of stuttered disfluencies, then differences in speech and language fluency profiles would only become apparent *after* the onset of stuttering. Also, it would be expected that group differences would only be present for speech samples with stuttered disfluencies present. That is, group differences would not be present for speech samples with no stuttered disfluencies.

2.8.1.4 Trade-offs in the Speech of People who Stutter

The effect of stuttered disfluencies on speech production would also be informed by any associations of clinical stuttering measures (i.e., Percent Syllables Stuttered) with speech and language measures found for participants who stutter. It was hypothesised that stuttering participants use certain speech ‘trade-offs’ in order to maintain fluency in speech. This would be consistent with linguistic trade-off models, such as Crystal’s (1987) ‘bucket’ theory, which predicts that increased complexity and/or demand in one area of speech and language production are associated with decreases in accuracy and/or complexity of another area of speech and language production. A trade-off can also be conceptualised as ‘compensation’ made by the speaker. People who stutter often trade-off articulation rate to maintain fluency (Onslow, et al., 1996). Therefore, Percent Syllables Stuttered was predicted to have a negative association with articulation rate, expressed as Syllables Spoken per Second.

According to multifactorial accounts of stuttering and dynamic accounts of speech production (e.g., van der Merwe, 2009), it has been established that increasing language demand and/or complexity can also affect the fluency in young children by increasing their production of disfluencies. Therefore, it was also predicted that Percent Syllables Stuttered would be negatively associated with language ability (i.e., Mean Length of Utterance Morpheme, Number of Different Word Roots, and Correct Information Units). Compensation may also be achieved through increased production of pauses in speech.

In addition, there may be other trade-offs across speech motor control and language-based measures external to measures of stuttering. For example, differences in components of the language system (lexical and syntactic) have been hypothesised to impact on the forward flow of speech language production (Anderson & Conture, 2000), and may impact on overall articulation rate.

2.8.1.5 Speech Motor Control Processes and Linguistic Processes

To implicate *speech motor control* processes for the underlying cause of stuttering, differences would be observed for measures, short pause mean and/or articulation rate. Percent Intelligibility may also be implicated for children who stutter as it is considered to be a measure of speech motor control processes. Research indicates that this measure informs of articulation and phonological skill in particular (E. Klein & Flint, 2006).

Linguistic planning processes would be implicated if differences in the means of long pauses are observed. For children, differences could be observed for language-based measures of SALT, such as Mean Length of Utterance in Morphemes and Number of Different Word Roots and for adult participants, Correct Information Unit measures.

There are a number of measures which could implicate both speech motor control *and* language planning difficulties including the measures of error production, Percent Mazes for children and Performance Deviation measures for adults. Misclassification Rate and Speech Segment Mean from the Fluency Profiling System are measures derived from the calculation of the short and long pause distribution and are considered to be measures of holistic speech and language functioning.

2.8.1.6 The Null Hypothesis

The null hypothesis is there are no differences in speech and language functioning associated with stuttering when people who stutter are compared to control participants in natural speaking contexts. More specifically, there will be no group differences for (a) children based on groupings by both *Family History* and *Stuttering Status* in Study 1, (b) school-aged children based on grouping by whether they stutter or not in Study 2, and (c) adults based on grouping by whether they stutter or not in Study 3.

Table 2.1: Summary of potential findings to indicate cause or consequence of stuttering

Evidence for Cause of Stuttering	Evidence for Consequence of Stuttering
Familial Factor	Speech and Language Fluency Profiles
Group differences in speech production ability exist between those with a familial history and those without (Study 1)	Group differences in speech and fluency profiles exist after the onset of stuttering between those who develop a stutter and those who develop typically (Study 1)
Greater number of children with family history to start stuttering compared to those without a family history to start stuttering (Study 1)	No group differences in speech and language fluency profiles exist between the perceptually fluent speech of those who stutter and the speech of those who don't stutter (ALL Experiments)
Speech and Language Fluency Profiles	Group differences in clinical stuttering measures associated with speech and language fluency profiles exist between those who stutter and those who don't (ALL Experiments)
Group differences in speech and language fluency profiles as predictor variable(s) exist before the onset of stuttering, between those who will develop a stutter and those who will develop typically (Study 1)	
Group differences for speech and language fluency profiles exist between the perceptually fluent speech samples of those who stutter and the speech of those who don't stutter (ALL Experiments)	

CHAPTER 3: GENERAL METHODS

To avoid repetition, this chapter provides a general methodology for the gathering of speech and language measures common to all three studies of this project. It is intended that this chapter be read in conjunction with the methods sections of each of the ensuing study chapters.

3.1 Data Gathering Methodology

Participant characteristics, equipment and procedures for speech sampling are described in more detail in the corresponding study chapters. Table 3.1 gives an overview of the characteristics of the three studies in this project.

3.1.1 Clinical Stuttering Measures

Stuttering diagnosis for all participants was determined through agreement among different observers, including qualified speech pathologists, in regards to the presence of core stuttering behaviours (Wingate, 1964). A frequency count of Percent Syllables Stuttered and Stuttering Severity Score was gathered to quantify the frequency and severity of stuttering for individuals. These measures were gathered to characterise stuttering for participants who stutter, not to determine diagnosis of stuttering.

Percent Syllables Stuttered is one of the most widely used measures of stuttering frequency in clinical and research settings (Cordes & Ingham, 1994). Guitar (2006) characterises stuttering severity indicating mild (0-2%), moderate (2-12%), severe (12-25%) and very severe (>20%). However, people who stutter may produce speech with no or little percent syllables stuttered depending on the speech sample the rating is based upon. For example, due to the episodic nature of stuttering and the variability of stuttering in children, a Percent Syllables Stuttered criterion for stuttering does not reliably determine the presence or absence of stuttering. Adults who stutter may employ therapy techniques to minimise or eliminate the frequency of stutters in their speech yet they still consider themselves to have a stutter. O'Brian et al., (2004) reported 30% of adults who stutter displayed a percent syllables stuttered rating of 2.9% or below.

Percent Syllables Stuttered also has limitations in providing a comprehensive profile of the characteristics of an individual's stutter. The measure cannot inform about where stuttered disfluencies occur or the duration of the stutters of a speaker. Therefore, severity rating scales were also used in this study. A 9-point scale was used for severity ratings; a score of 1 represents no stuttering and 9 represents extremely severe stuttering (Sue O'Brian, Packman, & Onslow, 2004). For Study 1, clinical stuttering measures were only gathered after a child was diagnosed to be stuttering. See Chapter 4, Methods (section 4.2), for more detailed information on how a stuttering diagnosis was determined.

Table 3.1: Summary details for studies in this project

	Study 1	Study 2	Study 3
Total Participant Number	18	26	24
Participant Groups	With Family History (*n* = 9) Without Family History (*n* = 9)	Children Who Stutter (*n* = 13) Controls (*n* = 13)	Adults Who Stutter (*n* = 12) Controls (*n* = 12)
	Children Who Started Stuttering (*n* = 5) Children Who Developed Typically (*n* = 13), within the period of this study		
Number of Sessions/Samples Data	Four (3month intervals)	One	One
Participant Age Range	First Session: 21 to 48 months Final Session: 30 to 57 months	3;11 to 9;0 years	25 to 67 years
Speech Sampling Procedure	Conversational/Play	Structured Monologues	Structured Monologues
Measures Gathered			
Stuttering Measures	YES	YES	YES
Pause Measures With Stutters	YES	YES	YES
Pause Measures No Stutters	YES	YES	YES
Articulation Rate With Stutters	YES	YES	YES
Articulation Rate No Stutters	YES	YES	YES
SALT Language Measures	YES	YES	NO
CIU Measures	NO	NO	YES
PD Measures	NO	NO	YES

Note. SALT = Systematic Analysis of Language Transcripts, CIU = Correct Information Units, PD = Performance Deviation.

Stuttering was defined as repetitions and prolongations of sounds, syllables, and audible and inaudible cessation of speech (Wingate, 1964). These core stuttering behaviours feature in the definition proposed by WHO (1977).

Ratings were completed by the primary investigator who is a qualified speech pathologist experienced in the management of stuttering disorders. Percent Syllables Stuttered was completed using a *TrueTalk* button press rating device produced by Synergistic Electronics. See study chapters regarding the speech samples used for ratings.

Only Percent Syllables Stuttered was included in subsequent statistical analyses as these scores were highly correlated with scores from the severity rating scales, ranging from 0.91 to 0.99 for all studies. This is in line with a study conducted by O'Brian, Packman, Onslow, and O'Brian (2004) where both measures also correlated with each other for adult speakers.

3.1.1.1 Reliability of Stuttering Clinical Measures

To demonstrate reliability with Percent Syllables Stuttered ratings, a qualified speech pathologist external to this project conducted ratings on at least 30 percent of all stuttering speech samples. The reliability co-efficient calculated was inter-judge correlation of the absolute Percent Syllables Stuttered ratings for the samples. Percentage agreement among stuttering disfluencies was not obtained. These samples were randomly selected for each Study 1 (n = 5), Study 2 (n = 4), and Study 3 (n = 4). For the samples rated for Study 1, an inter-rater reliability of 0.78 was achieved. For Study 2, the samples rated by both clinicians achieved an inter-rater reliability of 0.77, and for adults in Study 3, an inter-rater reliability of 0.88 was achieved for the samples rated.

3.1.2 The Fluency Profiling System: Pause analysis methodology

3.1.2.1 Segmentation and Identification of Pauses

Speech samples from participants were transcribed and pauses were manually segmented into PRAAT (Boersma & Weenink, 2010). Transcription was orthographic. For the purposes of gathering articulation rate (procedure describe later in this chapter, section 3.1.3), additional notes about the phonetic form of a speaker's productions were also made if words were produced in a way that did not follow the normal number of syllables.

Apart from one participant's recording for one session, all data for all studies were fully transcribed verbatim. The Session 3 audio recording for Participant 11 in Study 1 was of compromised quality. The sections of unacceptable quality were removed, resulting in a shorter recording that was used for the pause analysis.

Figure 3.1 gives an example of the PRAAT window with an utterance segmented and transcribed onto a tier. Pause boundaries were entered in PRAAT, and speech was transcribed into a single tier – refer to the bottom row of Figure 3.1. Segments containing 'noise' as a result of vocal tract activity were segmented as 'speech'. Periods of silence with no identifiable vocal tract activity were segmented as a 'pause'.

The PRAAT program provided features that allowed for more accuracy in the identification and measurements of pauses and speech segments. Integrated visual and audio feedback was used for pause segmentation and transcription of the speech sample. The beginning and end of a speech segment was defined as the onset and the offset of vocal activity as displayed on a Fast-Fourier-transformation-based spectrogram – refer to the third row of Figure 3.1. In addition, the audio playback in PRAAT was used in conjunction with visually monitoring the amplitude wave, which is based on the intensity analysis of the audio. Segmentation and speech transcription was completed with a display window ranging from 1.0 to 3.75 seconds. To identify shorter pauses, a display window of 50 milliseconds was used.

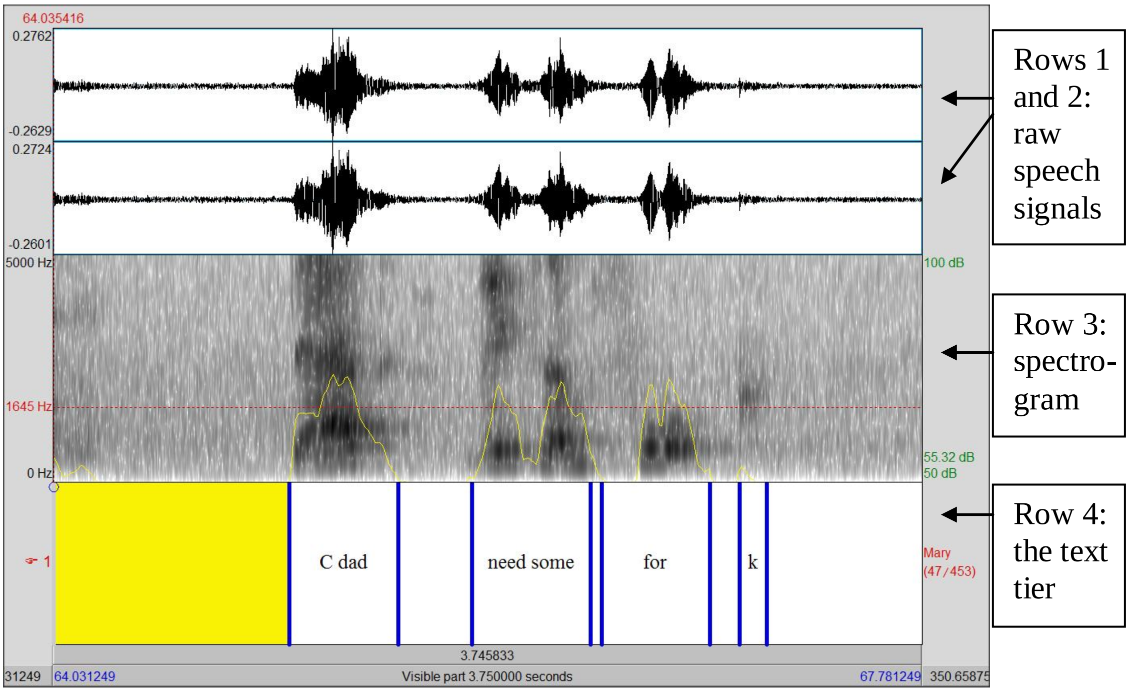


Figure 3.1: Example of PRAAT window (3.75 seconds) for the segmentation of pauses. The display includes a raw speech signal (the top two rows of Figure 3.1 – two rows in the case of audio files that were recorded in stereo), a spectrogram (third row), and the segmentation tier where speech transcription is entered into (bottom row). The yellow ‘trace’ line in the spectrogram, third row, displays the amplitude wave.

Speech segments were comprised of linguistic units in spoken English, ranging from single phonemes to sentences and included unintelligible segments. Filled pauses (i.e., ums, ers and ahs), revisions and all types of disfluencies were classified as speech provided there was involvement of vocal tract activity. Laughter, cries, vocalisations and sound effects associated with speech and/or play were also characterised as speech. These behaviours are thought to reflect a range of communicative functions and involve vocal tract activity.

At times, breathing also involved vocal tract activity and was audible and visible in the spectrogram. However, they were segmented as ‘silent’ segments as they are considered to be a product of the necessary physical act of replenishing air for speech production and not specific to communicative functions. A cut-off criterion of 20 milliseconds was adopted for all pauses. There was no set criterion for speech segment duration (Kirsner, Dunn, Hird, et al., 2003).

For all speech samples, examiner/parent speech was transcribed into the same tier as the participant's speech. In Study 1, speech samples were largely conversational, and as such, examiner and parent speech were frequent. In Study 2 and 3, the speech samples elicited were monologues and examiner speech was restricted to initial task instructions and prompts throughout the sample. Back channel responses, such as, 'oh', 'mm hm', and 'yeah', produced by the examiner were not transcribed and were removed. These responses were typically used by the examiner to signify understanding and affirmation of listening.

At the completion of pause segmentation and speech transcription, the data related to pause duration and speech segment duration were extracted from the relevant tier produced in PRAAT. Each line of pause-speech data comprised of (a) the duration of the pause segment in milliseconds, (b) the duration of the speech segment in milliseconds, and (c) the transcript of the speech segment. Figure 3.2 provides an example of the pause-speech data in these cycles. The first two columns 'pause' and 'speech' display the duration of pause and speech segments, in milliseconds, respectively. The third column 'text' displays the speech transcription associated with that line of pause-speech data.

In case there were lags in starting the speech sample after recording started, the first line of pause-speech data was deleted in all speech samples. All examiner speech was also deleted, as well as the immediate subsequent line of pause-speech data for the participant. This was done to ensure that the pause analysis was a reflection of the use of pauses in the participant’s speech production processes rather than due to the formulation of responses to the questions and comments of the examiner or parent.

PAUSE DURATION (milliseconds)	SPEECH DURATION (milliseconds)	TEXT
602	388	PERSONAL 2: I live in a
50	308	s
821	142	treet
43	62	that
41	293	's
40	431	close
163	107	d off
28	412	it's
34	70	a one way
36	212	s
451	187	treet
37	677	it's a
814	553	dead end street
40	350	and nobody
123	277	goes up
516	73	there
37	175	be
44	41	cause it
37	205	's
30	188	als
31	553	o on
		top of a hill

Figure 3.2: An example of pause-speech data cycles with transcription (text)

3.1.2.2 Pause Distribution Analysis Data Output

Raw pause-speech data were subjected to distributional analysis using an Expectation Maximization algorithm (McLachlan & Peel, 2000) under MATLAB (The MathWorks, 2004). The algorithm calculated the means, standard deviations, and the relative proportion of each pause distribution. The pause measures gathered for this study include short and long pause duration means (log), speech segment duration means (log), proportion of pauses in time and misclassification rate. The MATLAB analysis provided three data outputs, all of which can be viewed in Appendix A. These are:

1. Figure A.1: A visual display of the pause frequency data plotted against duration (log).

2. Figure A.2: A visual display of the speech segment frequency data plotted against duration (log).

3. Figure A.3: An output with descriptive pause data. Measures included the mean and standard deviation of short and long pause distributions, the percentage of misclassifications of pauses into distributions and the speech segment mean and standard deviation durations.

4. Figure A.4: A Long Pause Speech Segment transcript. This is where the transcript is displayed with short pauses folded signified by a forward slash and each line of speech segment data is bound by a long pause determined by the distributional analysis.

3.1.2.3 Measures of the Fluency Profiling System

Summary data output for the Fluency Profiling System can be seen in Appendix A, Figure A3. Measures gathered for this study included Short Pause Mean (log), Long Pause Mean (log), Misclassification Rate, Speech Segment Mean (log), and Proportion of Pause Time. Proportion of Pause Time, a measure of the time occupied by pauses relative to time occupied by speech, was calculated by dividing the pause time by the total sample time and multiplying by 100. This measure includes all pauses the speaker produced that were over the 20-millisecond criterion, so the measure includes long pauses as well as short pauses.

All measures are related to each other as they are derived from a single system. Speech segments are divided according to long pauses produced by a speaker with short pauses collapsed within each segment. They can give an indication of how a speaker plans an utterance according to the time required for speech planning processes. If a speaker produces long pauses more frequently, the Speech Segment Mean calculation is expected to be shorter. This measure is more reliable when the speaker produces longer monologues.

Misclassification Rate (%), which indicates the degree of overlap of the short and long pause distributions for a speaker, is smaller when the two pause distributions are highly separable. Proportions of short and long pauses were only analysed for participants in Study 3 (adults) to make comparisons with a previous study of pauses in adults conducted by Love and Jeffress (1971).

3.1.2.4 The Reliability of Pause Segmentation

The pause segmentation and reliability analyses were completed by the primary investigator. A reliability study conducted within the author's research group by Oehmen, Kirsner and Fay (2010) examined the standard deviations of the short and long pause distributions of segmentations conducted by four different raters on four different speech files. Each rater segmented each sound file twice. They found that *intra*-rater reliability, which is the agreement and identification of boundaries placed for pauses across repeated segmentations, was higher than *inter*-rater reliability across different raters. This suggests that there are differences in the interpretation of where pauses are in speech between raters, but for repeated segmentations by the same rater there was a higher consistency. The *intra*-rater standard deviations across the four different speech files for *short* pauses were on average from 0.01 – 0.18, and for *long* pauses from 0.00 – 0.05. In contrast, the inter-rater standard deviations were considerably higher for short pauses with an average from 0.16 – 0.50, and long pauses with an average from 0.07 – 0.32. This indicates that long pauses were identified with more consistency than short pauses.

Due to the time consuming nature of the manual process of pause segmentation (one minute of speech can take up to 60 minutes to segment), reliability checks were conducted for a limited number of speech samples. In this case, a speech sample from one participant from each study was selected at random for reliability checks using a simple random selection method. For Study 1, there were four data sessions so a different participant was selected for each data session. The samples of the participants were then edited to aim for five minutes of speech. The time between the first and second segmentation of the edited samples was approximately two months.

Table 3.2 shows the average standard deviations for the short and long pauses across the two segmentations. In congruence with the study by Oehmen and colleagues (2010), on average there was less variability for segmentation of long pauses for this study (*SD*=0.045) than that of short pause segmentation (*SD*=0.053). This confirms that long pauses were more reliably identified on the spectrogram than short pauses. It can be seen that the standard deviations obtained in this study are comparable to the average standard deviations found in the study of Oehmen and colleagues (2010), demonstrating acceptable intra-rater reliability.

Table 3.2: Intra-rater variability for pause segmentation expressed as average of the standard deviations for the short and long pause distributions across two ratings

Speech file	Short Pause SD	Long Pause SD
Study 1 – Session 1	0.05	0.04
Study 1 – Session 2	0.10	0.09
Study 1 – Session 3	0.05	0.05
Study 1 – Session 4	0.08	0.05
Study 2	0.02	0.03
Study 3	0.02	0.01

3.1.3 Articulation Rate

Articulation rate was calculated for all participants and was expressed as Syllables Spoken per Second. Silent pauses and disfluencies were deleted from the speech sample times to inform about the temporal efficiency of speech execution processes. Disfluencies removed included filled pauses, such as ‘ums’, ‘ers’ and ‘ahs’ and part-word repetitions. For the participants who stutter, articulation rates were calculated with and without stuttered disfluencies. The procedure for the removal of stuttered disfluencies is described in section 3.1.5.

Previous studies have typically adopted a universal 250-millisecond criterion (e.g., Tumanova, Zebrowski, Throneburg, & Kulak Kayikci, 2011) for silent pauses. The cut-off duration for long pauses in this project was dependent on a speaker’s unique long pause threshold from the Fluency Profiling System and Expectation Maximization algorithm used, which is calculated after all pause data was collected.

Syllables were counted from The *Long Pause Speech Segment Transcript* (MATLAB output data, see Appendix A, Figure A4) from the Fluency Profiling System. Each pause-speech data cycle was separated only by long pauses with short pauses collapsed in each pause-speech segment. The first part of the analysis involved identification and deletion of any pause-speech segments containing non-speech events, such as laughter, cries, vocalisations, non-stuttered disfluencies (i.e., filled pauses, revisions, or false starts) together with any segments containing unintelligible speech.

For a syllable to be counted, it needed to have conveyed information and be perceived as a syllable by the primary investigator. Whether a syllable was perceived was determined as part of the process of pause segmentation and speech transcription procedure using PRAAT. Playback of audio was used in conjunction to the Long Pause Speech Segment transcript to assist with syllable counting. Syllables were counted for each qualifying pause-speech segment. The total number of syllables for each participant was added then divided by the time of the sample in seconds to get a measure of Syllables Spoken per Second.

3.1.4 Language-Based Measures

Language measures are not described in detail in this chapter. Information regarding these measures is presented in individual study chapters as different measures were utilised for the children in Experiments 1 and 2, compared to the adults in Study 3. Systematic Analysis of Language Transcripts (SALT: Miller, 2008) was used for children. Calculation of Correct Information Unit (CIU: Nicholas & Brookshire, 1993) and Performance Deviation (PD: Brookshire & Nicholas, 1995) were conducted for adults. These measures were chosen based on age-appropriate analyses and measures from SALT were chosen for children as data were available from previous research for comparisons.

3.1.5 Removal of Stuttered Disfluencies

The removal of stuttered disfluencies was implemented to help ascertain the contribution of stuttered disfluencies for speech and language output of people who stutter. This was possible for pause and articulation rate measures only. Pause and articulation measures did not depend on language content. Therefore, it was possible to remove stutters for these measures without affecting the validity of the measures.

Language-based measures were not gathered with stuttered disfluencies removed from the samples due to the tendency for stuttering to occur on content words, particularly for adults who stutter (Dworzynski, et al., 2003). Deletion of stutters, which also carry linguistic content would directly affect the meaning of the speaker’s language output making it incomplete and/or not making sense, and as such, difficult to gather.

The SALT for children in Experiments 1 and 2 classifies stuttered disfluencies and other disfluencies such as filled pauses and false starts, by coding them as Percent Mazes. For adults in Study 3, disfluencies were investigated through the procedures outlined for Performance Deviations (see Chapter 6, Methods, section 6.2, for more information).

The procedure for investigating the perceptually fluent speech in this study differs from previous studies. Essentially, stuttered disfluencies were removed from the natural speech of the speakers, referred to as ‘residual fluency’. This is defined as the “speech that remains in an utterance after all disfluency segments have been removed” (Logan, et al., 2011, p. 132). This is in contrast to many previous studies, which have adopted speaking tasks with reduced complexity and/or reduced spontaneity to avoid stuttered disfluencies. Many of such tasks were unnatural speaking tasks. The same definition of stuttering by Wingate (1964), which was used to gather clinical stuttering measures (described earlier), was used to identify stuttered disfluencies in PRAAT.

3.1.5.1 The Fluency Profiling System Measures with No Stuttered Disfluencies

Stuttered disfluencies were identified in PRAAT and coded in the same tier as the pause segmentation and speech transcription. Pause-speech data lines containing stutters were removed from the data set. The modified data set with stuttered disfluencies removed was then subjected to a repeat analysis using the Expectation Maximization within MATLAB to gather the pause distribution measures.

Some stutters spanned across more than one speech segment when a pause of at least 20 milliseconds was identified between speech segments. This was often the case when a block or repetition was produced when more than one speech segment component of the disfluency was present. Consider the following example of one stutter, '*b_ (pause 20 milliseconds) be_ (50 milliseconds) behind'.* This stutter comprises of three speech segments separated by two pauses greater than 20 milliseconds.

Sometimes the pause which preceded a stuttered data line was noticeably part of the stutter itself. For example, this was observed for stuttering blocks where an unusually long pause precedes the stutter. These preceding pauses were automatically removed with the data line containing the stuttered disfluency because the preceding pause was part of the pause-speech duration data cycle that contained the stuttered disfluency. For the previous example, '*b_ (pause 20 milliseconds) be_ (50 milliseconds) behind'*, the following three pause-speech data lines would have been removed:

Pause Duration Segment	Speech Duration Segment	Text
180	10	b (stuttered)
20	30	be (stuttered)
50	800	behind (non-stuttered)

Figure 3.3: An example of a stutter within pause-speech data. The first two stuttered lines and the proceeding non-stuttered line were removed as part of the stutter removal procedure.

In addition, the data line immediately following a stuttered pause-speech data line was deleted. This data line occurring *after* was considered to be a perceptually fluent speech segment. The reason for deleting a ‘fluent’ data line after the ‘stuttered’ data line has its foundation in the concept that the vicinity of an identified stuttering event may be part of the entire stuttering ‘event’. According to dynamic accounts of stuttering, the stuttering ‘event’ does not even exist. This has been described by Smith (1999, p. 30) saying that “the dynamic processes contributing to relative fluency and disfluency may be quite distant in time and space from the ‘event’ that we perceive as fluency.” It is possible that a stuttering event spreads to nearby speech segments as time is required to re-establish stable speech processes (Sawyer & Yairi, 2010).

Furthermore, Howell and Wingfield (1990) found that listeners could identify whether the perceptually fluent speech of people who stutter were adjacent to stuttered words or not. The authors found that this was related to the speech rate and intensity in segments close to stuttered disfluencies.

3.1.5.2 Articulation Rate with No Stuttered Disfluencies

The modified Long Pause Speech Segment Transcripts obtained with stuttered disfluencies removed was used to re-calculate Syllables Spoken per Second. Removal of stuttered disfluencies resulted in fewer total syllables in the sample size. However the syllables remaining were still considered sufficient for this measure for all participants. See individual study chapters for details regarding sample size.

3.2 Statistical Analyses Conducted

3.2.1 Between-Groups Statistical Tests

3.2.1.1 Independent Samples t-Tests

Independent samples *t*-tests were conducted for Experiments 2 and 3 to evaluate the differences between the speech and language measures collected for the groups. This was conducted to compare the speech of the control participants to that of the participants who stutter: (a) with stuttered disfluencies, and (b) without stuttered disfluencies in their samples. Stutter removal was conducted to allow for the perceptually fluent speech of those who stutter to be analysed independently of stuttered speech. After stuttered disfluencies were removed, the resultant pause and articulation rate data of stuttering participants were subjected to independent samples *t*-tests with controls. The data from the control participants were not altered.

Due to the longitudinal data schedule for Study 1, repeated measures analyses were conducted to investigate difference between-groups. This is described in more detail in the chapter for this study, Chapter 4, section 4.3.

3.2.1.2 Analysis of Covariance

Analysis of Covariance (ANCOVA) was used to investigate associated speech and language variables between the groups. To investigate trade-offs used by people who stutter for maintaining their speech, analyses were conducted with speech samples containing stuttered disfluencies. This allowed for a direct comparison of how speech and language measures related for the people who stutter compared to the control participants. Residuals and predicted values were examined to check that the spread of variability was not constant. No adjustments had been made for multiple comparisons.

Combinations of measures hypothesised to indicate trade-offs used by people who stutter *across* speech motor control and language-based domains were investigated (speech motor control measure *with* a language-based measure). 'Integrated' measures reflecting both speech motor control and language ability were also paired up with speech motor control and language-based measures. For example, Proportion of Pause Time is considered to be an integrated measure as it reflects the time required for both speech and language planning processes. Percent Mazes and Performance Deviations were also considered to be integrated measures as they included disfluencies that could be motor or language-based. Table 3.3 illustrates the measures subjected to ANCOVA. Measures are grouped according to whether they were measures of *speech motor control*, *language-based measures,* or *integrated measures*.

Table 3.3: Measures subjected to Analysis of Covariance, grouped as measures of speech motor control, language-based or integrated

Speech Motor Control	Language-Based	Integrated
Short Pause Mean (ALL studies)	Long Pause Mean (ALL studies)	Proportion of Pause Time (ALL studies)
Syllables Spoken per Second (ALL studies)	Mean Length Utterance (Experiments 1 and 2)	Percent Mazes (Experiments 1 and 2)
Percent Intelligibility (Experiments 1 and 2)	Number of Different Word Roots (Experiments 1 and 2)	PD Total (Study 3)
	No. Total Utterances (Study 2)	Seconds per PD (Study 3)
	CIU Percent (Study 3)	
	Seconds Per CIU (Study 3)	

Note. CIU=Correct Information Unit, PD=Performance Deviation.

The ANCOVA analysis model included group interactions as a starting point. If a group interaction was not significant, it was removed from the analysis model to examine only the main effects (group and measure main effects). Significant *group interactions* indicate that the pattern of performance for an association between two measures differed between the two groups. Significant *group main effects* indicate that the groups differed in the average performance of the measures in the association but the pattern of performance did not differ (e.g., direction of the association). *Measure main effects* indicate the significance of an association between two measures not based on a group factor. Therefore, they inform about associated measures that were common for all participants regardless of the group factor.

Significant group interactions and group main effects are reported in the format 'Covariate Variable *with* Dependent Variable.' All measures were tested as both covariate (predictor variables) and dependent variables. Consider the following example of an association with the measures Short Pause Mean and Mean Length Utterance. There are two variations of the association: (a) Short Pause Mean (Covariate) *with* Mean Length of Utterance (Dependent), and (b) Mean Length of Utterance (Covariate) *with* Short Pause Mean (Dependent). Each variation was tested in the ANCOVA. If both variations of the association appeared as significant group interactions or group main effects, the combination with the stronger significance was presented.

The associations of group interactions and group main effects found to be statistically significant were further examined separately per group to investigate the nature of the significant effect. This is also a *measure main effect* but examined separately for participants per group rather than with the groups collapsed. P values for associations per group are presented, in addition to the direction of that association. Figures are only presented for significant group interactions in individual study chapters, with the covariate on the *x*-axis, and the dependent on the *y*-axis.

3.2.2 Within-Group Statistical Tests: Stuttering groups only

3.2.2.1 Univariate Regression Analysis

To investigate the impact of stuttered disfluencies on speech and language output and possible trade-offs used by people who stutter regression analysis was conducted. Clinical stuttering measures (e.g., Percent Syllables Stuttered) were paired up with speech and language-based measures for participants who stutter.

3.2.2.2 Paired Samples t-Tests: Pre- stutter and post- stutter removal

To examine the impact of stuttered disfluencies on pause and articulation measures, paired-samples *t*-tests were conducted. The two conditions for this analysis were measures *with,* and measures *without,* stuttered disfluencies in speech.

CHAPTER 4: SPEECH AND LANGUAGE FLUENCY PROFILES IN CHILDREN, WITH AND WITHOUT A FAMILY HISTORY OF STUTTERING, BEFORE AND AFTER THE ONSET OF STUTTERING

This first study was exploratory in nature. It examined the speech and language fluency profiles in children with and without a known family history of stuttering. It tracked and compared these children as they either started to stutter or continued to develop typically. No child was identified to be stuttering at the start of the study, however by the end, five out of 18 children were stuttering. This allowed for the investigation of potential markers for the onset of stuttering, together with the investigation of the speech and language development of those who continued to develop typically.

4.1.1 Specific Hypotheses

4.1.1.1 Typical Speech and Language Development

In regards to typically developing children, pause distribution measures are likely to be a function of processes sensitive to developmental change. This could be related to the development of neural capabilities and cognitive processes such as attention and working memory. Pauses are also likely to be sensitive to speech and language development such as communicative intention, receptive language ability, speech motor development and phonological ability.

Long pauses are likely to be sensitive to an increase in cognitive ability and language planning ability, as well as to the improved coordination of breathing (Kirsner, Dunn, Hird, et al., 2003). Therefore, this measure along with Proportion of Pause Time was predicted to decrease with developing speech and language skill. For young children, long pauses are also likely to be associated with the production of non-verbal communication such as the use of gestures and facial expressions. As children become more apt in stringing sentences together more efficiently and fluently through increased use of syntactic rules and increased vocabulary, they become less reliant on gestures as a primary means of communication. A shift towards verbal communication may be signified by a reduction of the duration and frequency of long pauses that children produce.

As short pauses are thought to be related to speech motor control processes they are likely to be sensitive to developing phonological and articulation skills. Based on previous studies, articulation rate should increase with age. As articulation becomes more practiced and the ability to produce rapid speech gestures becomes more efficient, automatic and stable (Logan, et al., 2011; Nip, et al., 2011), a decrease in the mean duration of short pauses would also be expected.

Mean Length of Utterance Morpheme and Number of Different Word Roots were expected to increase with age to reflect general language growth in children (Heilmann, et al., 2010). Percent Intelligibility and Percent Mazes should increase as well, however they have not been commonly reported to be reliable indicators of speech and language development. As such, the gains for these measures were not expected to be as large as that of Mean Length of Utterance Morpheme and Number of Different Word Roots.

For typically developing children, Percent Intelligibility should increase with age as a reflection of the increased precision and accuracy of speech sound production. An increase in Percent Mazes was expected as a function of children using more complex syntactic structures in their speech production to express more complex ideas. This includes explaining spatial, temporal and causal relationships in narrative tasks (Leadholm and Miller, 1992, as cited in Watkins & Yairi, 1997)

4.1.1.2 Family History of Stuttering

It was hypothesised that a greater number of children who start to stutter would have a positive family of stuttering. To support the hypothesis that children with a positive family history have more unstable speech motor systems that lead to an increased susceptibility to stuttering, it was predicted that their speech and language fluency profiles would differ from those of control children. This difference in regards to speech and language fluency profile measures could be in terms of a mean difference, a variance difference, or both. Measures of speech motor control processes are of particular interest, such as Syllables Spoken per Second as a measure of articulation rate and Short Pause Mean.

4.1.1.3 The Onset and Development of Stuttering

For children who start to stutter, there may be speech and language variables that could predict the onset of stuttering. To support the hypothesis of unstable speech motor systems prior to the onset of stuttering, it was predicted that there would be group differences for measures of speech motor control. This includes measures such as short pause mean and/or articulation rate data. Reilly and colleagues (2009) found that children who started stuttering had higher expressive vocabulary scores. The Number of Different Word Roots, the vocabulary measure gathered in this study, would be of great interest in predicting the onset of stuttering.

Following the onset of stuttering, speech and language performance may also change. It is possible that differences in patterns of performance arise as a means for the child to cope with the stuttering. A number of cognitive, language and speech motor developments occur at the same time for young children learning language and since all areas are intricately linked to each other, they can similarly affect each other. Specifically, for this study, it was hypothesised that speech motor control measures can impact language-based measures and vice versa. In addition, children who go on to develop a stutter may have higher ongoing unstable speech and language behaviour compared to children with normally-developing fluency (Packman, et al., 1996). This may be reflected in variance data over time.

4.1.2 Research Questions

The following research questions were asked for this study:

1. Which measure(s) are most informative about typical speech and language development?
2. Do more children with a positive family history of stuttering begin to stutter than children without a family history of stuttering?
3. Do children with a family history of stuttering have differences in their speech and language fluency profiles, compared to children with no family history of stuttering?
4. Are there any speech and language fluency predictor variables for the onset of stuttering?
5. Are the speech and language fluency profiles of children who start to stutter different to that of children who continued to develop typically?
6. How do stuttered disfluencies impact on speech and language fluency profiles for children who start to stutter?

4.2 Method

4.2.1 Participants

The participants (*n* = 18) were comprised of nine children with a known family history of stuttering and nine control children with no known family history of stuttering. Each control child was specifically selected to match the gender, and age within two months, of a child with a family history of stuttering. Due to challenges with the recruitment of children with a positive family history of stuttering, there was a gender distribution imbalance of the children in this study. There were seven females and two males in each group. All children were aged between 21 to 48 months (*M* = 29.40) at the beginning of the study.

Children aged between two and four years of age were selected as this is the time period commonly reported for the onset of stuttering and when children typically start to produce multi-word utterances (Karniol, 1995). Ten children were two years of age or under, four children were three years of age or under, and the remaining four children were four years of age or younger. All children were aged between 30 and 57 months (*M* = 38.45 months) when the study ended.

English was the first language for all participants. No child had a diagnosis of stuttering or any parental concerns regarding speech and language development at the start of the study. No hearing difficulties were reported for any child at the start of the study. Grouping for children according to *stuttering status* is explained below, under ‘Diagnosis of Stuttering.’

Children with a family history were recruited through members of The Speak Easy Association of Western Australia, a non-profit organisation and self-help group for people who stutter. Members who had young children and/or relations in their family were invited to participate in the study. Positive known family history was identified through detailed case-history gathering. Seven out of nine of the children had a first-degree family member who stutters (sibling or parent) and the remaining two children had second-degree relatives who stutter. The individual characteristics for children with a family history of stuttering are reported in Table 4.1.

Children in the control group did not have a known family history of stuttering. Children were recruited through The Telethon Health Institute of Western Australia where the families were already part of other health-related studies in young children. No child had a known history of neurological, psychological or intellectual impairments. None had a previous history of stuttering or other difficulties with speech and language.

Table 4.1: Individual characteristics of children with (n = 9) and without a positive family history of stuttering (n = 9)

Participant Number	Family History of Stuttering	Sex	Age (months) First Session	Age (months) Final Session	Degree Family Member With Stutter
1	+	F	23	32	Second
2*	+	F	36	45	First
3*	+	M	36	48	First
4	+	F	23	32	First
5	+	M	24	33	First
6	+	F	23	32	Second
7*	+	F	47	56	First
8	+	F	23	32	First
9*	+	F	27	37	First
10	-	F	24	33	N/A
11	-	F	37	46	N/A
12*	-	M	40	49	N/A
13	-	F	21	30	N/A
14	-	M	23	32	N/A
15	-	F	24	33	N/A
16	-	F	48	57	N/A
17	-	F	24	33	N/A
18	-	F	26	35	N/A

Note. * participant observed to develop stuttering during the course of the study

4.2.2 Apparatus

Speech and language samples of the children were recorded and video-taped. A Panasonic NV-GS300 mini DV camera with an external microphone was used. The camera recorded video at a resolution of 720x576 pixels at a rate of 25 frames per second. The camera recorded two-channel audio at a sampling rate of 44100Hz and a bit depth of 16 bits. The audio and visual components were recorded with automatic time-locked synchrony. The audio/video recordings were captured onto a desktop computer using Adobe Premier Pro 2.0, and the audio component of the recordings were then extracted in uncompressed PCM format and saved to WAV audio files. The WAV files were then imported into PRAAT for analysis, in accordance with the Fluency Profiling System. Video of the recordings were only used for the verification of ambiguous portions of speech samples during speech transcription.

4.2.3 Design and Procedure

Parents filled out a case-history questionnaire at the commencement of the study and were further interviewed to fill in gaps in the information when required. Appendix B details the pediatric case-history questionnaire.

4.2.3.1 Speech Sampling

Children were recorded whilst they engaged in a play and/or conversational session with a parent and/or examiner. Recording took place at the child's home in a quiet room with a closed door where possible. Background noise was kept to a minimum. In particular, electrical appliances with constant noise production, such as a fridge, washing machine, or switched-on computer were avoided. However, it was not possible to completely eliminate all background noise.

Speech samples were collected at three-month intervals over a period of nine months, with four data sessions (Session 1 – Session 4) in total. Parents were contacted by phone two weeks before sessions 2, 3 and 4. The aim of this call was to discover if there had been any significant changes to the child's general health or speech and language development since the previous data session. At the beginning of each session, it was double-checked with the parent through interview that the child had no significant changes to their health and/or speech and language development.

During the speech sampling sessions, children interacted and played spontaneously with a parent and/or the examiner. Parents were instructed that the interaction should be as natural as possible for the child and that the child should control and lead the interaction. There were no other instructions in regards to how the parent should or should not interact with their child. Each session targeted 20 minutes of total interaction time. This duration was deemed to be appropriate to collect a sufficient sample size, while also minimising fatigue and loss of interest from the child. A set of age-appropriate toys was provided by the examiner when necessary, though many children were comfortable playing with their own toys in their familiar home environment. Quiet toys and activities were encouraged to optimise the quality of the audio recording.

Across all recorded sessions for all children, an average *total* sample time (including all examiner/mum and child speech) was 18.31 minutes in duration (*SD* = 3.43, Range 4.4 – 29.43). Participant 11 had a marked shorter sample time at 4.4 minutes for session 3 due to a reduced quality of the recording. There were no group differences for total sample time, for any session between children according to grouping according to *family history* or *stuttering status*.

4.2.3.2 Diagnosis of Stuttering

Five children were observed to have started stuttering: three females and two males. The remaining 13 children continued to develop typically. Table 4.2 summarises the descriptive ages of children for all groupings of this study. The children who started stuttering were on average 11 months older than typically developing children.

Table 4.2: Descriptives for mean age (months) of children according to family history and stuttering status groupings

	Family History (*n* = 9)		No Family History (*n* = 9)		Started Stuttering (*n* = 5)		Typically Developing (*n* = 13)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Session 1	29	8.6	30	9.5	37	7.3	26	7.6
Session 2	32	8.6	33	9.5	40	7.3	29	7.6
Session 3	35	8.6	36	9.5	43	7.3	32	7.6
Session 4	38	8.6	39	9.5	46	7.3	35	7.6

Stuttering diagnosis was not determined based on a standard criterion (see section 3.1.1). For a child to be diagnosed with stuttering, consensus needed to be reached among the parent(s) of the child, the examiner, and a qualified speech pathologist assisting with this project. The presence of core stuttering behaviours as defined by Wingate (1964) was confirmed by all parties for a positive diagnosis of stuttering. This included identification of repetitions of whole and part words, prolongations and blocks. To confirm that stuttering was a new event in the child's speech development, a diagnosis was also only confirmed upon review of the speech samples collected as part of this study in addition to speech samples collected by the parents.

It was important for all parties to reach agreement to reduce false positive diagnoses as parents of children with a positive family history may be more anxious about their children developing a stutter. This may be due to those with a positive family history of stuttering having a heightened awareness of the disorder and its characteristics than parents of children without a family history of stuttering.

If a parent suspected that their child was stuttering at the time of the ‘pre-appointment check’, they were instructed to tape a short sample of their child’s speech for the examiner to evaluate. This sample tape, along with the full recording of the following data session, was analysed to identify the presence of core stuttering behaviours. Positive confirmation of stuttering was achieved if core stuttering behaviours were identified (Wingate, 1964). Core stuttering behaviours needed to be identified for both the sample tape and scheduled data session by the author and by another speech pathologist who evaluated both the parent sample tape and the scheduled data session. If a child developed a stutter, the previous data session was re-evaluated to ensure that it did not contain any stuttering as a confirmation that the stuttering was a new development and had begun between the sessions.

Four children out of the family history group started stuttering. They all did so between Session 1 and Session 2. This was between zero and three months after the start of this study. One child from the non-family history group started stuttering between Session 2 and Session 3. This was between three and six months after the start of the study. In all cases, it was the parents who first informed the examiner about a possible stuttering diagnosis during their pre-appointment check. As a result of seeking therapy services for their children (discussed below), the parents of four out of the five children who started stuttering had received confirmation of a diagnosis of stuttering for their child from an external qualified speech pathologist not related to this study. Table 4.3 summarises individual characteristics of the children who started stuttering.

One child, Participant 1, from the family history group was suspected of stuttering by the author as the child was observed to have an increased number of disfluencies, particularly part-word re6petitions. The child was monitored by the investigator via phone call checks to her parents. By the next data session, 3 months later, the child no longer produced the disfluencies. There may have been a possibility that this child started stuttering and recovered in that short time. However the diagnosis of stuttering was not confirmed. No other children in this study were suspected to have started stuttering.

The speech therapy of participants was not controlled for or restricted by this study. For ethical reasons, it was felt that if parents had a concern for their child's speech they had the option to follow this up independently. The author provided general advice and information about stuttering if parents sought it. Therapy services were not provided as part of this study. The parents of four of the five children who started stuttering had consulted an independent speech pathologist for stuttering therapy. Three of these children commenced speech therapy during the study and one started speech therapy after the completion of the study.

All children who were confirmed to have started stuttering during the study continued to stutter at the end of the study. Children who started stuttering between Session 1 and Session 2 had been stuttering for between six and nine months during this study. The child who started stuttering between Session 2 and Session 3 had been stuttering for between three and six months of this study.

Table 4.3: Individual characteristics of children who started stuttering (n = 5)

Participant Number	Sex	Family History	Age of Stuttering Onset (months)	Stuttering Onset Point in Study	Treatment Received During the Study	Approximate Stuttering Duration During the Study
2	F	+	36 – 39	Between S1 and S2	YES	6 – 9 months
3	M	+	36 – 39	Between S1 and S2	NO	6 – 9 months
7	F	+	47 – 50	Between S1 and S2	NO	6 – 9 months
9	F	+	27 - 30	Between S1 and S2	YES	6 – 9 months
12	M	-	43 – 46	Between S2 and S3	YES	3 – 6 months

Note. S = Session.

4.2.4 Data Collection Procedures

Please see Chapter 3, General Methods for details relating to clinical stuttering measures, the Fluency Profiling System procedure, articulation rate and the procedure for removing stutters from speech samples. Four speech samples were analysed for each participant in this study. The same speech samples were analysed to gather the speech and language measures.

4.2.4.1 Clinical Stuttering Measures

The speech samples of children who started stuttering were rated for clinical stuttering measures. A 500-syllable minimum sample was obtained to rate Percent

Syllables Stuttered using a rating device for all children except for Participant 2, Session 2, where a total of 390 syllables was available.

Ratings for Percent Syllables Stuttered were conducted with audio and video footage. On average, across all stuttering samples, the children had 1.76% syllables stuttered, with a range of 0.3% to 5.3% syllables stuttered. Table 4.4 shows the individual characteristics of children who stutter including the figures for Percent Syllables Stuttered.

Table 4.4: Age and percent syllables stuttered (%SS) of children who started stuttering per session (*n* = 5)

Participant	Session 2		Session 3		Session 4	
	Age	%SS	Age	%SS	Age	%SS
2*	39	5.3	42	0.4	45	0.3
3*	39	3.0	42	3.3	45	4.4
7*	50	0.6	53	0.8	56	0.6
9*	30	1.3	33	0.6	36	0.8
12	43	N/S	46	2.2	49	1.0

Note. * Positive family history, No child observed to be stuttering in Session 1, Age (months), N/S=Not Stuttering

4.2.4.2 The Fluency Profiling System Measures

All speech produced by the examiner and/or mum as well as every speech segment that the child produced immediately after was deleted. This *child only* speech sample time had an average sample time of 4.59 minutes (*SD* = 2.64, Range = 0.96 – 12.51 minutes) across all children for all sessions. There were no between-groups differences for the length of the *child only* speech samples for any session, according to grouping of *family history* and *stuttering status*.

After deletion of all pauses greater than 20 milliseconds from the *child only* samples, a *speech only* sample was on average 2.45 minutes (*SD* = 1.45, Range = 0.4 – 6.31 minutes) for all children across all sessions. No between-groups differences of *speech only* samples were noted for any session, according to grouping of *family history* and *stuttering status*.

4.2.4.3 Articulation Rate

See Chapter 3 General Methods (section 3.1.3) for details relating to the measurement of articulation rate. As previously mentioned, the Fluency Profiling System calculates a unique speaker threshold criterion, which is the point at which the short and long pause distributions intersect. The average threshold for children in this study was 145 milliseconds across all sessions. This means that on average, pauses above 145 milliseconds were excluded in the calculation of articulation rate.

An average of 420 syllables were counted for articulation rate (*SD* = 155) across all sessions, for all children. The number of syllables did not significantly differ between the groups based on *family history* or *stuttering status*, for any session. There was also no significant group difference for syllable sample size between-groups based on *stuttering status* after stuttered syllables were removed from the samples of children who stutter.

4.2.4.4 Systematic Analysis of Language Transcripts (SALT)

For children in this study and for children in Study 2, Systematic Analysis of Language Transcripts (SALT: Miller, 2008) software was used to calculate common language measures. Global measures from SALT were chosen based on previous research which found that they were reliable indicators for speech and language development and for impairment. These measures included Mean Length of Utterance Morpheme and Number of Different Word Roots.

Speech samples were transcribed separately from measures gathered from The Fluency Profiling System for this study. Utterances were segmented into communication units in accordance with the transcript conventions of SALT. A communication unit is defined as an independent clause with its modifiers (Loban, 1976). This segmentation method is based on grammatical rules but also allows for segmentation based on the pause and intonation characteristics in speech. Video and audio playback was used to facilitate transcription.

A sample of the transcripts was initially checked for segmentation into communication units by an independent speech pathologist with prior experience in using SALT for analysing children's speech and language samples. Thereafter, procedures were used to check for errors in the coding conventions.

One hundred utterances were taken from the middle portion of children's speech samples for each session for SALT analysis. The middle portion of the sample was selected to capture a more stable portion of the sampling session compared to the beginning and end of a sampling session. Traditionally, it has been recommended that a sample size of at least 50 utterances is required for the valid and reliable analysis of a child's speech and language production (Miller, 1981). However, 100 utterances was gathered for this study as it has been found to be sufficient for the documentation of age-related changes in children (Heilmann, et al., 2010).

4.3 Results

The Results section is presented in three main sections. The results are firstly presented for *speech samples for typical development* (*n* = 58). Thereafter, the results are presented according to groupings based on (a) *Family History* – positive (*n* = 9) versus no family history of stuttering (*n* = 9), and (b) *Stuttering Status* – children who started stuttering (*n* = 5) versus children who were typically developing (*n* = 13).

4.3.1 Speech and Language Samples of Typical Development

4.3.1.1 Summary of Analyses Conducted

To investigate typical speech and language development over time, a one-factor repeated measures analysis was conducted with *Age* (Session). There was no between-groups factor in this model. To explore how measures relate to each other, univariate regression analyses were conducted with the data collapsed across sessions.

4.3.1.2 Repeated Measures Analysis to Investigate Typical Development

Only speech samples regarded as typically developing were included in this analysis. The speech samples for children who started stuttering *before* stuttering was diagnosed (Session 1) were included in this analysis because between-groups analyses found no differences for the children based on *Stuttering Status* before they started to stutter (presented after this section). Fourteen ‘stuttering’ speech samples were removed leaving 58 non-stuttering speech samples available for analysis.

The repeated measures analysis found the following measures to be significant with increasing *Age:* (a) Short Pause Mean (*p* = .049), (b) Syllables Spoken per Second (*p* = .003), (c) Mean Length of Utterance Morpheme (*p* = .000) and (d) Number of

Different Word Roots (*p* = .000). Table 4.5 presents the averages for each measure according to age from one to four years. It is noted that the two- year old age bracket contained the highest number of observations (*n* = 39) with the four- year old age bracket containing the least (*n* = 4). The scatterplots for these measures as a function of age are presented in Figures 4.1 to 4.4.

Table 4.5: Means for speech and language measures according to age in years for typically developing speech samples only (*n* = 58)

	Mean by age (years)			
	1 (*n* = 6)	2 (*n* = 39)	3 (*n* = 9)	4 (*n* = 4)
FPS Pause Measures				
Proportion Pause Time	49.25	48.06	43.85	44.41
Short Pause Mean*	4.31	4.20	3.98	3.97
Long Pause Mean	6.34	6.12	5.90	6.03
Misclassification Rate	5.27	6.94	6.65	4.54
Speech Segment Mean	6.72	6.74	6.69	6.64
Articulation Rate				
Syllables per Second*	2.40	2.57	3.19	3.21
SALT Measures				
MLU Morpheme*	1.6	2.71	3.94	5.90
No. Different Words*	53.30	82.70	114.30	162.00
Percent Intelligibility	87.00	88.49	89.11	92.00
Percent Mazes	2.67	6.90	7.89	13.00

Note. * indicates that measure was significant with increasing *Age* according to repeated measures analysis, FPS=Fluency Profiling System, SALT=Systematic Analysis of Language Transcripts, MLU=Mean Length of Utterance. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

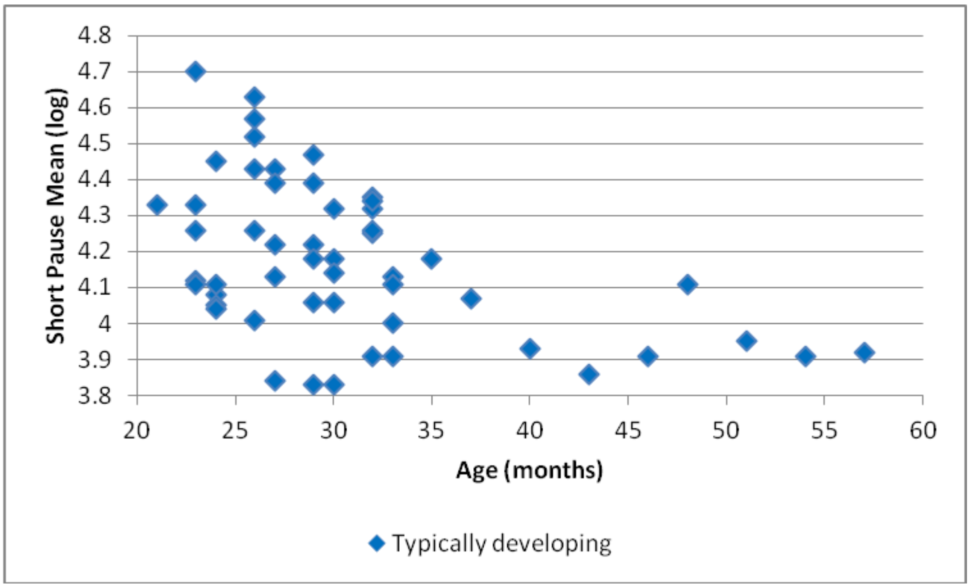


Figure 4.1: Short Pause Mean (log) as a function of Age in months for typically developing speech samples (n = 58)

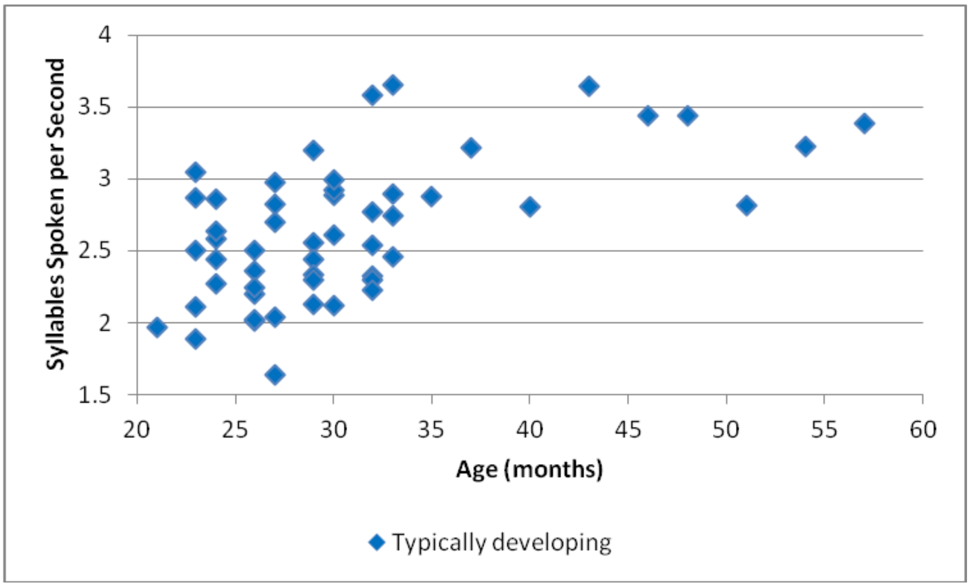


Figure 4.2: Syllables Spoken per Second as a function of Age in months for typically developing speech samples (n = 58)

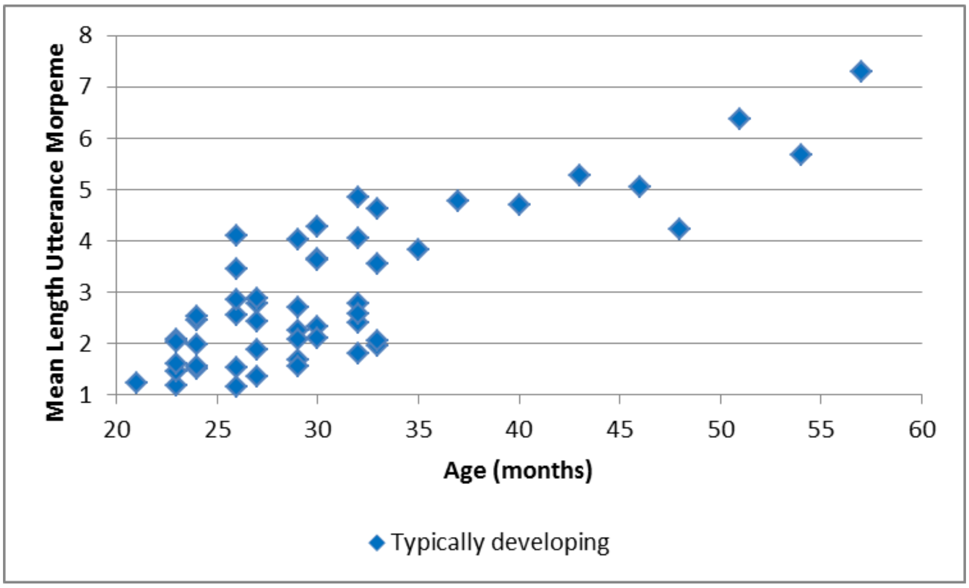


Figure 4.3: Mean Length of Utterance in Morphemes as a function of Age in months for typically developing speech samples (n = 58)

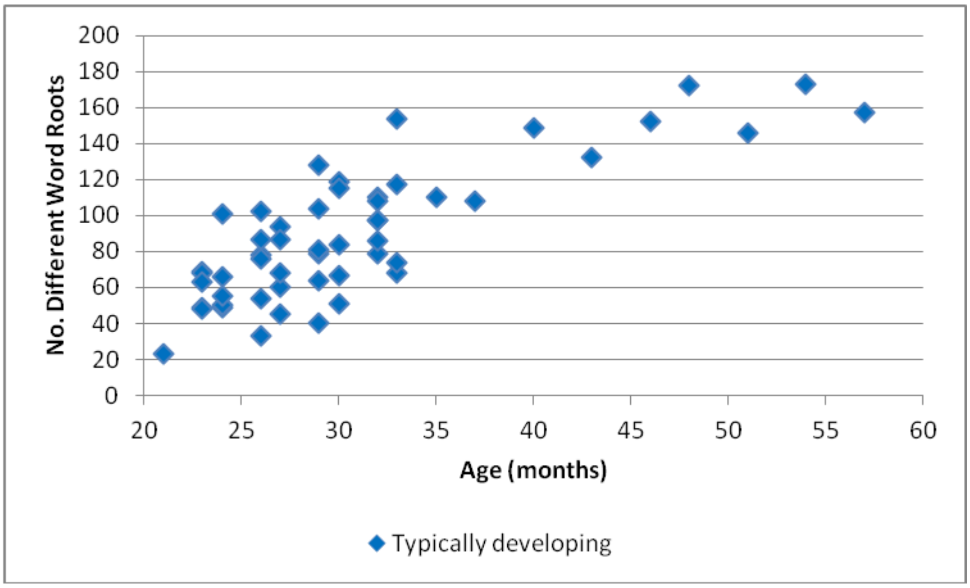


Figure 4.4: Number of Different Word Roots as a function of Age in months for typically developing speech samples (n = 58)

4.3.1.3 Univariate Regression Analyses to Investigate Associated Variables for Typical Development

To explore patterns of related speech and language variables in typical speech and language development, combinations of measures *across* and *within* the 'systems' were investigated. For example, Long Pause Mean and Proportion of Pause Time are both measures *within* the Fluency Profiling System found to associate positively with each other in this study. Short Pause Mean and Mean Length of Utterance Morpheme *across* the Fluency Profiling System and SALT were found to negatively associate with each other.

Investigation of measures *within* systems was conducted for measures from The Fluency Profiling System as this has not been attempted for the pediatric population to date. Based on previous studies, Mean Length of Utterance correlates strongly with Number of Different Word Roots. However, little is known about how other SALT measures associate in young children with typical speech and language development.

Table 4.6 displays the significant associations. The Table also displays the *p* values and direction, positive or negative, for the associations.

Table 4.6: Significant associated measures for three or more sessions for typically developing speech samples (*n* = 58)

Measure 1	Measure 2	*p* Value	Direction
FPS Pause Measures with FPS Pause Measures			
Proportion of Pause Time	Long Pause Mean	.000	+
Proportion of Pause Time	Misclassification Rate	.038	-
Proportion of Pause Time	Speech Segment Mean	.000	-
Short Pause Mean	Long Pause Mean	.003	+
Short Pause Mean	Speech Segment Mean	.000	+
Long Pause Mean	Misclassification Rate	.000	-
Long Pause Mean	Speech Segment Mean	.049	+
Articulation Rate with FPS Pause Measures			
Syllables Spoken per Second	Short Pause Mean	.000	-
Articulation Rate with SALT Measures			
Syllables Spoken per Second	MLU Morpheme	.000	+
Syllables Spoken per Second	NDWR	.000	+
Syllables Spoken per Second	Percent Mazes	.019	+
SALT Measures with FPS Pause Measures			
MLU Morpheme	Proportion of Pause Time	.021	-
MLU Morpheme	Short Pause Mean	.000	-
NDWR	Proportion of Pause Time	.000	-
NDWR	Long Pause Mean	.003	-
NDWR	Short Pause Mean	.000	-
Percent Intelligibility	Proportion of Pause Time	.020	-
Percent Mazes	Long Pause Mean	.011	-
Percent Mazes	Short Pause Mean	.017	-
SALT Measures with SALT Measures			
MLU Morpheme	NDWR	.000	+
MLU Morpheme	Percent Intelligibility	.014	+
MLU Morpheme	Percent Mazes	.000	+
NDWR	Percent Intelligibility	.003	+
NDWR	Percent Mazes	.000	+
Percent Intelligibility	Percent Mazes	.026	+

Note. FSP=Fluency Profiling System, S=Session, SALT=Systematic Analysis of Language Transcripts, MLU=Mean Length of Utterance, NDWR=Number of Different Word Roots. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

4.3.2 Summary of Statistical Analyses for Between-Groups Comparisons

4.3.2.1 Repeated Measures Analysis

To test for statistically significant differences between the groups, as a function of *Age* (session), and for group by age interaction, each dependent measure was analysed by a two-factor analysis of variance with repeated measures. One factor represented *Age* (by session). The other factor represented the *Group* classification of the child based on *Family History* or *Stuttering Status.* Two separate repeated measures analyses were conducted for each grouping based on *Family History* and *Stuttering Status.* The dependent variables were the speech and language fluency measures. If group interactions were not significant, they were removed to investigate the main effects for *Age* and for *Group*.

4.3.2.2 Logistic Regression

This analysis was conducted to determine if any of the speech and language measures could predict stuttering status, the outcome measure. Only data from Session 1 was used as no child was stuttering in this session.

4.3.2.3 Analysis of Covariance (ANCOVA)

See Chapter 3, General Methods (section 3.2.1.2) for background information regarding the ANCOVA. This analysis was conducted to investigate how speech and language measures relate between the groups. Measures were included in the analyses to test for specific hypotheses indicating possible trade-offs used by children who stutter, as well as by children with a family history of stuttering. All measures were tested as covariates and dependent variables.

The analyses were completed separately per grouping according to *Family History*, and *Stuttering Status*. The ANCOVAs were also conducted separately for each session (one to four) to investigate any changes for associated speech and language measures prior to and after the children started stuttering.

It is also worth noting that for this study, the ANCOVA model examined group interactions and group main effects only based on *Family History* and *Stuttering Status*. The reason for not including main effects in the analysis model was because speech samples of children observed to be typically developing were already subjected to a separate univariate regression analysis (Speech and Language Samples of Typical Development, section 4.3.1.3 above). The purpose of the univariate regression analysis was to explore associated measures for typical speech and language development.

4.3.2.4 Mann-Whitney Comparisons

Variances were calculated by averaging the standard deviation for each dependent measure for each child across the four sessions. The variances were not normally distributed therefore Mann-Whitney Comparisons were conducted. Variances were compared between-groups according to *Family History* and *Stuttering Status*.

4.3.3 Grouping One: Family history of stuttering

4.3.3.1 Likelihood of Stuttering Onset Based on Family History

Forty-four percent of the children from the family history group started stuttering compared to 11% from the group without a family history group. A Fisher's exact test was not significant for these percentages ($p = 0.29$).

4.3.3.2 Repeated Measures Analysis to Investigate Between-Groups Differences Based on Family History

The repeated measures analysis based on *Family History* was conducted for all four sessions. Table 4.7 shows the means and standard deviations for the Fluency

Profiling System measures, articulation rate and SALT language-based measures by group and by session. There were no group interactions or group main effects when comparing children with a family history of stuttering (n = 9), to children without a family history (n = 9).

To examine patterns of performance across age, marginal means were plotted for each dependent measure according to the groups and for each session. The plots can be seen in Appendix C. There were similar patterns of performance for many measures between children with and without a family history of stuttering when plotted across the sessions.

Some measures had noticeable differences between the groups despite non-significant results. These measures included Percent Intelligibility and Percent Mazes. Percent Intelligibility was reasonably consistent for the control group across the four sessions. Alternatively, the family history group showed a decrease in Percent Intelligibility at Session 3, before increasing again in Session 4. Percent Mazes increased slightly and steadily for the control group across the sessions, however the family history group showed more variable patterns with this measure, going up before coming down again by Session 4.

Table 4.7: Group descriptive data for FPS pause, articulation rate, and SALT measures for children with a family history (n = 9) and controls (n = 9) by session

	Session 1				Session 2				Session 3				Session 4			
	FH		Controls		FH		Controls		FH		Controls		FH		Controls	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
FPS Pause Measures																
Proportion Pause	47.45	9.08	48.58	10.8	48.17	10.12	47.71	7.18	41.77	8.64	42.15	6.87	46.65	9.34	46.67	6.33
Short Pause Mean	4.13	0.13	4.26	0.27	4.21	0.26	4.13	0.24	4.14	0.20	4.04	0.16	4.10	0.18	4.07	0.16
Long Pause Mean	6.04	0.33	6.27	0.54	6.00	0.44	6.10	0.38	5.86	0.38	5.95	0.41	6.00	0.38	6.04	0.38
Misclassification Rate	6.53	2.35	7.04	7.10	8.22	3.31	6.28	2.08	8.42	3.14	6.34	4.04	7.08	2.79	5.92	3.30
Speech Segment Mean	6.65	0.32	6.89	0.46	6.66	0.37	6.67	0.24	6.73	0.27	6.77	0.28	6.70	0.21	6.67	0.11
Articulation Rate																
Syllables Per Second	2.85	0.39	2.64	0.61	2.54	0.38	2.54	0.42	2.88	0.49	2.77	0.55	2.94	0.46	2.98	0.49
SALT Measures																
MLU Morpheme	2.47	0.85	2.79	1.33	2.93	1.10	3.18	1.65	3.03	1.14	3.74	1.44	3.71	1.51	3.84	1.69
No. Different Words	75.44	20.73	82.00	44.70	93.00	35.80	92.33	37.94	96.11	34.57	107.56	36.97	117.89	41.89	117.11	31.92
Percent Intelligibility	87.56	5.81	86.89	4.86	92.00	5.22	89.78	6.59	85.44	8.85	88.33	6.36	90.22	5.95	88.78	6.72
Percent Mazes	4.44	2.96	7.22	3.93	8.67	4.24	7.89	4.37	8.78	4.47	8.67	4.56	6.56	2.46	9.33	2.65

Note. FPS=Fluency Profiling System, SALT=Systematic Analysis of Language Transcripts, FH=Family History. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

4.3.3.3 Analysis of Covariance (ANCOVA) to Investigate Associated Variables Between-Groups Based on Family History

The ANCOVA conducted for groups based on *Family History* of stuttering found no group interactions or group main effects for related measures at any session. Again, because there were no significant group differences, the only reported main effects for measures with no group factor were for ‘typically developing’ speech samples (Speech and Language Samples of Typical Development, section 4.3.1.3 above).

4.3.3.4 Mann-Whitney Comparisons to Investigate Variance Data Between-Groups Based on Family History

The Mann-Whitney comparisons for the variances of each measure were not significant between the groups based on *Family History*.

4.3.4 Grouping Two: Stuttering status

The results from the stuttering status group analyses need to be interpreted with caution due to the low number of children in the positive stuttering status group ($n = 5$). The groups were also not matched for age with the stuttering group being older than the typically developing children. In Session 1, no child was considered to be stuttering. By Session 2, four children from the *Family History* group had started stuttering. By Session 3, one child from the non-family history group had started stuttering, bringing the total number of children stuttering to five. At Session 4, all five children continued to stutter. The remaining 13 continued to develop typically.

4.3.4.1 Individual Patterns in Speech and Language Development

In order to examine individual patterns of development, profile plots for each child were constructed for speech and language measures across the four sessions. The plots are presented in Appendices D to J. Children who were observed to start stuttering are indicated by an asterisk: these are participant numbers 2, 3, 7, 9, and 12.

The variability in children's speech and language ability from session to session was high. No consistent patterns or markers for stuttering onset were identified for any measure. No measure consistently increased or decreased in a linear fashion across all children, even for the typically developing children.

4.3.4.2 Logistic Regression Analysis to Investigate Predictor Variables for Stuttering

Syllables Spoken per Second (p = .019) was the only significant predictor variable from the logistic regression analysis, which was conducted only for Session 1. However, the children who started stuttering were also older, so this result should be interpreted with caution. This can be seen in the scatterplot Figure 4.5. Table 4.8 shows the means and standard deviations for speech and language measures by stuttering status group and session.

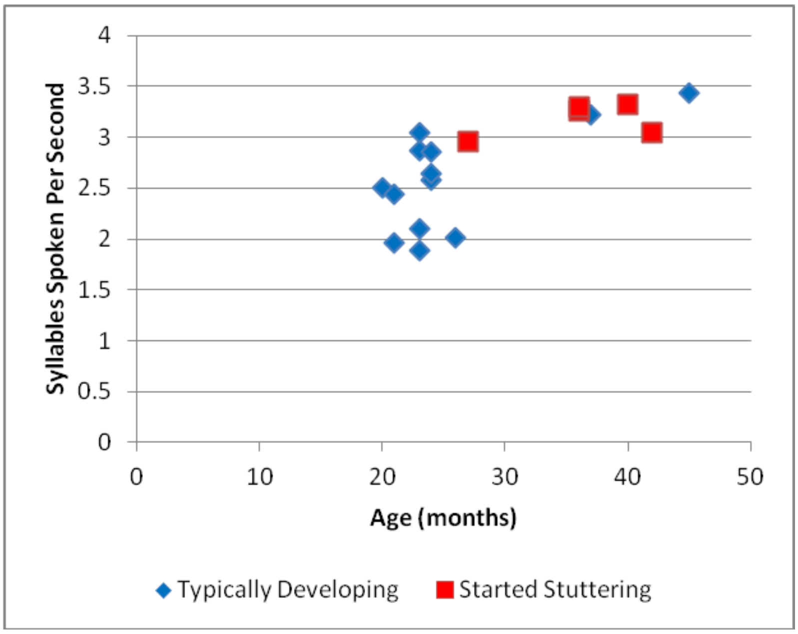


Figure 4.5: Syllables Spoken per Second as a function of age in months and for children based on stuttering status, for Session 1

Table 4.8: Group descriptive data for FPS pause, articulation rate and SALT measures for children who started stuttering (n = 5) and controls (n = 13) by session

	Session 1				Session 2[a]				Session 3[b]				Session 4[b]			
	CWS		Controls		CWS		Controls		CWS		Controls		CWS		Controls	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
FPS Pause Measures																
Proportion of Pause	44.94	10.68	49.20	9.48	43.83	6.47	49.52	8.89	38.54	9.27	43.28	6.78	42.02	8.67	48.45	6.89
Short Pause Mean	4.04	0.12	4.25	0.22	4.04	0.16	4.22	0.24	4.05	0.10	4.11	0.21	3.99	0.12	4.12	0.17
Long Pause Mean	5.95	0.23	6.24	0.49	5.73	0.35	6.17	0.36	5.63	0.40	6.00	0.34	5.85	0.26	6.09	0.39
Misclassification Rate	7.16	2.00	6.64	6.00	9.42	3.37	6.42	2.26	9.79	3.16	6.45	3.52	6.72	1.59	6.41	3.48
Speech Segment Mean	6.73	0.31	6.78	0.44	6.55	0.23	6.70	0.32	6.69	0.31	6.77	0.26	6.71	0.19	6.67	0.16
Articulation Rate																
Syllables per Second	3.18	0.16	2.58	0.50	2.75	0.37	2.45	0.38	3.22	0.27	2.67	0.51	3.18	0.22	2.87	0.50
SALT Measures																
MLU Morpheme	3.24	0.30	2.40	1.21	3.55	0.87	2.86	1.50	4.03	0.75	3.14	1.42	4.46	1.53	3.51	1.54
No. Different Words	96.8	8.17	71.77	37.73	113	31.70	84.85	35.22	123.8	9.58	93.38	38.05	143.8	39.00	107.38	30.71
Percent Intelligibility	88.2	5.93	86.85	5.11	92.6	3.78	90.23	6.52	82.4	10.31	88.62	5.94	90.40	5.32	89.15	6.68
Percent Mazes	7.00	1.87	5.38	4.13	10.8	2.77	7.31	4.33	11.4	4.67	7.69	3.97	8.80	3.27	7.61	2.75

Note. No children were stuttering in Session 1, [a] Four children were stuttering, [b] Five children were stuttering. FPS=Fluency Profiling System, SALT=Systematic Analysis of Language Transcripts, CWS=Children who Stutter. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

4.3.4.3 Repeated Measures Analysis to Investigate Between-Groups Differences Based on Stuttering Status

The grouping based on *Stuttering Status* compared the children who started to stutter (n = 5) to children who were typically developing (n = 13). The repeated measures analysis was conducted for Session 3 and Session 4 only. This was because Session 1 was subjected to logistic regression analysis (section 4.3.4.2 above). It was not necessary to include this session in the repeated measures. Also, Session 2 was not included for grouping based on *Stuttering Status* as it was only from Session 3 when all five children had started stuttering.

Repeated measures analysis was reanalysed for children based on *Stuttering Status* for speech samples of the children who started to stutter *after* stuttered disfluencies were removed from their speech samples. Age, expressed in months, served as a covariate for this analysis to control for expected differences in speech and language development due to age. The children who started stuttering were on average older than the typically developing children.

4.3.4.4 Between-Groups Differences with Stuttered Disfluencies in Samples

The repeated measures analysis found a significant group interaction for Percent Intelligibility (p = .028). No significant group main effects appeared. The children who started to stutter had a lower Percent Intelligibility for Session 3 (M = 82.4) compared to the typically developing children (M = 88.6). This measure increased greatly for the stuttering group in Session 4 (M = 90.4) overtaking the Percent Intelligibility for the controls (M = 89.15). Figure 4.6 shows the group means for Session 3 and Session 4.

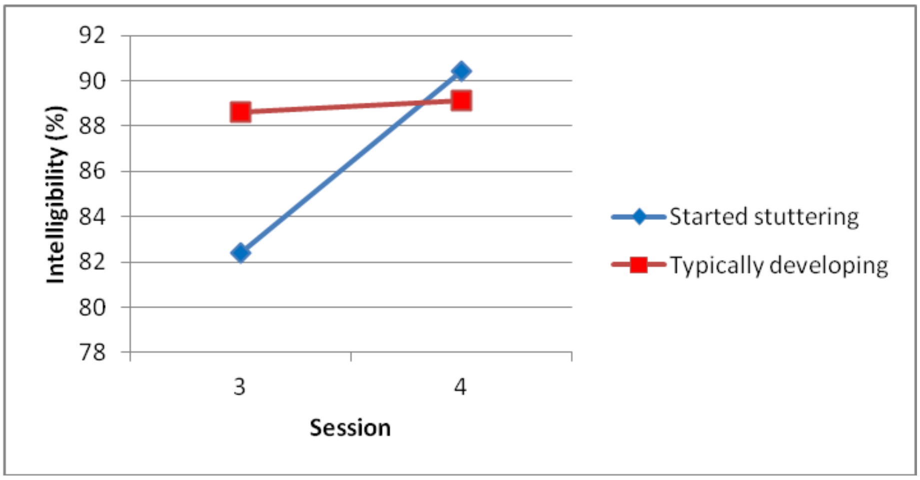


Figure 4.6: Group means for Percent Intelligibility according to stuttering status, for Sessions 3 and 4

Appendix K presents the plots for group marginal means for measures comparing *Stuttering Status* across sessions. Examination of the plots show expected patterns due to the age difference between the two groups. For example, the stuttering group, who were older than the typically developing children, had shorter Short Pause Means and higher number of Syllables Spoken per Second than the typically developing children. The stuttering group also had higher Mean Length of Utterance Morpheme scores and Number of Different Word Roots which is likely due to the age difference. Percent Intelligibility plotted over the four sessions can also be viewed in Appendix K.

4.3.4.5 Between-Groups Differences No Stuttered Disfluencies in Samples

Only measures from The Fluency Profiling System and articulation rate *after* stuttered disfluencies were removed were subjected to a re-run of the repeated measures analysis. No significant effects were found.

4.3.4.6 Analysis of Covariance to Investigate Associated Variables Between-Groups Based on Stuttering Status

Significant group interactions and group main effects from the ANCOVA are summarised respectively in Tables 4.9 and 4.10. For each significant result, the main effect and the direction for the association was examined separately per group. Scatterplots for significant group interactions are presented as Figures 4.7 to 4.13.

Table 4.9: ANCOVA significant group interactions for children who stutter (*n* = 5) and controls (*n* = 13) by session

Covariate Measure	Dependent Measure	GI *p* Value	CWS ME *p* Value (Direction)	Control ME *p* Value (Direction)
Session 2				
MLU Morpheme	Long Pause Mean	.019	.017 (+)	.121 (-)
NDWR	Long Pause Mean	.016	.144 (+)	.031 (-)
Session 3				
Long Pause Mean	Percent Intelligibility	.048	.321 (+)	.142 (-)
Proportion of Pause Time	Percent Intelligibility	.019	.190 (+)	.138 (-)
Session 4				
Long Pause Mean	Percent Intelligibility	.024	.006 (+)	.090 (-)
Syllables Spoken Per Second	Proportion of Pause Time	.029	.016 (+)	.966 (-)
NDWR	Proportion of Pause Time	.018	.215 (+)	.055 (-)

Note. No significant group interactions for S1. CWS=Children who Stutter, GI=Group Interaction, NDWR=No. Different Word Roots, MLU=Mean Length of Utterance, S=Session, Short Pause Mean, Long Pause Mean is in log.

There were no significant *group interactions* found for Session 1. No child was identified to have had started stuttering at this session. Significant group interactions were present for all remaining sessions. Proportion of Pause Time, Percent Intelligibility and Long Pause Mean were the only dependent variables to appear in the group interactions.

For session 2, two significant group interactions were present, Mean Length of Utterance *with* Long Pause Mean (Figure 4.7) and Number of Different Word Roots *with* Long Pause Mean (Figure 4.8). The group interactions were examined separately for each group. The association for Mean Length of Utterance *with* Long Pause Mean was significant for the children who stutter but not for the control children. The association for Number of Different Word Roots *with* Long Pause Mean was significant for control children but not for the children who stutter.

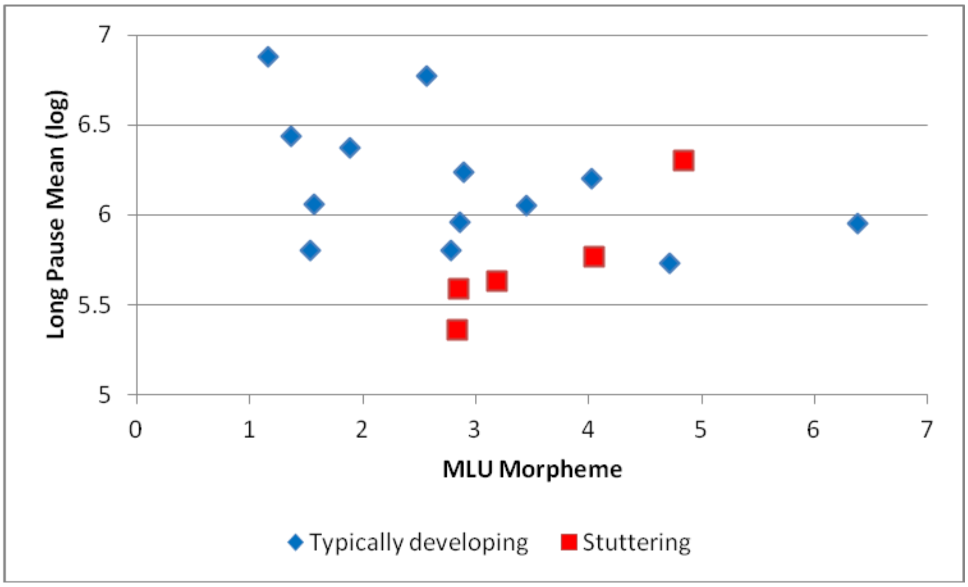


Figure 4.7: Group interaction for Mean Length of Utterance Morphemes (*x*-axis/covariate) *with* Long Pause Mean (log) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 2. Children who stutter (main effect, *p*=.017), control participants (main effect, *p*=.121).

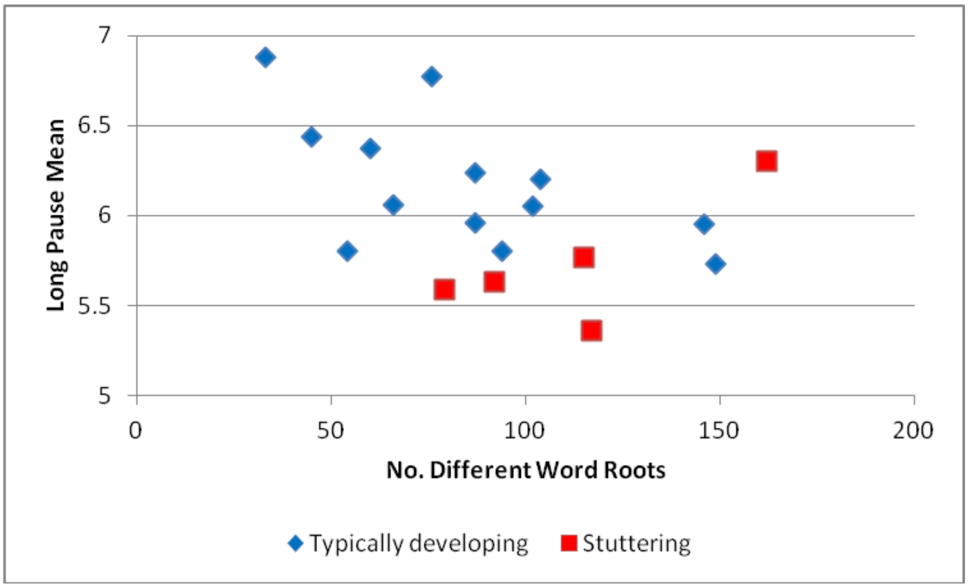


Figure 4.8: Group interaction for Number of Different Word Roots (*x*-axis/covariate) *with* Long Pause Mean (log) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 2. Children who stutter (main effect, *p*=.144), control participants (main effect, *p*=.031).

Group interactions for Sessions 3 and 4 are of particular interest because all five children had started to stutter by Session 3. For Session 3, Long Pause Mean *with* Percent Intelligibility was found to interact significantly between the groups (Figure 4.9). Proportion of Pause Time *with* Percent Intelligibility was also significant (Figure 4.10). For these two group interactions Percent Intelligibility was the dependent variable. This measure was the only measure which showed a significant between-groups difference for the repeated measures analysis between Session 3 and Session 4 (section 4.3.4.4). When the associations were examined separately per group, there were no significant main effects for either group. However the groups were observed to generally show opposite directions for the associations.

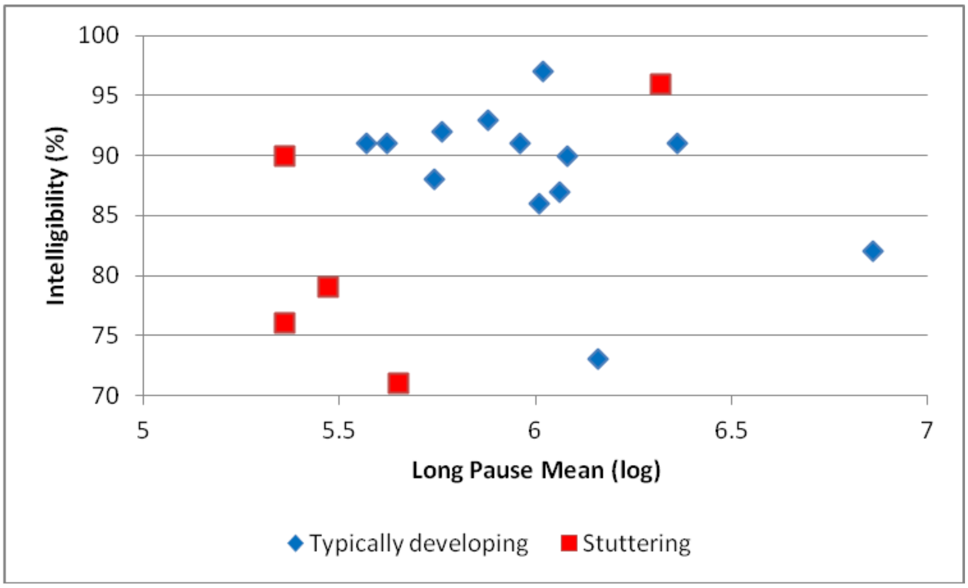


Figure 4.9: Group interaction for Long Pause Mean (log) (*x*-axis/covariate) *with* Intelligibility (%) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 3. Children who stutter (main effect, *p*=.321), control participants (main effect, *p*=.142).

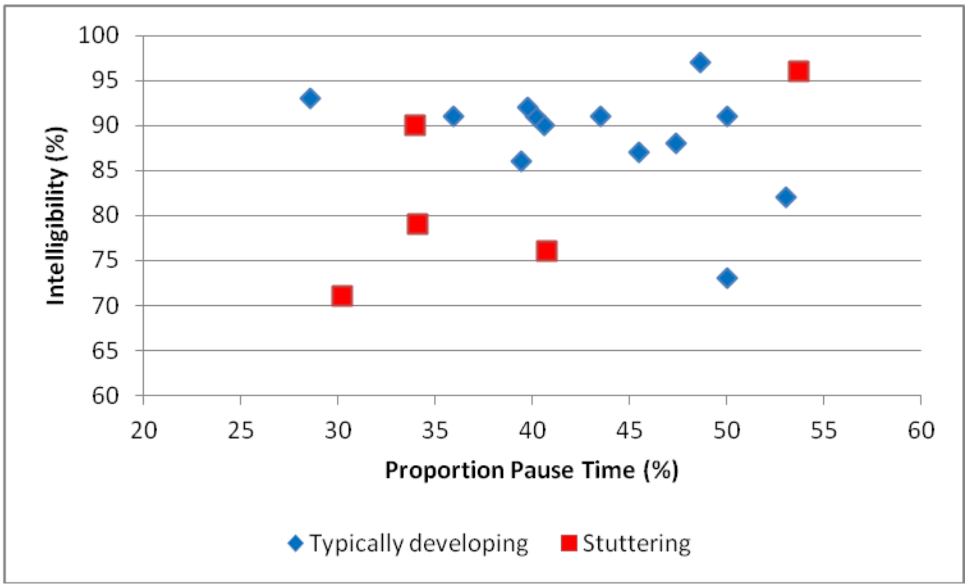


Figure 4.10: Group interaction for Proportion of Pause Time (%) (*x*-axis/covariate) *with* Intelligibility (%) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 3. Children who stutter (main effect, *p*=.190), control participants (main effect, *p*=.138).

For Session 4, there was a group interaction for Long Pause Mean *with* Percent Intelligibility (Figure 4.11). Long Pause Mean significantly predicted Percent

Intelligibility for the children who stutter only. In comparison, the control children showed an opposite trend for the association though their main effect was not significant. Syllables Spoken per Second *with* Proportion of Pause Time (Figure 4.12) had a significant main effect for the stuttering group but not for the control group. Number of Different Word Roots *with* Proportion of Pause Time (Figure 4.13) was not significant for either group. However the associations for each group were in the opposite direction.

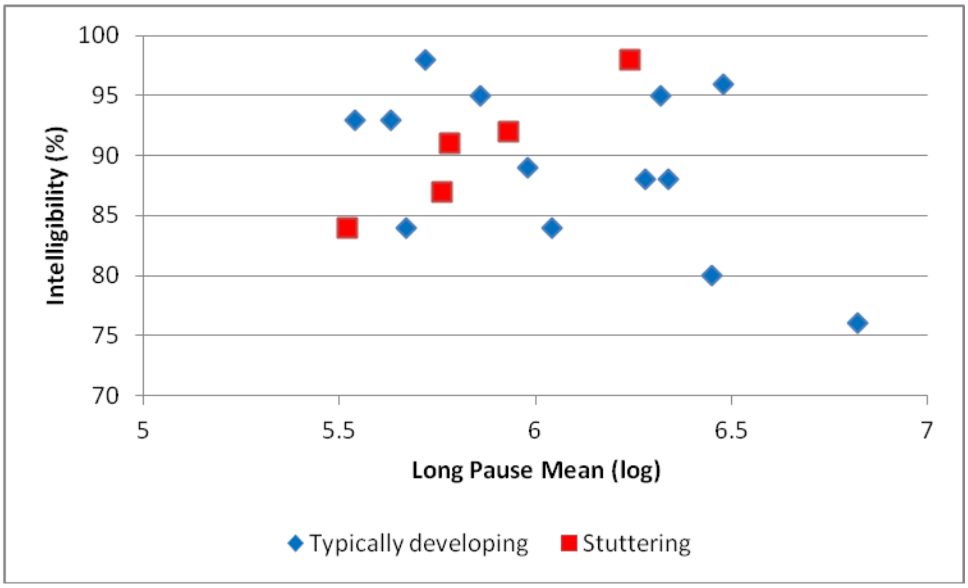


Figure 4.11: Group interaction for Long Pause Mean (log) (*x*-axis/covariate) *with* Intelligibility (%) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 4. Children who stutter (main effect, *p*=.006), control participants (main effect, *p*=.090).

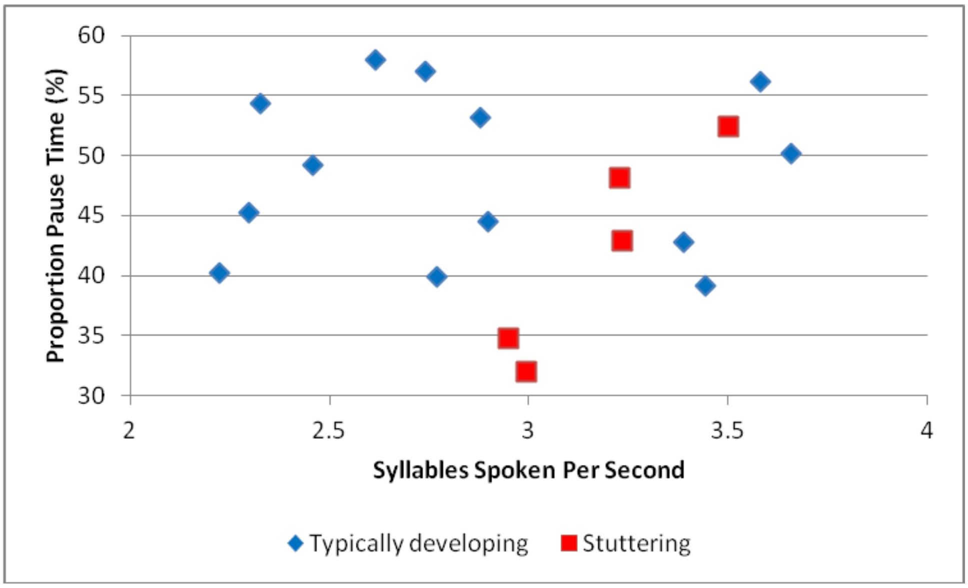


Figure 4.12: Group interaction for Syllables Spoken per Second (*x*-axis/covariate) *with* Proportion of Pause Time (%) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 4. Children who stutter (main effect, *p*=.016), control participants (main effect, *p*=.966).

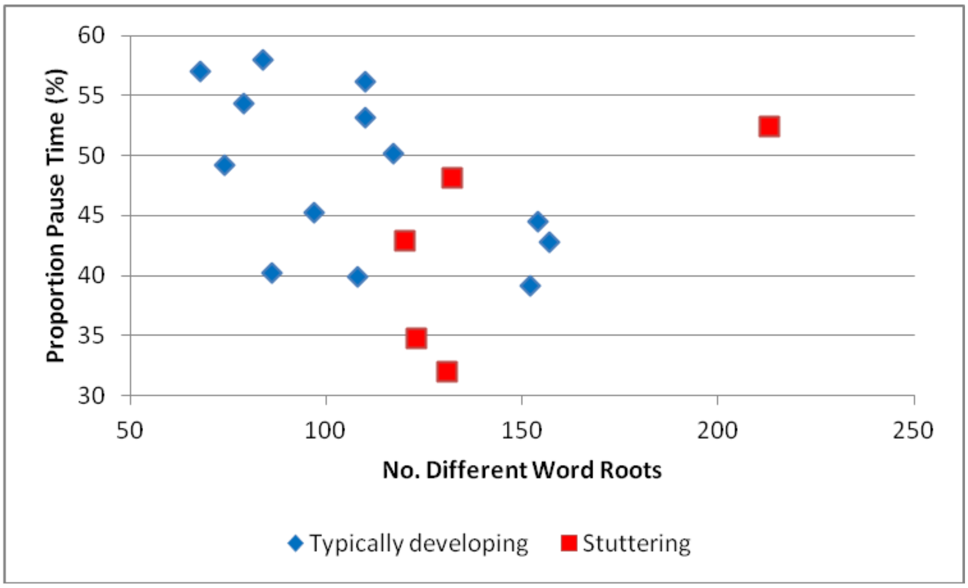


Figure 4.13: Group interaction for No. Different Word Roots (*x*-axis/covariate) *with* Proportion of Pause Time (%) (*y*-axis/dependent variable) with stutters in stuttering samples for Session 4. Children who stutter (main effect, *p*=.215), control participants (main effect, *p*=.055).

Significant *group main effects* are presented in Table 4.10. No group main effects were found for Session 4.

Table 4.10: ANCOVA significant group main effects for children who stutter (CWS) (*n* = 5) and controls (*n* = 13) by session

Covariate Measure	Dependent Measure	GME *p* Value	CWS ME *p* Value (Direction)	Control ME *p* Value (Direction)
Session 1				
Percent Intelligibility	Syllables Spoken Per Second	.015	.542 (-)	.307 (-)
Percent Mazes	Syllables Spoken Per Second	.034	.514 (-)	.438 (+)
Proportion of Pause Time	Syllables Spoken Per Second	.022	.450 (+)	.811 (+)
Long Pause Mean	Syllables Spoken Per Second	.043	.903 (-)	.537 (-)
Speech Segment Mean	Syllables Spoken Per Second	.022	.357 (-)	.325 (-)
Session 2				
Percent Intelligibility	Long Pause Mean	.042	.769 (-)	.931 (+)
Session 3				
Percent Intelligibility	Syllables Spoken Per Second	.015	.223 (+)	.281 (+)
Speech Segment Mean	Syllables Spoken Per Second	.049	.134 (-)	.568 (-)

Note. No significant group main effects for Session 4. No significant group interactions for Session 4.GME=Group Main Effect, NDWR=No. Different Word Roots, MLU=Mean Length of Utterance, S=Session. Long Pause Mean and Speech Segment Mean are in log.

All but one significant group main effect had Syllables Spoken per Second as the dependent variable, and the majority of these main effects were found in Session 1. As previously reported for the logistic regression analysis in section 4.3.4.2, a group difference for Syllables Spoken per Second has likely resulted from the difference in age between the groups. Children who stutter were older and had faster articulation rates than the typically developing children who were on average younger. Hence the appearance of Syllables Spoken per Second as the dependent variable for significant group main effects is not a surprise. The remaining group main effect, Percent Intelligibility *with* Long Pause Mean, was found in Session 2. When this group main effect was examined separately per group, there were no significant measure main effects.

4.3.4.7 Mann-Whitney Comparisons to Investigate Variance Data Between-Groups Based on Stuttering Status

Based on *Stuttering Status*, the Mann-Whitney comparisons for the variances of each measure were not significant for any measures between the groups.

4.3.5 Children who Started Stuttering: Within-group comparisons

4.3.5.1 Univariate Regression Analyses with Clinical Stuttering Measures

See Chapter 3, General Methods (section 3.2.2.1) for background information on this analysis. Only Sessions 3 and Session 4 were subjected to regression analysis as all children who were identified to have started stuttering did so by Session 3. Significant associations for Percent Syllables Stuttered as the clinical stuttering measure were found for Session 3 only.

Percent Syllables Stuttered was negatively associated with Short Pause Mean (p=.001) as can be seen in Figure 4.14. Percent Syllables Stuttered was positively associated with Number of Different Word Roots (p=.023) as can be seen in Figure 4.15, and positively associated with Percent Mazes (p=.004) as can be seen in Figure 4.16.

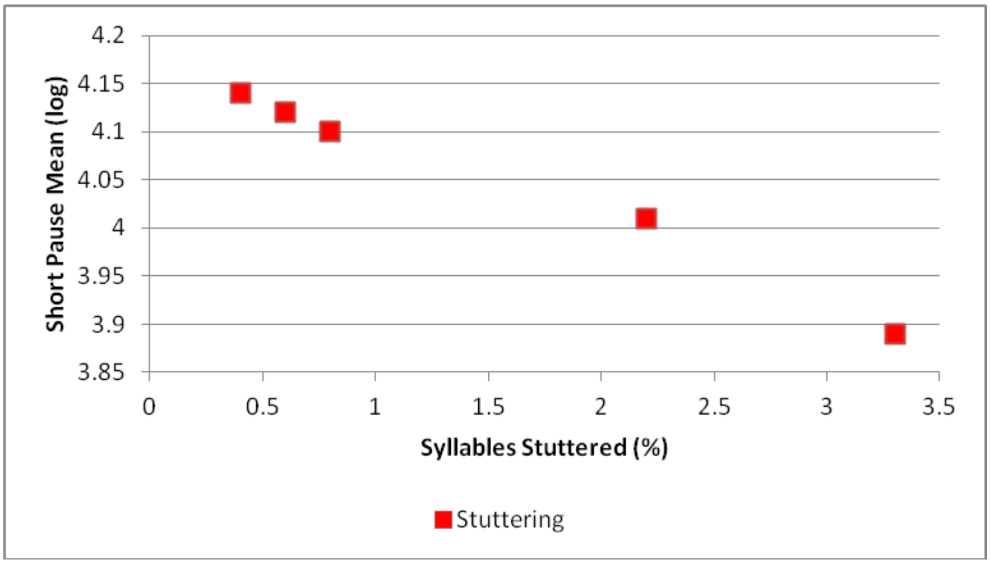


Figure 4.14: Short Pause Mean (log) (*y*-axis) as a function of Percent Syllables Stuttered (*x*-axis) for children who stutter (main effect, *p*=.001) for Session 3.

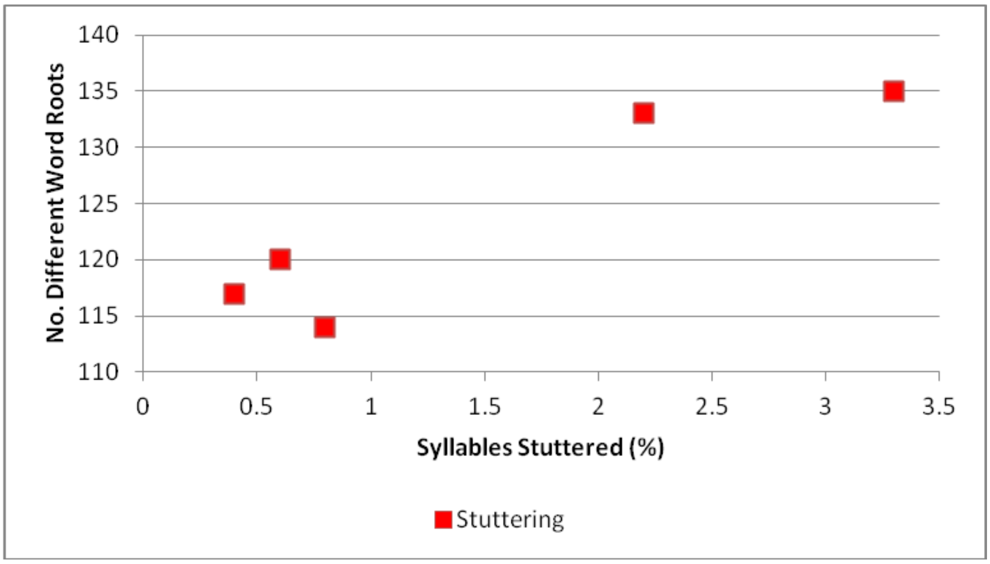


Figure 4.15: Number of Different Word Roots (*y*-axis) as a function of Percent Syllables Stuttered (*x*-axis) for children who stutter (main effect, *p*=.023) for Session 3.

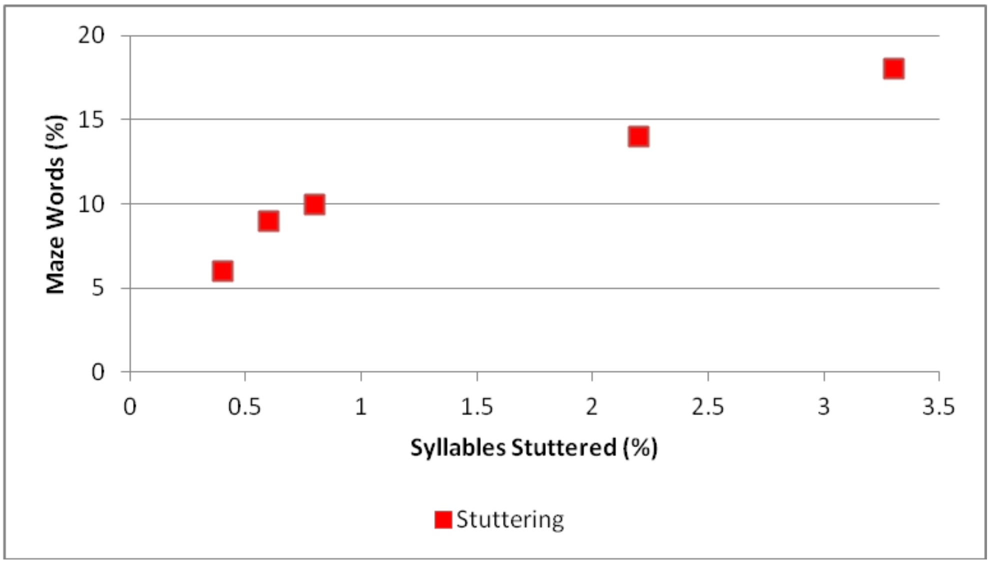


Figure 4.16: Percent Mazes (*y*-axis) as a function of Percent Syllables Stuttered (*x*-axis) for children who stutter (main effect, *p*=.004) for Session 3.

4.3.5.2 Paired Samples t-Tests for Pre-stutter and Post-stutter Removal

See Chapter 3, General Methods (section 3.1.5) for more information regarding the procedure for removing stuttered disfluencies from speech samples for measures from the Fluency Profiling System and for Syllables Spoken per Second.

Stuttered disfluencies were identified and deleted for the samples of the five children who started stuttering after a diagnosis of stuttering was confirmed. For four children this was from Session 2 onwards. For the remaining child this was from Session 3 onwards. Stuttered disfluencies affected a total of 14 speech samples. The sessions were collapsed to obtain group means for pause and articulation rate measures for the conditions, pre-stutter removal and post-stutter removal. Table 4.11 displays the means and standard deviations for measures pre-stutter and post-stutter removal.

Paired samples *t*-tests found significant effects for Proportion of Pause Time, $t(13) = 2.53$, $p = .025$, Speech Segment Mean, $t(13) = 3.34$, $p = .005$, and Syllables Spoken per Second, $t(13) = 2.32$, $p = .038$. Proportion of Pause Time decreased, and

Speech Segment Mean and Syllables Spoken per Second, both increased post-stutter removal.

Table 4.11: Means and standard deviations for pause and articulation measures, pre-stutter and post-stutter removal for the speech samples (n = 14) of the children who started stuttering (n = 5), collapsed across sessions

Measure	Pre-stutter Removal (n = 14)		Post-stutter Removal (n = 14)	
	M	*SD*	*M*	*SD*
Pause Measures				
Proportion of Pause Time*	41.44	8.25	40.97	8.40
Short Pause Mean	4.04	0.13	4.04	0.12
Long Pause Mean	5.74	0.34	5.74	0.34
Misclassification Rate	8.74	3.06	8.81	3.06
Speech Segment Mean*	6.67	0.24	6.73	0.22
Articulation Rate				
Syllables Spoken per Sec*	3.08	0.35	3.10	0.37

Note. * denotes significant effect using paired samples t-test, Long Pause Mean, Short Pause Mean and Speech Segment Mean are in log.

The properties of the deleted pause-speech segment data, as a result of removing stuttered disfluencies from speech samples, were further examined for each stuttering participant. See Table 4.12 for individual means for the children who stutter for Session 3 and Session 4. Across all children who stutter, the average durations of pause segments deleted for Session 3 and Session 4 were 406 and 303 milliseconds, respectively. The average durations of speech segments deleted for Session 3 and Session 4 were 449 and 419 milliseconds, respectively.

Table 4.12: Stuttered pause-segment cycle statistics removed from the speech of children who stutter (n = 5) for Session 3 and Session 4

Participant Number	Pause Segment Duration (*M*) (Milliseconds)	Speech Segment Duration (*M*) (Milliseconds)
Session 3		
2	384.50	409.50
3	296.63	330.11
7	668.17	378.67
9	348.23	729.54
12	332.89	396.00
Session 4		
2	256.44	483.10
3	287.69	310.77
7	441.12	399.38
9	240.30	511.05
12	289.21	388.96

Note. Each pause-speech data line consists of a pause segment duration and speech segment duration.

4.4 Discussion of Speech and Fluency Profiles in Children with and Without Family History of Stuttering and Before and After the Onset of Stuttering

The Discussion section is presented in three main parts. Firstly, a discussion of the results found for investigation of typically developing speech and language measures is presented. Thereafter the discussion is presented according to groupings based on *Family History* and *Stuttering Status*.

4.4.1 Summary of Findings

As a result of the small number of participants recruited for this study, the preliminary finding of this study has yielded inconclusive evidence to support a genetic predisposition as a factor for the onset of stuttering. The results do not indicate that those with genetic predisposition differ in speech and language development compared to children without a genetic predisposition. There were no differences in speech and language profiles for absolute means or for variances between children with and without a family history of stuttering.

Syllables Spoken per Second was the only significant measure found to predict stuttering. However, this finding should be interpreted with caution due to the children who stutter being older than the children who did not stutter.

The speech and language skills of children who started to stutter were comparable to that of the typically developing children before any onset of stuttering. After the onset of stuttering, there was a significant group interaction for Percent Intelligibility according to stuttering status as a function of age. It is hypothesised that stuttering caused a speech system breakdown affecting the intelligibility of speech.

Subtle group differences based on *Stuttering Status* were observed for associated speech and language measures. The differences only became present after the onset of stuttering. Therefore, such differences have arisen as consequences of stuttering rather than causes of stuttering. Children who stutter made adjustments to their speech production, indicated by a need to have ‘more time’ to maintain normal speech and language output. They produced longer long pauses and had a greater proportion of pause time in their speech to maintain language-based measures including Mean Length Utterance Morpheme and Number of Different Word Roots. There were no significant associations with Percent Syllables Stuttered to indicate that the production of stuttered disfluencies in speech accounted for these differences found between the groups.

4.4.2 Typical Speech and Language Development

The first research question of this study asked which speech and language measures could inform about typical development. Measures from the Fluency Profiling System have not yet been gathered for young children. Therefore, it was important to document patterns of normal speech and language development to aid in the interpretation of group differences found for statistical analyses conducted for this study.

The typically developing children showed high variability in their development of speech and language measures. The two exceptions to this were for Mean Length of Utterance Morpheme and Number of Different Word Roots, both of which increased consistently with age in a linear fashion.

With regards to individual speech and language development, the patterns of performance observed across sessions were highly variable in nature. This is consistent with dynamic accounts of speech and language development, which predict that the developmental trajectory of speech and language development is non-linear (Green & Nip, 2010). From session to session, the children sometimes showed patterns of forward change, backward change, or no change for the various measures gathered.

4.4.2.1 The Fluency Profiling System Pause Measures

As hypothesised, the duration of Short Pauses decreased with age. It was the only measure from the Fluency Profiling System to show a significant effect. A decreased Short Pause Mean indicates that the development of the skills associated with speech motor control was more consistent and robust than for Long Pause Mean and Proportion of Pause Time. Long Pause Mean and Proportion of Pause Time relate to cognitive ability and general speech planning and execution processes. Both measures decreased with age as hypothesised but the effects for these measures were not significant. Children produced shorter long pauses and had less proportion of pauses as their speech and language skills developed. Long Pause Mean and Proportion of Pause Time actually increased for children in the four- year age bracket when compared to children in the three- year age bracket. It is likely that this may have been an effect of the small sample size for the four- year old age group (n = 4). Alternatively, it is possible that these children were using more complex sentence structures that resulted in an increase in long pause duration.

4.4.2.2 Articulation Rate

Articulation rate significantly increased with age as expected. Young children made gains in speech and language skills that resulted in the ability to produce speech at a faster rate. Articulation rate figures reported for this study were comparable to previous studies (Logan, et al., 2011). The mean number of Syllables Spoken per Second for children in the three-year age bracket of this study was 3.19, and for children in the four-year age bracket it was 3.21. Both figures fell within the range for studies summarised by Logan et al., (2011) for children aged three- (Range = 2.9 – 3.9), and aged four- (Range = 3.1 – 3.9). No data for children younger than this was available from that study.

4.4.2.3 Systematic Analysis of Language Transcripts (SALT)

Two of the most widely cited measures from SALT, the Mean Length of Utterance Morpheme and Number of Different Word Roots had significant effects with age as hypothesised. Mean Length of Utterance and Number of Word Roots increased with age, confirming that these two measures are robust indicators of language growth.

The average number of different word roots produced by children in this study was less than that reported by Leadholm and Miller, 1992, as cited in Watkins and Yairi (1997). Children aged between 3;0 and 3;11 in this study produced on average 114 different word roots. According to Leadholm and Miller children aged 3;0 years produced on average 118 number of different word roots, and children aged 3;11 years produced on average 144 number of different word roots. The authors did not report any norms for older children. It is likely that differences in speech sampling methodology have contributed to the differences of the results.

Mean Length of Utterance Morpheme found for this study was close to averages reported for a study by Rice et al., (2010) for typically developing children up to four- years of age. However, for children aged four- to four- and a half years old, the average Mean Length of Utterance Morpheme for this study was higher at 5.90 when compared to the mean of control children in Rice’s study of 4.57. The average for this study was also higher than that of children from a study by Watkins and colleagues (1999). Watkins and colleagues reported a Mean Length of Utterance Morpheme of 4.64 and 5.31, respectively for children aged four- and five- years old.

It seems that children in this study had advanced language skills after the age of four- years. However the small sample size (n = 4 speech samples) for this age bracket dictates that a larger number of observations at this age is required to confirm these results. Mean Length of Utterance Morpheme as an indicator of language growth has been found to be most reliable up to a value of 4.0 (Rollins, Snow, & Willett, 1996). Beyond this number, the measure declines in reliability and has been found to be more of a reflection of the speaking context. For example, tasks where speakers have to produce narratives generally result in longer Mean Length of Utterance Morpheme compared to conversational tasks. Children reached a 4.0 Mean Length of Utterance Morpheme by the age of four- years in this study. This is likely due to the speaking task in this study which was more narrative-like with longer sentences and longer turns when compared to conversational tasks.

The remaining measures from SALT, Percent Mazes and Percent Intelligibility, increased with age though they did not reach significance.

4.4.2.4 Associated Measures

It is no surprise that the measures with significant effects as a function of age were also significantly associated with each other.

Articulation rate was negatively associated with Short Pause Mean as predicted. This result supports the notion that the time taken for articulatory shifts from one speech gesture to another as measured by short pauses is related to the number of syllables they execute in time. Individuals who produced shorter short pauses had also produced a higher number of syllables per second.

In line with previous studies, Mean Length of Utterance Morpheme and Number of Different Word Roots were significantly associated with each other, with both measures also being positively associated with articulation rate and Short Pause Mean.

This indicates that the development of speech motor output and efficiency, as measured by Syllables Spoken per Second and Short Pause Mean, are also associated with developing language skills.

There was also an indication of Long Pause Mean to be associated with language skill, as it was positively associated with both Number of Different Word Roots and Mean Length of Utterance Morpheme.

4.4.3 Family History

4.4.3.1 The Number of Children who Started Stuttering

The second research question posed for this study asked whether more children who start to stutter would be from the positive family history group. A total of four children at Session 2 of the study and a total of five children at Session 3 and Session 4 of the study, were stuttering. There was a higher percentage of children from the family history group who started stuttering (44%) compared to the non-family history group (11%). Though this was not statistically significant above chance levels due to the small number of participants and hence lack of power for this study, the percentage reported for children who started to stutter with a family history was four times more than that for children without a family history. It is plausible that this is a reflection of the contribution of genetics to the onset of stuttering and needs to be confirmed with larger-scaled studies.

The contribution of genetics to the onset of stuttering is further hypothesised upon interpretation of the results reported by Reilly and colleagues (2009). They reported that out of a total number of 1619 children, 137 had started to stutter by three-years of age. Of the children who started stuttering 8.8% had a positive family history as determined by reports from parents before any stuttering onset. This figure also did not reach significance as a predictor of stuttering status. However, after the onset of stuttering was identified, a number of parents in this study subsequently recalled a history of stuttering in the family that was not reported prior to their child's onset of stuttering. With this new information the authors reported that 51.8% of children who started to stutter in their study had a positive family history, higher than the 44% observed for this study. This modified figure was not subjected to statistical analysis by Reilly and colleagues for the same study. A re-analysis of the data would likely support a genetic predisposition for the likelihood of the onset stuttering for this study with a much larger sample size than the current study.

4.4.3.2 Differences Based on Family History Grouping

The third research question of the study asked if there were any differences in speech and language measures between children, based on a familial history of stuttering. No group interactions or group main effects appeared for the repeated measures analysis or for the ANCOVA. Even though four out of the nine children from the family history group had started stuttering during the study, there were no between-groups differences. Therefore, the results do not support the notion that having a positive family history for stuttering manifests as differences in speech and language fluency profiles when compared to having no family history.

The findings from this study do not support the hypothesis that children with a genetic predisposition to stuttering have unstable speech motor systems. On examination of the variances across the sessions for the measures of speech motor control abilities, there were no differences between the groups for natural speaking contexts for any sessions. Measures of speech motor ability were Short Pause Mean, Syllables Spoken per Second and Percent Intelligibility. Other measures from the Fluency Profiling System and SALT were not significant. This study only examined the variances for measures from session to session. It may be worthwhile for future studies to consider more specific measures of speech motor variability to investigate the stability of speech motor ability of those with and without a family history of stuttering. For example, kinematic data for the production of speech gestures could be investigated.

As findings from genetic studies of stuttering become clearer, it is likely that the interaction of genes and environment is likely to be further elucidated. Gene x Environment interaction studies aim to find evidence for environmental factors that modify the effect of genes on phenotypes (Pennington, et al., 2009).

4.4.4 Stuttering Status

4.4.4.1 Before the Onset of Stuttering

The next series of questions of this study were in regards to children who were observed to begin stuttering during the study compared to those who continued to typically develop.

Firstly, there were no consistent deviant patterns found for the children who started stuttering through examination of their individual speech and language fluency profiles when compared to those who were typically developing. The data indicate that the five children who started to stutter were developing typically up until they started stuttering. This is consistent with Nippold’s (2012) conclusion that language deficits do not contribute to the onset of stuttering.

Even though articulation rate, measured as Syllables Spoken per Second, was found to be a significant predictor for stuttering status from the logistic regression analysis, the age difference between the two groups have likely affected this result. Therefore as a predictor of stuttering status, this result remains inconclusive. Children who started stuttering were on average 11 months older than the typically developing children and articulation rate was found to increase significantly with age for typical speech and language development. Articulation rate was also the dependent variable for the majority of the significant group main effects found from the ANCOVA. This further demonstrates that there was a group difference for the measure.

Given that Kloth et al. (1999) found that the variability in articulation rate was indicative of the persistence of stuttering compared to the recovery of stuttering; it would be beneficial if future research could confirm this measure as a predictor of the onset of stuttering. A positive finding could imply that the speech motor ability of children who started stuttering were perhaps too advanced for them to coordinate successfully, resulting in a speech motor breakdown. This finding would be in line with the notion that children who stutter speak at a rate beyond what their speech motor abilities allow (e.g., Conture, Louko, & Edwards, 1993).

Reilly et al's (2009) study is the only other study which has found that the onset of stuttering can be predicted by speech and language skill. The authors found that the onset of stuttering was predicted by a higher expressive vocabulary score at the age of two years old. In comparison, the vocabulary measure of Number of Different Word Roots gathered for this study was not found to be a predictor.

4.4.4.2 After the Onset of Stuttering: Group differences for absolute means

No between-group differences for language-based measures were noted for the children who started stuttering when compared to typically developing children. This finding is consistent with Watkins et al. (1999) who found no group differences in language ability for children before and soon after the onset of stuttering. They concluded that children who started stuttering had comparable speech and language skill before and soon after the onset of stuttering. Similar to the data and procedures conducted for this study, Watkins et al. also collected measures from SALT from conversation.

Percent Intelligibility was the only significant group interaction which appeared in the repeated measures analysis. Children who started stuttering had a reduced Percent Intelligibility at Session 3 but then improved at Session 4. In contrast the control group showed little change over the same sessions for this measure. This group difference appeared only after stuttering started and it regressed by approximately 10% for the stuttering group when compared to their previous session (Session 2). This result indicates that stuttering had negatively affected the Percent Intelligibility of those who started stuttering.

4.4.4.3 Group Differences for Associated Measures: Breakdown in percent intelligibility

The circumstances surrounding the associated changes that occurred with Percent Intelligibility were examined further. The results of the ANCOVA suggest that this temporary breakdown in speech motor control was possibly due to the added demands that stuttering had placed on the speech and language systems of the children who started stuttering. As a compensatory mechanism, the children may have produced more pauses and longer pauses in order to maintain levels of Percent Intelligibility.

After controlling for Percent Intelligibility, a significant group main effect at Session 2 was seen for Percent Intelligibility *with* Long Pause Mean. However in subsequent sessions, there were significant group *interactions* with Percent Intelligibility. Proportion of Pause Time and Long Pause Mean, each interacted significantly between the groups *with* Percent Intelligibility at Session 3. At Session 4 there was a group interaction for Long Pause Mean *with* Percent Intelligibility. There are important features of the nature of these significant effects.

The first point to note is that the group main effect became a group interaction in later sessions, highlighting that there were more unusual patterns of performance for Percent Intelligibility for the children who stutter when compared to the typically developing children. This was particularly evident when the children had stuttered for longer. Percent Intelligibility was the dependent measure for all associations in Session 3 and Session 4, in comparison to Session 2 where it was the predictor measure. This finding suggests that Percent Intelligibility became an effect of, rather than predictor of, Proportion of Pause Time and Long Pause Mean.

The associations of the significant group interactions at Session 3 were not significant when examined separately for each group. Instead, the data tended to show opposite trends for the associations in children who started to stutter compared to the typically developing children. The children who stuttered showed positive associations for Proportion of Pause Time *with* Percent Intelligibility and Long Pause Mean *with* Percent Intelligibility, whereas the typically developing children showed negative associations.

The only significant association found was for Long Pause Mean *with* Percent Intelligibility, for children who stuttered at Session 4. This association was positive. Of the children who stuttered, those who had higher Percent Intelligibility also produced longer long pauses. It could be that to maintain intelligibility levels longer long pauses were produced. If this was the case, the compensation used by the children who stutter was effective. Percent Intelligibility at Session 4 was at levels comparable to the typically developing children by after decreasing in Session 3.

The working hypothesis is that production of longer long pauses and greater proportion of pauses in speech demonstrate that children who stutter required ‘more time’ for speech production processes. They may have needed this extra time due to a general increase in speech and language skill. However, children who stutter also had the added demand to cope with stuttering. Therefore, Percent Intelligibility was compromised.

Syllables Spoken per Second, Mean Length of Utterance Morpheme and Number of Different Word Roots, all increased as expected from Session 2 to Session 3 for the children who stutter. There were no between-groups differences for the absolute means of these measures. Cumulatively however, the general increase in speech and language skill may have been too much for the children who stutter to coordinate, resulting in the breakdown observed for the intelligibility of speech. The presence of stuttered disfluencies is unlikely to be able to fully account for the decline observed for Percent Intelligibility. The frequency of stuttering for Session 3 was low with an average of only 1.46% syllables stuttered.

It is possible that articulation rate and Percent Mazes had contributed to unintelligibility of speech even though no group differences were found for these measures. Percent Mazes was observed to follow a similar pattern of performance to that of Percent Intelligibility. This measure increased from Session 2 to Session 3 and then decreased by Session 4 suggesting that the two variables are related. Percent Intelligibility and Percent Mazes positively significantly associated with each other for the typically developing data. Articulation rate was observed to increase by more than twice the number of syllables per second between Session 2 and Session 3 for the children who stutter compared to the typically developing children for the same time span. Children who stutter had an increase of 0.47 syllables per second. Typically developing children had an increase of 0.22 syllables per second.

Lastly, phonological difficulty for the children who stutter is another possible contributor for the decline observed for Percent Intelligibility. Phonological skills have been previously identified as an area of difficulty for children whose stutters persisted compared to those who recovered (Paden, Yairi, & Ambrose, 1999). Phonological difficulty is also the most commonly reported speech disorder to be concomitant with stuttering for children who stutter (Gregg & Yairi, 2007). Perhaps children who stutter had a mismatch of language and phonological ability and with the added factor of stuttering intelligibility was noticeably compromised. Phonological ability was not specifically measured for this study and future studies would benefit from investigating this.

4.4.4.4 Group Differences for Associated Measures: Speech and language trade-offs

The results from the ANCOVA analysis further suggest that children who stutter may have traded-off certain areas of speech and language production to maintain their average performances. There were additional group interactions from the ANCOVA for Session 2 and for Session 4 which demonstrated the subtle changes in speech and language output affected by stuttering.

There were two group interactions found for Session 2. These were Mean Length of Utterance Morpheme *with* Long Pause Mean and Number of Different Word Roots *with* Long Pause Mean. The children who stutter displayed positive relationships for these associations. The positive relationship for association Mean Length of Utterance Morpheme *with* Long Pause Mean was significant. Stuttering children who produced more advanced language output, measured as Mean Length of Utterance Morpheme and Number of Different Word Roots, also produced longer long pauses. This may be an indication that the children who started to stutter compensated for language output very soon after the onset of stuttering by producing longer long pauses in speech. Conversely, the control children displayed negative relationships for the group interactions. The association for Number of Different Word Roots *with* Long Pause Mean was significant. Negative relationships were expected for typical development given that language-based measures increase and long pause durations decrease with age.

In Session 4, it was found that children who stutter who had greater proportion of pauses in time also tended to have increased articulation rate and higher Number of Different Word Roots. These group interactions suggest that the changes had spread to other areas of speech and language, not just for Percent Intelligibility. The positive relationship for the association, Syllables Spoken per Second *with* Proportion of Pause Time, was significant for the stuttering children only. Perhaps pause time was not a factor for typically developing children for maintaining their articulation rates as they did not show a significant association for Syllables Spoken per Second and Proportion of Pause Time.

A positive association for Number of Different Word Roots *with* Proportion of Pause Time show that for some children who stutter who produced higher Number of Different Word Roots also had higher Proportion of Pause Time in their speech. However, this main effect was not significant. Conversely, the typically developing children showed a negative relationship for this association. This negative association is expected given that Proportion of Pause Time decreases with age whereas Number of Different Word Roots increases with age.

It is reiterated that the results from the ANCOVA should be interpreted with caution due to the small sample size. Also, as with any correlational data, causal relationships cannot be determined. It is interesting to note that there were no group interactions from the ANCOVA for Session 1 when no child was considered to be stuttering and that Session 4 had the highest number of group interactions. This further confirms that the changes to speech and language measures observed in this study were consequences of stuttering. Additionally, a range of the speech and language measures gathered were found to be involved with significant group interactions and group main effects. This suggests that the effects of stuttering and the adjustments made by the children who stutter broadly impacted on the measures of speech motor control and language ability.

4.4.4.5 Associations with Percent Syllables Stuttered

The final question asked for this study was how stuttered disfluencies impact on speech and language fluency profiles of children who stutter. There were significant associations with Percent Syllables Stuttered for Session 3. There were no significant associations in Session 4. This suggests that the changes in speech and language associated with stuttered disfluencies were largely temporary.

The first of these associations was a positive relationship with Percent Mazes. That is, the higher percentage of mazes produced was related to a higher frequency of stuttered disfluencies produced in speech. This association was not surprising as the Percent Mazes encompasses all types of disfluencies that halt the flow of speech, including stuttered disfluencies.

There was a negative association for Percent Syllables Stuttered with Short Pause Mean. Children who produced longer short pauses also had less stutters in their speech. Perhaps longer transitions between articulatory gestures were produced as a compensatory mechanism in order to reduce the frequency of stuttered disfluencies in speech.

On the other hand, the association for Percent Syllables Stuttered with Number of Different Word Roots does not suggest compensation or a negative impact of stuttering on language output. The relationship was positive. Those who produced a higher number of different word roots also stuttered more frequently. It is possible that at this early stage of stuttering, a speech motor compensation (short pause mean) was favoured over a language-based compensation by the children who stutter. An alternative explanation is that perhaps this association reflects the relationship that stuttering has with linguistic properties of speech. This would be in line with observations that children who stutter with higher linguistic demands also have a greater tendency for fluency breakdown.

It was interesting that no significant associations with Percent Syllables Stuttered were observed for Session 4. This is likely due to three out of the five children who started stuttering had decreased Percent Syllables Stuttered in Session 4 compared to their ratings in Session 3. However as indicated by the ANCOVA analysis, Session 4 had the highest number of group interactions involving speech and language measures. This could be because the compensations in the speech of children who stutter had spread elsewhere rather than occurring mainly at the level of stuttered disfluencies.

4.4.4.6 Removal of Stuttered Disfluencies

After stuttered disfluencies were removed from speech samples it was found that Proportion of Pause Time decreased and Syllables Spoken per Second increased significantly. This indicates that stuttered disfluencies were comprised of longer pauses relative to their speech segments, and that the production of stuttered disfluencies slowed down articulation rate. The results also confirm that stuttered disfluencies impact on timing aspects of speech production significantly.

It should also be noted that the results of this analysis are interpreted with caution. As the speech sampling context was conversational, it meant that many of the children's 'fluent' pause-speech data were deleted in addition to the pause-speech lines containing stuttered disfluencies. Additionally, some of the children who started stuttering had a very low frequency of Percent Syllables Stuttered. On average the Percent Syllables Stuttered for Session 2 was 2.55, for Session 3 it was 1.47, and for Session 4 it was 1.42, hence for some of the measures there were no differences between the measures pre-stutter and post-stutter removal.

4.4.5 Conclusions

The results show that a family history of stuttering may predict the onset of stuttering if confirmed in future studies with larger number of participants. The data did not support the notion that stuttering originated from deviations in the speech and language processes for spoken language. Rather, stuttering may just merely manifest through overt speech, and that the fluency disruptions experienced by people who stutter are likely to be the consequences of stuttering. In this regard, the underlying deficits in stuttering are likely to originate from differences in neurological functioning.

It was found that soon after stuttering begins, children make changes to their speech production output. This is likely to be a result of having to deal with the dysfunction associated with stuttering. The concept of compensation and trade-off in order to maintain fluency is consistent with the notion of the demands and capacities explanation of fluency breakdown (e.g., Starkweather, Gottwald, & Halfond, 1990). However, this can also be explained with multifactorial models of stuttering, which emphasise the role of linguistic, cognitive, affective, motor and social factors for a person who stutters (e.g., Smith, 1999). The study found that factors impacted on speech fluency (stuttered disfluencies) in conjunction with measures of speech and language output.

The study provided a thorough investigation of the relationship between speech, language and fluency measures. The results confirm that looking for absolute differences between-groups should not be the only focus for investigating the speech and language ability of individuals who stutter (e.g., Anderson, et al., 2005). Through the investigation of how subcomponents of language relate to each other, Anderson and colleagues (2005) found evidence that children who stutter have more dissociation of receptive and expressive language ability than control children.

4.4.6 Study Limitations and Future Research

The small sample size is an obvious limitation for this study. Despite one third of children in this study beginning to stutter this is a small number of participants to inform the evidence base about the ongoing speech and language development associated with stuttering. A larger-scale study which follows children for a longer period of time is required to confirm the findings and hypotheses derived from the results of this study.

The gender distribution for this study was determined by the availability of the participants recruited to participate in the study. With seven females and two males in each of the family history and control groups the distribution was imbalanced. As a result, the distribution of the children who started to stutter, with a female to male ratio of 1.5:1 was also not representative of the gender ratio reported in previous studies where more males stutter compared to females (Yairi & Ambrose, 2005). Furthermore, results from this study should be interpreted with caution as speech and language difference between the genders was not specifically investigated. Further investigation into this aspect would be warranted in future studies with larger number of participants.

Due to the lack of a standardised criterion or measure used to determine stuttering diagnosis, it may be possible that the children who started to stutter in this study do not reflect the purer form of stuttering reported elsewhere in research studies or that the children may have been misdiagnosed with stuttering. However, it is argued that the procedure for diagnosis of stuttering used in this study was congruent with the standard practice of speech pathologists in Western Australia, where stuttering is diagnosed through identification and agreement of core stuttering behaviours between observers. As such, the diagnosis of stuttering used for this study was deemed appropriate for the setting of the study. It may be worthwhile to strengthen the reliability of the diagnosis that a standard criterion is used for future studies.

Despite the comprehensive speech and language measures gathered in this study, the language measures gathered using SALT do not offer detailed accounts for specific areas of speech and/or language abilities. For example, the complexity of use of syntactic structures is not captured in detail from any measure of SALT. Also, phonological ability measured as Percent Intelligibility is considered a broad measure.

More specific measurement of phonological ability would be an area for future research to further investigate the group difference found for Percent Intelligibility based on the stuttering status. Phonological ability is thought to be related to the short pause distribution. However, what remains unknown is how phonological delay and/or disorder would affect the short pause distribution. Short pause duration was found to decrease with an increase in age, so it could be hypothesised that an increase in phonological ability is associated with a decrease in the mean duration of short pauses. Measuring pauses in the speech of children with articulation difficulty has been previously attempted by Deputy, Nakasone, and Tosi (1982). They found no differences in pausing frequency and duration, even though they measured pauses as short as 10 milliseconds in duration.

On average across all samples the number of pauses available for distribution analysis was 360 pauses per participant. However, for some of the files of the children's speech samples in this study became shorter in duration due to the procedures necessary to prepare files for pause analysis. Deletion of parent/examiner speech together with the subsequent child data line resulted in a reduction of data due to the conversational nature of the interactions. For older children who produced more speech, the removal of these subsequent child data lines did not pose a threat to data integrity. Younger children had shorter speech samples and are noted to have less speech input for pause analysis. The pause distribution analysis was still able to generate data based on these samples. However, for future studies it would be worthwhile to target a longer speech sampling time for younger children.

4.4.7 Study Summary

The study was limited in finding evidence to support a genetic predisposition for the onset of stuttering. The results did not show any differences in speech and language function as measured in spontaneous speech between children with and without a family history of stuttering. This study found that the speech and language development of children until stuttering onset occurs is otherwise normal. However, preliminary evidence from this study supports that for young children who start to stutter, differences in their speech and language ability can be seen very soon. Changes to speech and language output were observed for children who started stuttering between three- to six- months after the onset of stuttering.

Some changes in speech output could be attributed to the impact of stuttered disfluencies on speech and language measures, whereas other changes involved speech and language measures themselves. These early deviant effects may continue to develop if stuttering continues, and this has implications for the assessment and monitoring of children who start to stutter. In addition to the fluency skills related to the production of stuttered disfluencies, a more comprehensive investigation of the child’s speech and language skills should be included in the battery of assessments for children who start to stutter.

CHAPTER 5: SPEECH AND LANGUAGE FLUENCY PROFILES IN SCHOOL-AGED CHILDREN WHO DO AND DO NOT STUTTER

This study investigated speech and language fluency profiles of school-aged children who stutter for a single session. The same speech and language measures were gathered for participants in this study as for Study 1. To investigate the early to moderate-term effects of stuttering, school-aged children who had been stuttering for more than six months participated. The impact of stuttered disfluencies on spontaneous speech processes was analysed through identification of associations with Percent Syllables Stuttered and investigation of speech samples with and without overt stuttered disfluencies.

Results from Study 1 of this study found that, soon after the onset of stuttering, there were changes to speech and language output. The repeated measures analysis revealed a significant group interaction for Percent Intelligibility with Age when comparing the children who started to stutter to the typically developing children. There was a temporary decline for Percent Intelligibility resulting from system dysfunction for the children who started stuttering.

The ANCOVA revealed significant group interactions to demonstrate speech and language associations to be deviant for the children who started to stutter compared to the controls. The group interactions indicated that children who stutter required more time for speech production processes. Children who stutter produced more and longer pauses in order to maintain average performance of speech and language measures when compared to typically developing children. Lastly, the presence of significant associations for Percent Syllables Stuttered with speech and language measures further support the impact of stuttered disfluencies on speech and language output.

5.1.1 Hypotheses

General hypotheses for this study are presented at the end of Chapter 2, Literature Review. It was further hypothesised that if a child continues to stutter, the impact of stuttering may become more severe. This would be indicated by group differences for measures when comparing the perceptually fluent speech of children who stutter to the speech of control participants. School-aged children who stutter may adopt more noticeable trade-offs in speech to maintain fluency. This would be indicated by significant associations with Percent Syllables Stuttered. The impact of stuttered disfluencies would be indicated by differences in speech and language measures for speech samples before and after stuttered disfluencies were removed.

Stuttering for a longer time may also lead to dissociations across subcomponents of speech and language output. Trade-offs between speech and language-based measures gathered for this study could be possible, particularly when the speech and language skills of the children are still developing. Dissociations for the receptive and expressive abilities of children who stutter have been found in previous studies (e.g., Anderson, et al., 2005; Coulter, Anderson, & Conture, 2009).

5.1.2 Research Questions

The following research questions were asked for this study:

1. Do school-aged children who stutter differ in their speech and language fluency profiles compared to school-aged children who do not stutter?
2. How do stuttered disfluencies impact on speech and language fluency profiles for children who start to stutter?

5.2 Method

5.2.1 Participants

Twenty six children participated in the study, 13 children who stutter and 13 children who do not stutter. Each control child was specifically selected to match the gender, and age within two months, of a child that stuttered. All children were aged between 47 and 107 months.

There were eight males and five females in each group. Mean ages in each group were 65 months for children who stutter, and 66 months for control children. No child had a history of neurological, psychological or intellectual impairment. At the time of the study there were no reports of hearing difficulties for any child and English was the first language for all participants. Control children had no previous history of stuttering and no known difficulties with speech and language.

There was no standard measure used for the diagnosis of stuttering (see section 3.1.1). A diagnosis of stuttering was assessed by a qualified speech pathologist and confirmed by the child's parent(s) through identification of the presence of core stuttering behaviours (Wingate, 1964). Eleven out of thirteen of the children had also received speech pathology treatment for their stutter confirming a diagnosis of stuttering from a qualified speech pathologist not related to this study. The children were also required to have been stuttering for more than six months, as confirmed by the child's parent(s). The average time since the onset of stuttering was approximately 25.54 months. All children who stutter had been stuttering for a period of 12 months or more with the exception of one child, Participant 9, who had been stuttering for 11 months.

There was no attempt to control or restrict the speech therapy of any participant during the study. Eleven out of the 13 stuttering children had previously received speech pathology treatment for their stutter and eight of them were still receiving therapy in some form at the time of this study. Out of the eight receiving therapy, only two children were receiving regular treatment sessions. The remaining six children were on maintenance phases of therapy programs and as such were not receiving regular direct treatment from a speech pathologist during the study. Two children had never received any formal speech therapy for their stuttering, and a stuttering diagnosis for these children was confirmed by the primary investigator of this study.

Children who stutter were recruited through advertisements placed in community newspapers and from local speech pathology services from within the Perth metropolitan area. Control children were recruited by word-of-mouth, through colleagues, family and friends of the examiner.

Group participant characteristics are reported in Table 5.1. Individual stuttering participant characteristics are reported in Table 5.3. This table also includes Percent Syllables Stuttered for the children who stutter, the procedure of which is described in Section 5.2.4: Data Collection Procedures, below.

Table 5.1: Characteristics of school-aged children (*n* = 13) who stutter and controls (*n* = 13)

	Stuttering		Controls	
	M	*SD*	*M*	*SD*
Age (months)	65	18	66	20
Syllables Stuttered (%SS)	1.8	1.53	_	_
Time Since Stuttering Onset (months)	25.54	14.34	_	_

Note. Dash indicates no clinical measures were obtained.

5.2.2 Apparatus

Speech and language samples of the children were recorded and video-taped. The same apparatus was used as in Study 1. Please refer to Chapter 4 Methods (section 4.2.2) for more information.

5.2.3 Design and Procedure

Parents completed a case-history form about their child's speech, language and general development. For children who stutter, parents also gave details about the time since stuttering onset, characteristics of the stutter, and previous or current treatment. Appendix L details the questions asked in the case-history questionnaire.

The speech samples consisted of structured monologues collected by the examiner. Data were recorded in a single session. Speech samples were collected at the participants' homes, in a quiet room as free from distractions as possible. For each speech sampling session, an initial play and conversation component was conducted to establish rapport with the child. Thereafter, four spontaneous speaking tasks were employed for the purposes of speech and language analysis. The entire session was video recorded but only the four monologues were subjected to speech and language fluency analysis. Monologue topics were chosen based on narratives that school-aged children would typically encounter at home or at school (Jardine, 2004). The monologue topics are listed in Table 5.2.

Speech samples were elicited using a conversational mapping procedure outlined by Hadley (1998). The interviewer shares a personal experience related to the topic before encouraging the child to produce their own response. Such interview style elicitations have been demonstrated to produce longer utterances than free play interactions (Hadley, 1998). A standard examiner story was used for each topic and implemented for all participants. See Appendix M for the scripts verbatim.

Table 5.2: Speech sampling protocol for school-aged children (Jardine, 2004)

Type of Monologue	Interview Question
Personal Narrative	"Tell me all about what you did yesterday"
Procedural Narrative	"What's your favourite game to play? I don't know how to play that game! Tell me all about how you play that game"
Descriptive Narrative	"What's your favourite toy in the whole wide world? Tell me all about it!"
Story generation/fictional generation	"If you could be a superhero for a day, who would you be? What would you do all day?"

5.2.4 Data Collection Procedures

Please see Chapter 3, General Methods for details relating to measures collected for this study including clinical stuttering measures, the Fluency Profiling System analysis procedure, articulation rate and the procedure for removing stuttered disfluencies from speech. See Chapter 4, Study 1, for details regarding the procedure for SALT (section 4.2.4.4). The same speech samples consisting of the four monologue tasks were subjected to all analysis procedures.

5.2.4.1 Clinical Stuttering Measures

A minimum sample of 300 syllables was used to rate Percent Syllables Stuttered for all children with the exception of two, in which only 148 and 196 syllables were available. On average the children had 1.84% syllables stuttered, with a range of 0.7% to 4.8% syllables stuttered.

Table 5.3: Individual characteristics and stuttering measures of school-aged children who stutter (*n* = 13)

Participant Number	Sex	Age (months)	Syllables Stuttered (%)	Time since stuttering onset (months)	Current therapy
1	M	50	2.8	20	YES
2	F	52	5.0	16	YES
3	M	63	1.4	33	YES
4	F	50	0.7	26	YES
5	M	58	0.7	34	NO
6	M	76	0.7	58	NO
7	M	90	2.8	48	YES
8	M	107	4.8	23	YES
9	F	47	1.1	11	YES
10	M	58	1.0	22	NO
11	F	70	0.8	16	NO
12	M	75	1.1	13	YES
13	F	49	1.0	12	NO

5.2.4.2 The Fluency Profiling System Pause Measures

After the deletion of all speech produced by the examiner as well as every speech segment that the child produced immediately after an examiner speech segment, a *child only* speech sample time remained. With stuttered disfluencies included in the speech samples of the stuttering group, the *child only* total speech times collected across all children were on average 3.73 minutes per child. The *child only* sample time did not significantly differ between the groups (Stuttering: M = 3.83, SD = 146, Control: M = 3.62, SD = 166). After deletion of all pauses greater than 20 milliseconds from the *child* *only* samples, a *speech only* sample remained. The average *speech only* sample time collected across all children was 2.08 minutes per child. This *speech only* sample time did not differ between the groups (Stuttering: *M* = 2.04, *SD* = 0.88, Control: *M* = 2.12, *SD* = 0.62).

5.2.4.3 Articulation Rate

For children who stutter, articulation rate was calculated for speech samples with and without stuttered disfluencies. An average 420 syllables per child was counted for articulation rate (*SD* = 155) across all children and for the samples with stuttered disfluencies included in the samples of children who stutter. The total number of syllables produced did not significantly differ between the groups (Stuttering: *M* = 390 syllables, *SD* = 142, Range = 148 – 581, Control: *M* = 450 syllables, *SD* = 166, Range = 94 – 794). For the samples with stuttered disfluencies deleted, the total number of syllables did not differ between the groups (Stuttering: *M* = 353 syllables, *SD* = 138, Range = 96 – 536).

Long pauses were deleted for the calculation of articulation rate based on each child's unique pause threshold. This long pause threshold was on average at 182 milliseconds across all speech samples (for the stuttering samples containing stutters).

5.2.4.4 Systematic Analysis of Language Transcripts (SALT)

Please see Chapter 4, Methods for Study 1 (section 4.2.4.4) for information on the procedure used to gather measures using SALT (Miller, 2008).

The total number of utterances produced by each child was analysed for this study and expressed as Number of Total Utterances because all children had the same opportunity to produce four narratives each. A minimum sample of 50 utterances was collected for each participant except for two stuttering children who produced 33 and 37 utterances in total. Children who stutter produced on average 66 utterances (Range = 33 – 102, *SD* = 8.28), and control children produced 67 utterances (Range = 50 – 98, *SD* = 13.30). There was no significant group difference for Number of Total Utterances produced.

Speech and language measures from SALT were not examined for samples with stuttered disfluencies removed. Chapter 3, General Methods (section 3.1.5) discussed this in more detail. Stuttered disfluencies and other disfluencies such as filled pauses, revisions and false starts, were coded as Percent Mazes according to SALT.

5.3 Results

Please see Chapter 3, General Methods for background information regarding statistical analysis methods.

5.3.1 Between-Groups Comparisons: **t**-*Tests*

Table 5.4 shows the group means and standard deviations for the speech and language measures gathered. For the children who stutter, descriptive statistics for speech samples with and without stuttered disfluencies are presented.

5.3.1.1 Group Differences with Stuttered Disfluencies in Samples

A significant group difference was present for Short Pause Mean, $t(24) = 2.98$, $p = .007$. Children who stutter produced longer short pauses ($M = 4.26$ log) compared to control children ($M = 3.98$ log). Figure 5.1 displays the means per group for Short Pause Mean.

5.3.1.2 Group Differences No Stuttered Disfluencies in Samples

When stuttered disfluencies were removed from the speech samples of children who stutter, a significant difference remained for Short Pause Mean, $t(24) = 2.91$, $p = .009$. Children who stutter produced longer *short* pauses ($M = 4.25$) than the speech of the control children ($M = 3.98$). Figure 5.2 displays the group means for this condition. There was a significant difference for Long Pause Mean, $t(24) = 2.24$, $p = .036$. Children who stutter produced longer *long* pauses ($M = 6.55$) compared control children ($M = 6.20$) when stutters were no longer in their samples. Figure 5.3 displays the group means for Long Pause Mean.

Table 5.4: Descriptive data for FPS pause, articulation rate, and SALT measures for school-aged children who stutter (CWS) pre-stutter and post-stutter removal (*n* = 13), and controls (*n* = 13)

	CWS With Stutters		CWS No Stutters		Controls	
	M	*SD*	*M*	*SD*	*M*	*SD*
FPS Pause Measures						
Proportion of Pause Time	47.67	12.22	46.93	12.15	41.62	7.68
Short Pause Mean	4.26	0.29	4.25	0.29	3.98	0.17
Long Pause Mean	6.49	0.43	6.55	0.46	6.20	0.33
Misclassification Rate	5.76	2.96	4.90	2.79	4.94	2.69
Speech Segment Mean	7.01	0.34	7.09	0.36	6.93	0.27
Articulation Rate						
Syllables Spoken per Second	3.17	0.64	3.21	0.66	3.23	0.55
SALT Measures						
Number of Total Utterances	66.46	18.28	-	-	66.54	13.30
MLU Morpheme	5.28	1.31	-	-	6.43	1.55
NDWR	132.23	40.70	-	-	138.69	33.87
Percent Intelligibility	97.31	2.21	-	-	98.85	1.86
Percent Mazes	14.15	5.29	-	-	10.46	4.96

Note. Dash indicates measure not obtained for this condition, FPS=Fluency Profiling System, SALT=Systematic Analysis of Language Transcripts, MLU=Mean Length of Utterance, NDWR=Number of Different Word Roots. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

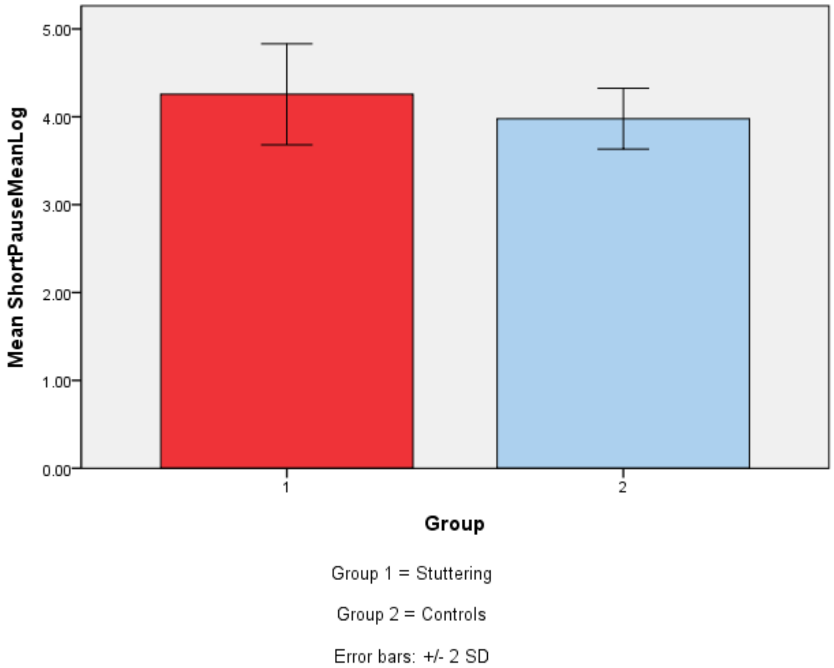


Figure 5.1: Between-groups means for Short Pause Mean (log) *pre-stutter* removal

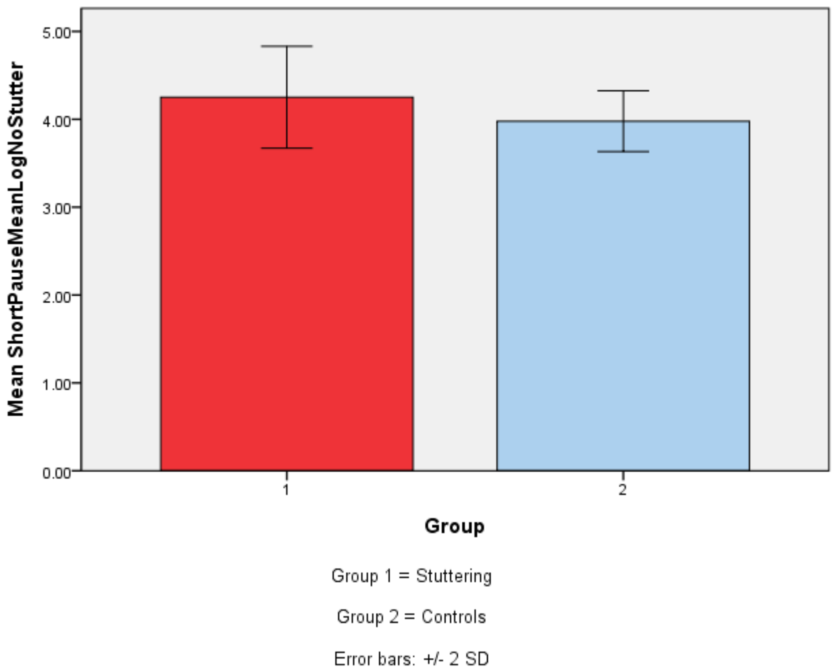


Figure 5.2: Between-groups means for Short Pause Mean (log) *post-stutter* removal

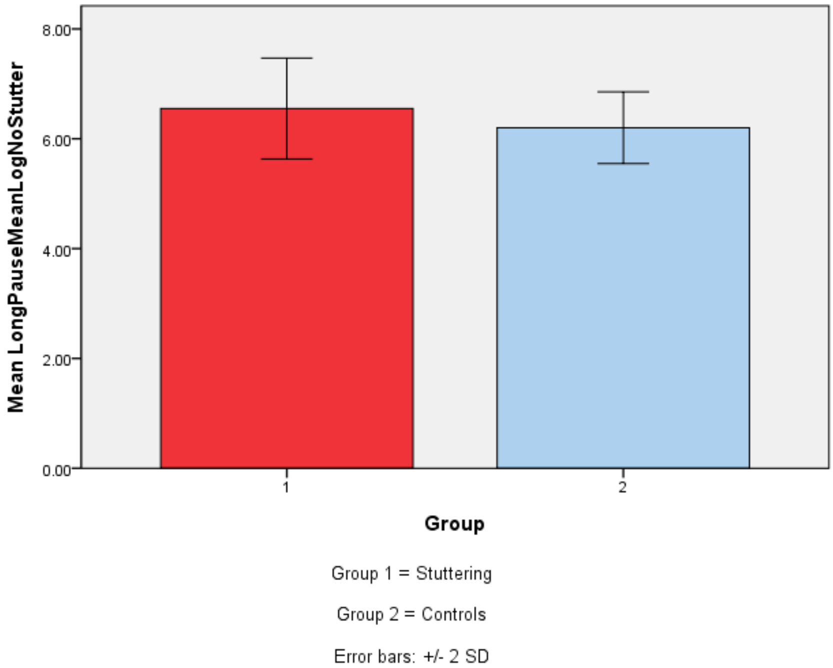


Figure 5.3: Between-groups means for Long Pause Mean (log) *post-stutter* removal

5.3.2 Between-Groups Comparisons: Associated measures

See Chapter 3, General Methods (section 3.2.1.2) for background information about the ANCOVA. Group interactions were examined and if they were not significant, group main effects and measure main effects (associations) were examined. Significant group interactions and group main effects are reported in the format ‘Covariate Variable *with* Dependent Variable.’

5.3.2.1 Group Interactions

Table 5.5 displays the significant effects. The Table also presents the significance values and the direction for the associations per group, per group interaction and group main effect. A range of measures appeared as covariates with Percent Mazes, Mean Length of Utterance Morpheme, Proportion of Pause Time and Syllables Spoken per Second as dependent variables.

Table 5.5: ANCOVA significant group interactions for school-aged children who stutter (CWS) (*n* = 13) and controls (*n* = 13)

Covariate Measure	Dependent Measure	*p* Value of Effect	CWS ME *p* Value (Direction)	Control ME *p* Value (Direction)
Long Pause Mean	Percent Mazes	.021	.708 (+)	.004 (-)
Proportion Pause Time	Percent Mazes	.004	.228 (+)	.004 (-)
Syllables Spoken Second	MLU Morpheme	.047	.732 (+)	.005 (+)
MLU Morpheme	Proportion Pause Time	.036	.002 (-)	.155 (-)
NDWR	Proportion Pause Time	.022	.000 (-)	.319 (-)
NDWR	Syllables Spoken Second	.013	.776 (-)	.000 (+)
Percent Intelligibility	Syllables Spoken Second	.018	.406 (-)	.008 (+)

Note. NDWR=No. Different Word Roots, MLU=Mean Length of Utterance, Long Pause Mean is in log.

The associations for the significant group interactions were examined separately for each group. Long Pauses and Proportion of Pause Time were both negatively associated *with* Percent Mazes for the control group only (Figures 5.4 & 5.5, respectively). Syllables Spoken per Second was positively associated *with* Mean Length of Utterance Morpheme (Figure 5.6), and Number of Different Word Roots and Percent

Intelligibility were both positively associated *with* Syllables Spoken per Second (Figures 5.7 & 5.8, respectively) for the control group only.

Mean Length of Utterance Morpheme and Number of Different Word Roots were both negatively associated *with* Proportion of Pause Time (Figures 5.9 & 5.10, respectively) only for children who stutter.

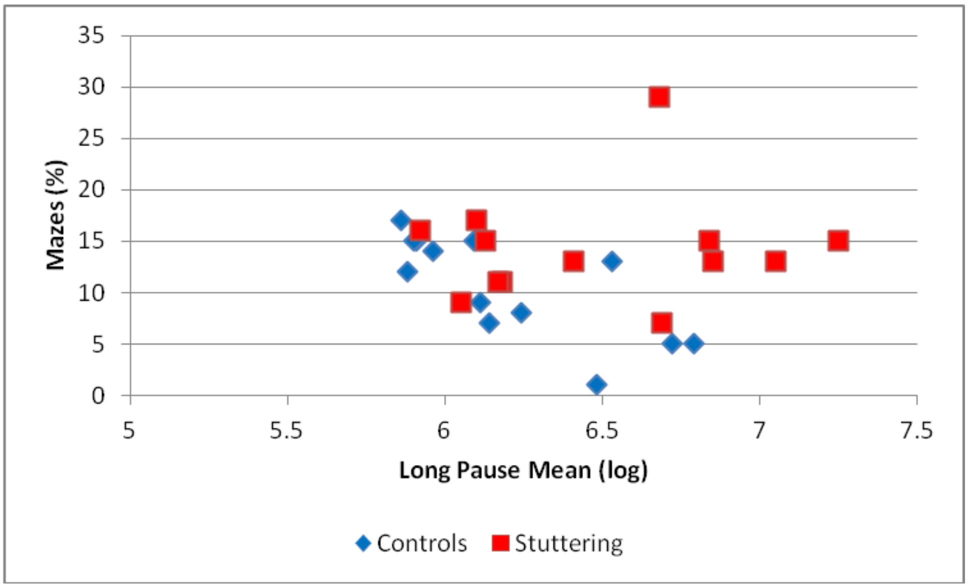


Figure 5.4: Group interaction for Long Pause Mean (log) (*x*-axis/covariate) and Mazes (%) (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, p=.708), control participants (main effect, p=.004).

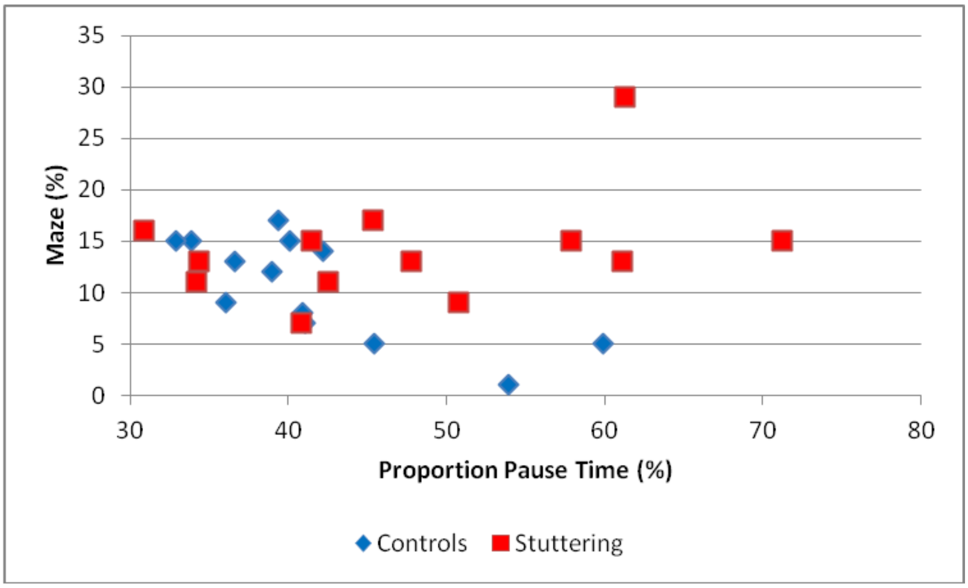


Figure 5.5: Group interaction for Proportion of Pause Time (%) (*x*-axis/covariate) and Mazes (%) (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, *p*=.228), control participants (main effect, *p*=.004).

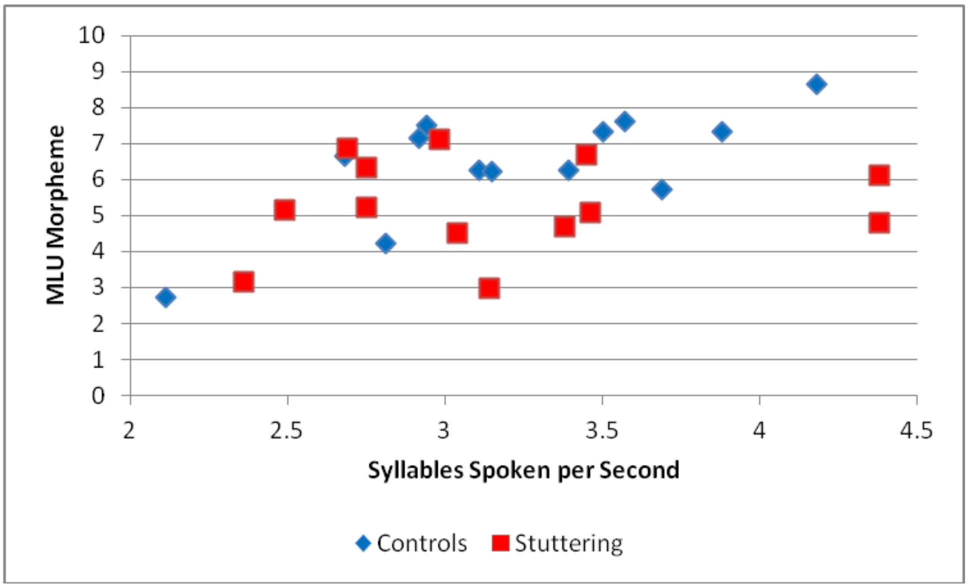


Figure 5.6: Group interaction for Syllables Spoken per Second (*x*-axis/covariate) and Mean Length of Utterance Morphemes (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, *p*=.732), control participants (main effect, *p*=.005).

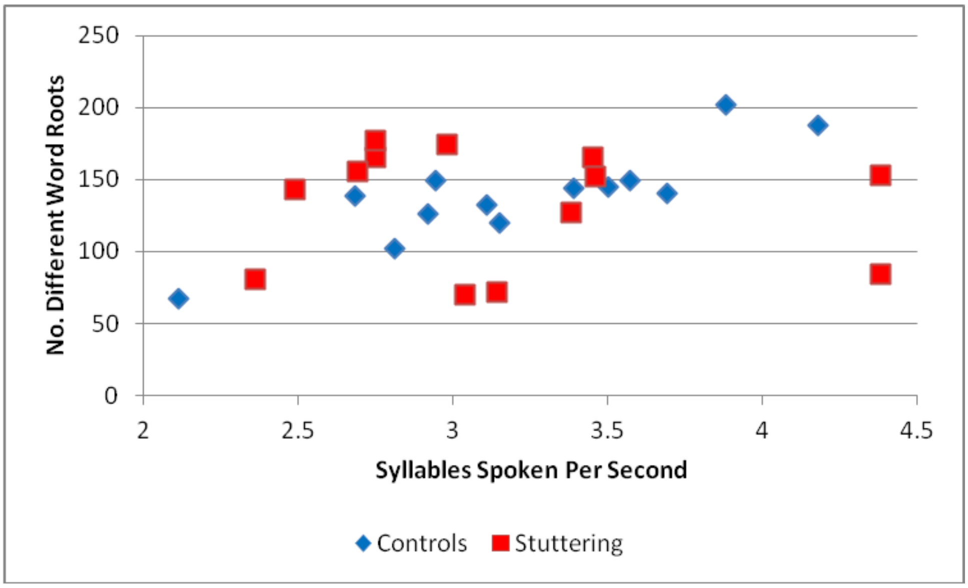


Figure 5.7: Group interaction for Syllables Spoken per Second (*x*-axis/covariate) and Number of Different Word Roots (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, p=.776), control participants (main effect, p=.000).

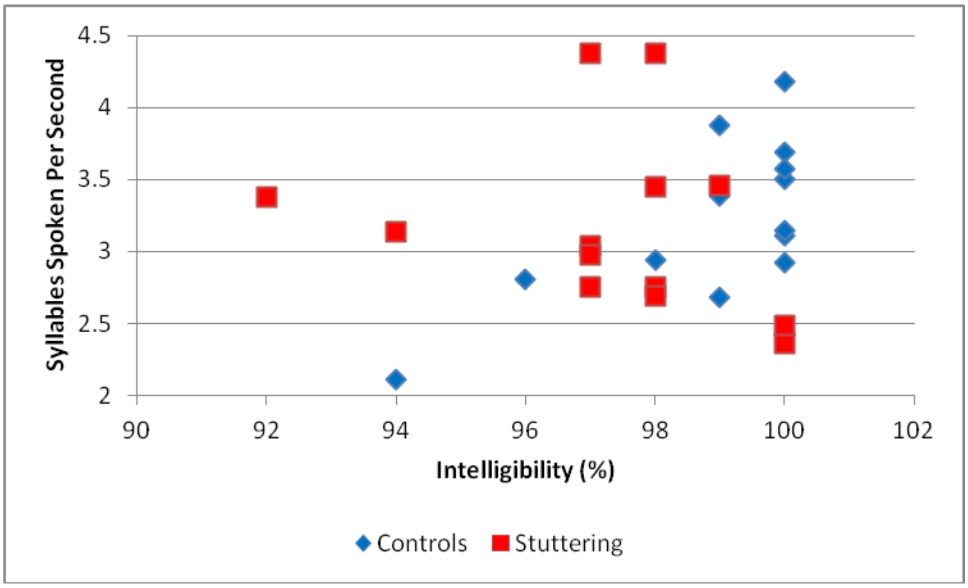


Figure 5.8: Group interaction for Intelligibility (%) (*x*-axis/covariate) and Syllables Spoken per Second (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, p=.406), control participants (main effect, p=.008).

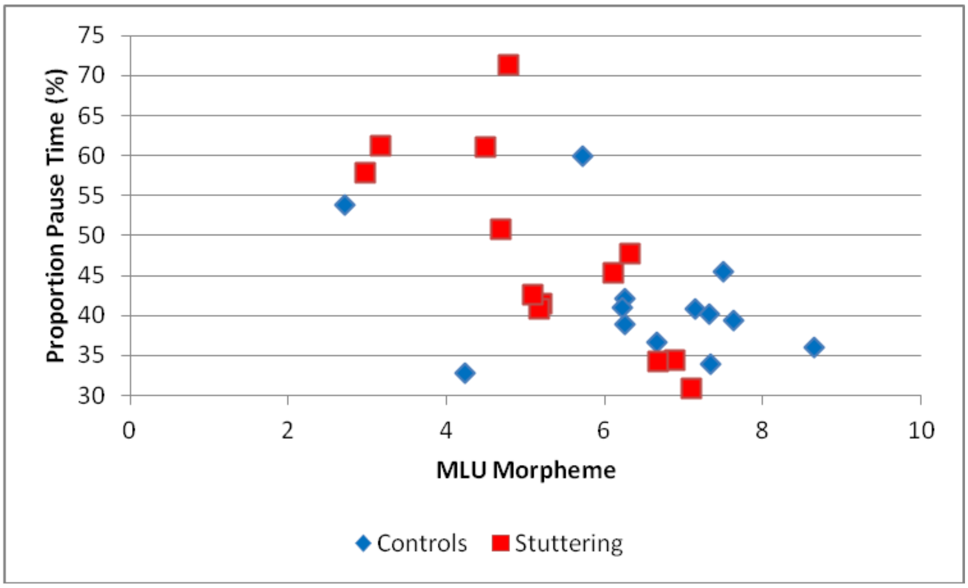


Figure 5.9: Group interaction for Mean Length of Utterance Morphemes (*x*-axis/covariate), and Proportion of Pause Time (%) (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, *p*=.002), control participants (main effect, *p*=.155).

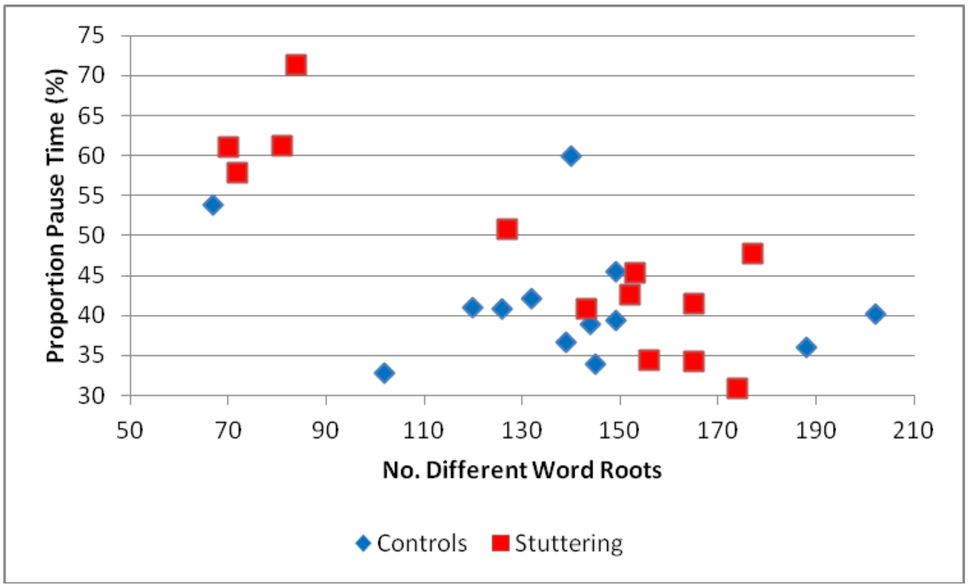


Figure 5.10: Group interaction for Number of Different Word Roots (*x*-axis/covariate) and Proportion of Pause Time (%) (*y*-axis/dependent variable) with stuttered disfluencies in samples. School-aged children who stutter (main effect, *p*=.000), control participants (main effect, *p*=.319).

5.3.2.2 Group Main Effects

Table 5.6 shows the significant group main effects. A number of significant group main effects appeared for associations with Short Pause Mean as the dependent measure. There was also a between-groups difference for Short Pause Mean for the independent samples *t*-tests pre-stutter removal. Mean Length of Utterance Morpheme, Number of Different Word Roots, Percent Intelligibility, Percent Mazes and Number of Total Utterances were all found to significantly predict Short Pause Mean. Long Pause Mean, which significantly differed between the groups for the post-stutter removal condition, appeared in a group main effect with Number of Total Utterances as the dependent measure.

Table 5.6: ANCOVA significant group main effects for school-aged children who stutter (CWS) (n = 13) and controls (n = 13)

Covariate Measure	Dependent Measure	p Value of Effect	CWS ME p Value (Direction)	Control ME p Value (Direction)
MLU Morpheme	Short Pause Mean	.047	.267 (-)	.020 (-)
NDWR	Short Pause Mean	.007	.331 (-)	.070 (-)
Percent Intelligibility	Short Pause Mean	.017	.559 (+)	.016 (-)
Percent Mazes	Short Pause Mean	.013	.666 (+)	.667 (-)
No. Total Utterances	Long Pause Mean	.043	.033 (-)	.288 (-)
No. Total Utterances	Short Pause Mean	.007	.048 (+)	.370 (+)

Note. ME=Main effect, MLU=Mean Length of Utterance, NDWR=No. Different Word Roots, Long Pause Mean and Short Pause Mean are in log.

5.3.2.3 Measure Main Effects

Table 5.7 displays the significant measure main effects with no group factor. Proportion of Pause Time was negatively associated with Number of Total Utterances. Long Pause Mean was negatively associated with Number of Different Word Roots, and with Number of Total Utterances. Short Pause Mean was negatively associated with Syllables Spoken per Second, and with Mean Length of Utterance Morpheme.

Table 5.7: ANCOVA Significant measure main effects with no group factor (n = 26)

Measure 1	Measure 2	p Value	Direction
Proportion of Pause Time	No. Total Utterances	.039	-
Long Pause Mean	NDWR	.026	-
Long Pause Mean	No. Total Utterances	.012	-
Short Pause Mean	Syllables Spoken Second	.003	-
Short Pause Mean	MLU Morpheme	.031	-

Note. NDWR=Number of Different Word Roots, MLU=Mean Length of Utterance, Long Pause Mean and Short Pause Mean are in log.

5.3.3 Within-Group Comparisons: Children who stutter only

5.3.3.1 Univariate Regression Analyses with Clinical Stuttering Measures

Regression analyses were conducted to investigate relationships between clinical stuttering measures (Time Since Onset of Stuttering, Percent Syllables Stuttered) and speech and language measures for the stuttering group only. Significant associations were found only for measures with Percent Syllables Stuttered.

There was a significant positive association for Percent Syllables Stuttered and Proportion of Pause Time (p = .004). There were significant negative associations for Percent Syllables Stuttered with Mean Length of Utterance Morpheme (p = .031) and with Number of Different Word Roots (p = .007). The scatterplots for these associations are presented in Figures 5.11, 5.12, and 5.13, respectively.

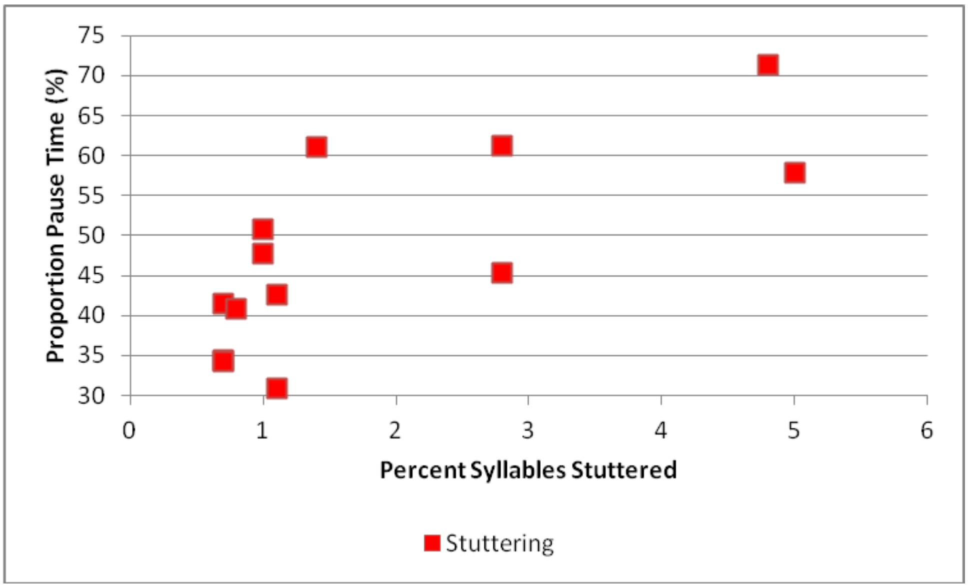


Figure 5.11: Proportion of Pause Times (%) (y-axis) as a function of Percent Syllables Stuttered (x-axis) for school-aged children who stutter (p = .004).

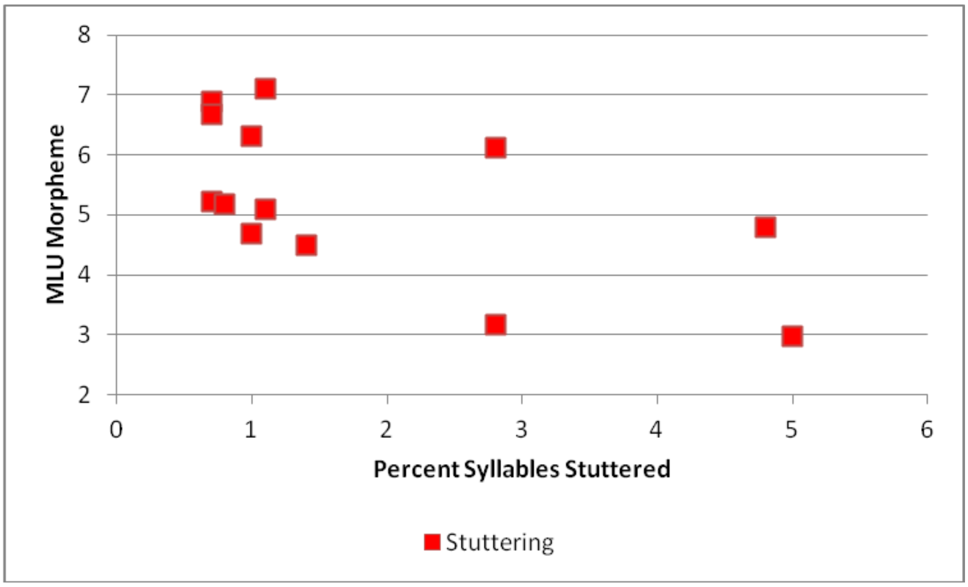


Figure 5.12: Mean Length of Utterance in Morphemes (y-axis) as a function of Percent Syllables Stuttered (x-axis) for school-aged children who stutter (p = .031).

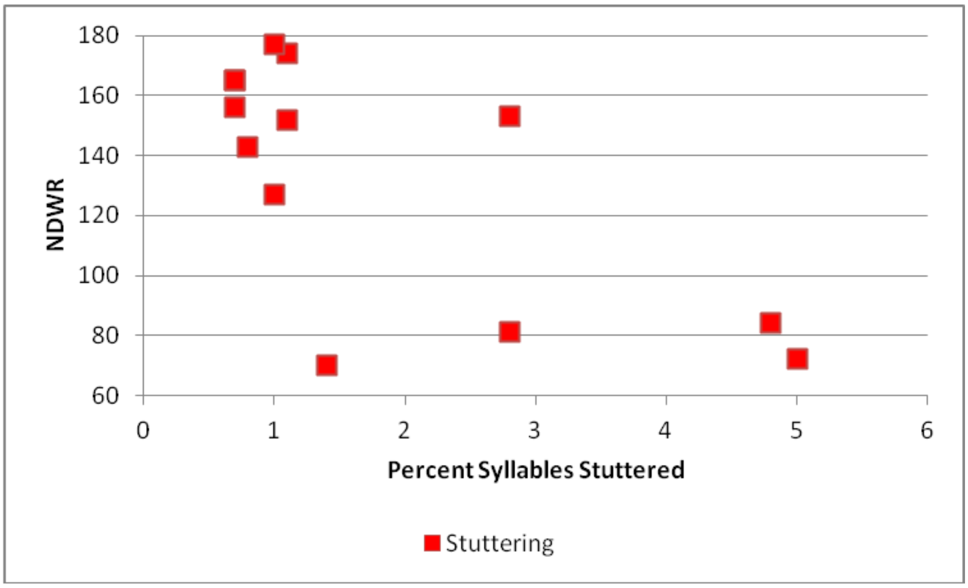


Figure 5.13: Number of Different Word Roots (*y*-axis) as a function of Percent Syllables Stuttered (*x*-axis) for school-aged children who stutter (p = .007).

5.3.3.2 Paired Samples t-Tests for Pre-stutter and Post-stutter Removal

Paired-samples *t*-tests for the two conditions pre-stutter and post-stutter removal were conducted to examine the impact of stuttered disfluencies on pause and articulation measures for the stuttering group. Speech Segment Mean from the Fluency Profiling System was the only measure that was significant, $t(12) = 2.64$, $p = .022$. Post removal of stuttered disfluencies resulted in longer duration of speech segments for the children who stutter (*Pre-stutter Mean* = 7.01, *Post-stutter Mean* = 7.09).

Table 5.4 (presented above) shows the means and standard deviations for the measures pre-stutter and post-stutter removal for the children who stutter and for the control group. As can be seen in this table, the group means for some measures for children who stutter had moved towards the means of the controls when stuttered disfluencies were removed. This included Proportion of Pause Time, Short Pause Mean and Syllables Spoken per Second. Misclassification Rate decreased below the mean of the control children. Speech Segment Mean became longer but it did not result in a significant group difference. The children who stutter already showed a higher mean for this measure than the control children *pre-stutter* removal. Long Pause Mean increased post-stutter removal and resulted in a significant difference between the groups after stuttered disfluencies were removed (*t*-tests above).

The properties of the pause-speech segment data containing stuttered disfluencies were further examined for each stuttering participant. See Table 5.8 for individual means for the children who stutter. Across all children who stutter pause segments deleted had an average duration of 438 milliseconds. The average duration removed of speech segments was 508 milliseconds.

Table 5.8: Descriptive statistics for the stuttered pause-segment cycles removed from the speech of children who stutter (n = 13)

Participant Number	Pause Segment Duration (M) (Milliseconds)	Speech Segment Duration (M) (Milliseconds)
1	390.27	328.08
2	313.67	495.69
3	228.25	456.50
4	419.53	589.12
5	712.00	717.60
6	156.60	415.13
7	544.71	526.05
8	885.89	328.33
9	347.22	769.50
10	567.27	648.57
11	298.76	571.53
12	362.42	321.68
13	474.14	436.91

Note. Each pause-speech data line consists of a pause segment duration and speech segment duration

5.4 Discussion of Speech and Fluency Profiles in Children who do and do not Stutter

5.4.1 Summary of Findings

Findings from this study support that children who stutter have whole-system dysfunction as indicated by slower speech production processes than children in the control group. This was signified by group differences for Long Pause Mean and Short Pause Mean for the perceptually fluent speech of children who stutter. Children who stutter showed differences compared to the controls in regards to how some speech and language skills associated with each other, indicating the possible use of trade-offs in speech. There were no group differences for any language measures based on absolute means. The negative effect of stuttered disfluencies on speech and language output was confirmed with findings in this study.

5.4.2 Group Differences for Absolute Means

The first question posed in this study asked whether children who stutter differed in their speech and language fluency profiles compared to their normally fluent peers.

Children who stutter produced longer *short* pauses in their speech compared to controls when stuttered disfluencies remained in their speech. When stuttered disfluencies were removed from their speech samples, children who stutter produced significantly longer *long* and longer *short* pauses than controls. The real-time difference between the groups for long pauses was 206 milliseconds, and the difference for short pauses was 18 milliseconds. This finding is in line with an extensive body of previous research that has repeatedly demonstrated that the differences seen in the speech of people who stutter are inherent even when they are not observed to be stuttering (see also, Bloodstein & Bernstein Ratner, 2008).

The Short Pause Mean group difference post-stutter removal, suggests that children who stutter are taking more time with speech motor processes that arise from speech motor planning and/or speech motor programming processes (van der Merwe, 2009). Specifically, short pauses reflect the time taken for articulatory shifts from one speech gesture to the next speech gesture. Articulatory shifts are dependent on co-articulatory factors and place assimilation in consonant sequences between and within syllables. Given that the real-time means for this measure was 54 milliseconds for the control children and 70 milliseconds for the children who stutter, it is likely that short pauses are largely articulatory in nature.

Articulation rate measured as Syllables Spoken per Second was unable to fully account for the group difference for Short Pause Mean because the group difference for this measure was not significant post-stutter removal. This indicates that it was the *transition* between articulatory gestures, rather than the execution of speech units in syllables where children who stutter differed compare to control children. Syllables Spoken per Second and Short Pause Mean were found to correlate with each other as hypothesised. The relationship was a negative one for typically developing children in Study 1 and also for children in this study. This was indicated by a significant measure main effect from the ANCOVA with no group factor. The faster the children articulated, the shorter their short pauses were. For children who stutter, this was also the case even with stuttered disfluencies remaining in their speech samples.

A non-significant result for Syllables Spoken per Second is consistent with some previous studies of children who stutter (e.g., Hall, et al., 1999; Logan, et al., 2011).

Other studies have reported different findings, showing a significant difference in this measure (e.g., Meyers & Freeman, 1985). The average articulation rate for this study was 3.23 syllables spoken per second for children in the control group aged 5;6 years. In comparable speech sampling tasks to this study, Logan and colleagues (2011) reported syllables spoken per second to range from 3.20 to 4.30 for children who were younger at five years of age. According to these norms the articulation rate for children in this study is considered to be slower. This is surprising given that the articulation rates for children in this study should be faster than that of other studies. This is because the silent pause threshold used to calculate the measure was on average 182 milliseconds, based on each child's unique pause threshold. This threshold is lower than the usual criterion of 250 milliseconds (Goldman-Eisler, 1968) used to calculate syllables spoken per second. There are likely differences in methodology that have impacted on articulation rate. What remains unknown is how these variables affect articulation rate (Logan, et al., 2011).

Differences in the temporal aspects for vowel-consonant transitions have not been found for children who stutter in previous studies (e.g., Caruso, Conture, & Colton, 1988; Zebrowski, et al., 1985). Stop gaps were measured for children who stutter for single words and did not differ in duration compared to controls (Zebrowski, et al., 1985). The difference in results between the study by Zebrowski and colleagues and the present study may be attributed to differences in task and number of cases available for analysis. Zebrowski and colleagues measured stop gaps from a total of 16 productions of single words. In comparison, an average number of 156 short pauses were measured per child for this study in connected speech.

It is plausible that other speech, language and/or cognitive processes have contributed to the group difference found for Short Pause Mean. The removal of stutters and pause-speech segments after stuttered segments served to minimise the contribution of stuttered disfluencies on pause and articulation measures. However, the removal of stuttered disfluencies and pause-speech segments does not account for strategies used by children who stutter to control or avoid stuttering. Such strategies may be related to the production of brief pauses in speech not discernible as stuttered disfluencies.

It is thought that young children generally lack the cognitive and motor ability to modify stuttered disfluencies (Guitar, 2006). However, it is possible that young children use similar ongoing avoidance and delay strategies as used by adults who stutter. Given that eight out of 13 of the children were also receiving therapy at the time of this study, they may also be using some strategies learned from therapy. Unfortunately, there is no reliable way to quantify the contribution of compensatory techniques for the children in this study, which is an area for future research.

Short pauses may also be related to error repair and lexical retrieval processes. It is thought that short pauses relating to such processes are not likely to be as abundant as short pauses relating to articulatory transitions. Therefore, it is unlikely that the Short Pause Mean difference has stemmed from such processes.

Pauses related to error repair processes, revisions and interjections, were not identified and removed as part of the process for removing stuttered disfluencies. Children who stutter produced a higher percentage of mazes (comprising of stuttered and non-stuttered disfluencies) than controls. However because the group difference for Percent Mazes was not significant, the short pause difference cannot be explained by a difference in production in mazes. Investigating the type and occurrence of non-stuttered disfluencies could provide further insight into the role of these disfluencies on the production of short pauses.

A delay in the access of words cannot be ruled out as another contributor to the Short Pause Mean difference between the groups. Lexical encoding for speech production has been previously implicated as an area of difficulty for children who stutter (Pellowski & Conture, 2005). However, given that children who stutter produced a comparable number of different word roots in speech than controls in this study, this is unlikely to be the sole reason as to why children who stutter produced longer short pauses in speech.

The *Long Pause Mean* differences found after stuttered disfluencies were removed indicate that stuttered disfluencies have masked the true production of long pauses in the speech of children who stutter. Shorter long pauses were produced by the more frequent fragmentations of pauses due to the interruption caused by stuttered disfluencies. The differences in Long Pause Mean, therefore, indicate that children who stutter took more time for speech production. This could be related to difficulties with conceptualisation and language planning, as long pauses have been found to be related to these processes (Goldman-Eisler, 1968).

Number of Total Utterances as a measure of general communicative competence did not differ between the two groups. However, without a measure of the informativeness and relevance of the speech output it is possible that the group difference in long pauses was due to difficulties with conceptualisation processes for the children who stutter.

Though the absolute group differences did not reach statistical significance for any language measure, there was evidence from the ANCOVA to indicate that longer long pauses were associated with reduced language output. Measure main effects with no group factor were present for Long Pause Mean and Number of Different Word Roots, as well as for Long Pause Mean and Number of Total Utterances. Longer long pauses were associated with fewer different word roots and fewer total utterances produced across all children. There was evidence from the ANCOVA to indicate that the group difference in the production of long pauses is related to differences in language skill between the groups. This is discussed below, in section 5.4.3.

In conjunction with a group difference for Short Pause Mean, a significant group difference for Long Pause Mean suggests that children who stutter take longer with linguistic planning, speech motor planning, and execution processes of speech production. To account for a whole system dysfunction, it is plausible that difficulty with higher level linguistic planning processes are cascading down to effect speech motor control planning, programming, and/or execution processes (van der Merwe, 2009). It is suggested that reverse effects are also possible. This was indicated by results of the ANCOVA, whereby both speech and language measures were implicated as covariate variables in significant group interactions and group main effects.

5.4.3 Group Differences for Associated Measures

The group interactions and group main effects found for the ANCOVA show that children who stutter have unusual patterns of performance when language measures were examined in relation to speech measures. It was found that speech and language measures can similarly impact on each other. The reader is reminded that the ANCOVA analysed speech samples that contained stuttered disfluencies for children who stutter. This was conducted to examine differences in patterns of performance for speech and language fluency measures in the natural speech of children who stutter.

The significant *group main effects* confirm that the children who stutter performed differently to the control children for Short Pause Mean and Long Pause Mean. These two measures were the only measures to appear as dependent variables in the ANCOVA group main effects. This was despite a non-significant group difference for Long Pause Mean when stuttered disfluencies remained in the speech samples of children who stutter.

There were three *group interactions* where articulation rate appeared as both the covariate and dependent measure with SALT measures. The group interaction where Syllables Spoken per Second was the covariate variable was for Syllables Spoken per Second *with* Mean Length of Utterance Morpheme. The group interactions where Syllables Spoken per Second was the dependent measure were for Number of Different Word Roots *with* Syllables Spoken per Second and Percent Intelligibility *with* Syllables Spoken per Second.

The associations for these group interactions were only significant for the control children indicating that these children had more advanced patterns of speech motor skill associated with more advanced language-based skills and intelligibility. Syllables Spoken per Second, Mean Length of Utterance Morpheme and Number of Different Word Roots were found to increase significantly with age for typically developing speech samples in Study 1. While the effect for Percent Intelligibility was not significant it did consistently increase with age as expected (see Chapter 4).

Children who stutter did not show the same significant positive associations. This indicates that they have a mismatch of language skills in relation to their speech motor skills. However, because Syllables Spoken per Second appeared as both the covariate and dependent variable, this indicates that the speech motor and language-based skills can similarly impact on each other. Articulation rate, as the covariate variable, was able to predict language-based skills measured as Mean Length of Utterance Morpheme. On the other hand, as the dependent variable, Number of Different Word Roots and Percent Intelligibility were able to predict Syllables Spoken per Second.

For the children who stutter, the associations of Number of Different Word Roots *with* Syllables Spoken per Second and Percent Intelligibility *with* Syllables Spoken per Second were observed to be in the opposite direction to that of the controls. Though these main effects were not significant for the stuttering group, some children who stutter with higher Percent Intelligibility and some with greater Number of Different Word Roots also had slower articulation rates. This indicates possible trade-offs of speech motor skill for these children. Children who stutter maintained levels of intelligible speech and produced an appropriate number of different word roots in their spontaneous speech but at the same time produced speech at a slower rate.

For the association for the group interaction, Syllables Spoken per Second *with* Mean Length of Utterance Morpheme, the children who stutter showed an expected pattern for the direction of the relationship. However, the association did not reach statistical significance as it did for the control group. Again, children who stutter show a mismatch of skills and this could be due to subtle differences in language ability between the groups measured as Mean Length of Utterance Morpheme.

Furthermore, data from the regression analyses showed that Number of Different Word Roots and Mean Length of Utterance Morpheme were negatively correlated with Percent Syllables Stuttered. That is, children who stutter who produced a higher frequency of stutters in their speech also had reduced language output. This suggests a negative impact that stuttered disfluencies has on language output.

There were also two group interactions Long Pause Mean *with* Percent Mazes, and Proportion of Pause Time *with* Percent Mazes. These group interactions can also be informed by typical speech and language development. While these measures did not have significant effects with age for children in Study 1, Long Pause Mean and Proportion of Pause Time both showed a decreasing trend and Percent Mazes an increasing trend with age. Therefore, it would be expected that if a child produces a greater number of mazes, the long pauses in their speech would be shorter and the proportion of pause time would be smaller. The control children demonstrated this expected pattern, due to the significant negative associations for these group interactions. Children in the control group produced less mazes in conjunction with shorter long pauses and smaller proportions of pauses in time. However, again, the children who stutter lacked significant main effects for these associations.

Children who stutter generally produced similar levels of maze words irrespective of their long pause durations and their proportion of pause times. Children who stutter appeared deviant in their production of mazes and this is likely due to stuttered disfluencies produced in speech being coded as Percent Mazes. As maze words included other typical disfluencies such as restarts and filled pauses, it is possible that children who stutter were deviant in their production of both stuttered and non-stuttered disfluencies.

For the group interactions Mean Length of Utterance Morpheme *with* Proportion of Pause Time and Number of Different Word Roots *with* Proportion of Pause Time, it is expected that the more a child pauses, the less speech output they will have. Both groups showed a general trend for this pattern with the main effects only significant for the children who stutter. Therefore, the children who stutter actually did not show deviant patterns for these associations.

5.4.4 Impact of Stuttered Disfluencies on Speech and Language Fluency Profiles

The final question addressed in this study related to how stuttered disfluencies impact on speech and language measures of children who stutter. As previously discussed, it was found that Percent Syllables Stuttered negatively affected language output for the measures of Mean Length of Utterance Morpheme and Number of

Different Word Roots. It was also found that Percent Syllables Stuttered positively correlated with Proportion of Pause Time, indicating that stuttered disfluencies contributed to the total pause time in speech. This is further confirmed when pause measures are examined after stutters are removed.

After stutters were removed it was found that some speech and language measures ‘normalised’; that is, their means moved closer to the means of the control group. These measures include Proportion of Pause Time, Short Pause Mean and Syllables Spoken per Second. This further suggests that stuttered disfluencies impacted on the speech and language output of children who stutter in negative ways. Long Pause Mean was the only measure which showed larger deviation from the control mean resulting in a significant group difference post-stutter removal.

The only significant *within*-groups measure, pre-stutter and post-stutter removal, was for Speech Segment Mean from the Fluency Profiling System. Speech Segment Mean of children who stutter significantly increased in duration after stuttered disfluencies were removed as indicated by a paired samples *t*-test. A longer speech segment however does not necessarily imply more advanced speech and language skill. This measure was not found to consistently increase with increasing age in Study 1, and it did not relate to Mean Length of Utterance Morpheme for typically developing speech samples.

Speech segments are separated by long pauses, that is, the long pause distribution cut-off. Therefore, they are a function of both the production of short and long pauses in speech. The measure is not related to long pause duration per se, but it is related to how *often* a long pause is produced. Shorter speech segments pre-stutter removal indicates that the presence of stuttered disfluencies have resulted in the breaking up of long pauses more frequently. That is, there was more frequent disruption to the ongoing production of long pauses due to stuttered disfluencies. This resulted in shorter speech segments being produced.

When the descriptive properties of 'stuttered' pause-speech segments were examined the mean duration (real-time) of *pauses* deleted from stuttered pause-speech data lines was 438 milliseconds. This duration is between the average short pause mean of 70 milliseconds and average long pause mean of 658 milliseconds. However, being much closer to the average long pause mean duration, indicates that the pauses associated with the production of overt stuttered disfluencies were predominantly part of the long pause distribution, in particular, in the lower-duration half of the long pause distribution. Therefore, when stuttered disfluencies were removed, the *long* pause mean duration would generally increase. Subsequently, the long pause distribution shifted to the right (increased in duration) with a group difference appearing when compared to the long pauses of the control children.

5.4.5 Conclusions

A major finding of this study was that the children who stutter in this study had slower speech production skills (planning and execution) as indicated by group differences in Long and Short Pause Mean for their perceptually fluent speech. The group difference found for long pause means suggest that linguistic processes may impact on existing inefficient motor systems of those who stutter (Peters, et al., 2000; Peters & Starkweather, 1990).

Indirectly, the results of this study support accounts of deficient linguistic processes to be the origin of stuttered disfluencies including the *EXPLAN* model (Howell & Au-Yeung, 2002), *The Neuropsycholinguistic Theory of Stuttering* (Perkins, et al., 1991) and Postma & Kolk's (1993) *Covert Repair Hypothesis.* The models assert that the origin of deficit of stuttering arises in linguistic processes and its impact on speech execution, particularly at the moment a stuttered disfluency is produced. However, because the tasks employed in this study were natural speaking tasks and the impact of linguistic processes on the production of stuttered disfluencies was not directly investigated, it is difficult to ascertain which model best fits in with the results of this study.

Further to this, the findings of this study seem to better support the *EXPLAN* model as the results indicate a broad involvement of speech planning and execution processes to be implicated in childhood stuttering. It is the dyssynchronies between planning and execution processes for speech production that contribute to stuttering. The *EXPLAN* model also predicts that increases in speech rate and planning difficulty can affect fluency (see Savage & Howell, 2008), similar to the notions of speech and language trade-off observed for the children in this study and for children in Study 1.

Another major finding was evidence of trade-offs across speech and language areas used by the children who stutter. Children who stutter had a mismatch of speech and language skill compared to controls. This further supports multifactorial accounts of stuttering, which emphasises different factors relating to stuttering, and the dynamic nature of speech production (Smith, 1999).

5.4.6 Study Limitations and Future Research

To assist in elucidation of the processes that may have contributed to the differences seen in Long and Short Pause duration between the groups, it could be worthwhile identifying the role of each pause as speaker produces. For example, pauses can be identified to be related to transitions from one articulatory gesture to another, to overt error production and repair or to the production of visible breaths. Unfortunately, this would be a highly time-consuming and challenging task. The average total number of pauses found for each child in this study was 260 pauses and the processes relating to many pauses are largely invisible.

This study investigated younger participants, rather than adults who stutter, to help discover differences in speech and language functioning that is less impacted by compensatory strategies. However it is likely, though the extent of which is largely unknown, that children who stutter are using compensation strategies to control their stutter. Until a method is devised to reliably measure these aspects, additional clinical stuttering measures may help to assist with investigating the role of such factors. This is an area for future research.

Measures from SALT provide a broad picture of speech and language ability of participants but it does not inform specific skills such as the complexity of syntactic structures a child may use. It would be beneficial to investigate whether children who stutter show differences in more sensitive language-based measures since the results from this study indicated language planning differences for children who stutter. Previous research has focussed more on detailed syntactic analysis of the speech of children who stutter, indicating differences at detailed levels of analysis. For example, it has been found that children who stutter tend to use simpler language structures and words than children who do not stutter (Wall, 1980).

It would be valuable to investigate the relevance and appropriateness of the child's responses to the personal narrative questions. Investigation of such aspects of communication could provide further insight into the language ability, comprehension and conceptualisation processes of children who stutter, and whether or not it has possibly contributed to the group difference found for Long Pause Mean for this study. One possibility for future research is to adopt a methodology such as Correct Information Unit analysis (CIU: Nicholas & Brookshire, 1993) for the speech samples of the children. This analysis could inform about the informativeness and efficiency of a child's response to the structured monologues. To date the procedure has only been used with adult speakers. With further development of age-specific normative data this procedure could also be used with children.

Investigations of more complex speech and language production tasks, such as tasks requiring interpretation and/or synthesis of information to produce a narrative, may also be fruitful. These tasks draw on higher cognitive load which may have implications for speech and language fluency.

5.4.7 Study Summary

In summary, the results in this study indicated that stuttering and stuttered disfluencies have broad impact on the speech and language skills of children who stutter. Stuttered disfluencies had negatively impacted on speech and language output. This confirms the hypothesis that for children who had been stuttering for longer they showed more noticeable differences in speech and language functioning when compared to controls. Stuttering had impacted on the ongoing development of important speech and language skills.

In Study 1, differences were only found between the groups for related measures soon after the onset of stuttering. The changes to speech and language output, as a result of stuttering were subtle. There was a lack of group differences found for the absolute means of measures. The exception was the group interaction found for Percent Intelligibility and this was a temporary change. In Study 1, it was also found that children who started to stutter compensated for their stutter. This was indicated by a general increase in time required for speech production processes, in order to maintain some areas of language performance.

This study found that children who stutter were slower in speech production processes as indicated by differences in both Long and Short Pause production. Measures from SALT were also implicated more frequently for the school-aged children in this study than for children in Study 1. This included measures such as Mean Length of Utterance Morpheme, Number of Different Word Roots and Intelligibility. Measures of speech and language were not correlated where they were expected to do so when compared to children who do not stutter.

It appears that difficulties occurring as a result of the impact of stuttering have become entrenched in the developing speech and language skills of the school-aged children observed in this study. Also, stuttered disfluencies were found to negatively affect the language output of the children who stutter. Therefore, the evidence suggests that the reason for slowness in speech production comes from difficulty experienced as a result of stuttering, and has implications for the ongoing development of speech and language skill of children who stutter.

CHAPTER 6: SPEECH AND LANGUAGE FLUENCY PROFILES IN ADULTS WHO DO AND DO NOT STUTTER

For the investigation of the long-term effects of stuttering, this study investigated speech and language fluency profiles of adults who stutter for a single session. The same measures from the Fluency Profiling System and articulation rate were gathered as per previous studies of this thesis. However, language-based measures differed for the adults in this study compared to measures collected for children in Experiments 1 and 2.

The language-based measures collected include Correct Information Unit (CIU: Nicholas & Brookshire, 1993) and Performance Deviation (PD: Brookshire & Nicholas, 1995) measures. The impact of stuttered disfluencies on spontaneous speech processes was analysed through the identification of associations with Percent Syllables Stuttered and the investigation of speech samples with and without overt stuttered disfluencies. Stuttering clinical measures on the use and practice of fluency techniques were also gathered for the adults to explore their role in speech and language measures.

The results from Study 1 showed that stuttering had a negative impact on speech and language output in children soon after stuttering began. Study 2 showed that, for school-aged children who had been stuttering for a longer time than the younger children in Study 1, the impact of stuttering was broad and co-developed with speech and language skills.

6.1.1 Hypotheses

Based on the findings of the previous studies of this project, if stuttering was not addressed and continued to interfere with speech and language development, it is reasonable to hypothesise that adults who stutter would have marked difficulties with speech and language skill compared to adults who do not stutter. Such differences could be seen for measures indicative of language planning and competence (e.g., Long Pause, Percent Correct Information Unit). However, there is a lack of evidence to indicate that adults who stutter have difficulties with conceptualisation and higher level language planning. The general consensus is that adults who stutter know exactly what they want to say (World Health Organization, 1977).

For an individual who has a chronic stutter, the development of stuttering is commonly reported to involve changes to both the type of stuttering disfluencies (Van Riper, 1971; Wingate, 1964), and the strategies used to cope with stuttering. This latter change may be directly related to specific techniques learned in therapy, or individually adapted strategies to manipulate speech motor characteristics in order to control stuttering. For example, adults who stutter will often adjust the timing aspects of speech motor control, such as reducing their speech and/or articulation rate in order to maintain fluency in speech (Onslow, et al., 1996).

Therefore it was hypothesised that the adults who stutter would have differences in their speech and language measures compared to controls. These differences would be due to the overt stuttering behaviours and/or compensatory strategies rather than the underlying differences in speech production ability. The effects of stuttered disfluencies would be confirmed if group differences exist when stuttered disfluencies remain the speech samples of adults who stutter, but the differences were not present in samples with the stuttered disfluencies removed.

Differences due to compensatory mechanisms would be informed by significant associations for measures of stuttering frequency and the use of fluency techniques with measures of speech and language output. The trade-offs used to maintain fluency by adults who stutter was hypothesised to implicate speech motor control measures, particularly measures of timing. This includes Syllables Spoken per Second and the production of pauses in speech.

In addition, the adults who stutter may compensate for difficulties with speech motor control by trading-off areas of language-based skills, in an attempt to maintain fluency. This would be evident through the production of an increased number of Performance Deviations (i.e., filled pauses, irrelevant productions, and false starts), and/or reduced linguistic quality (Correct Information Unit).

6.1.2 Research Questions

The following research questions were asked for this study:

1. Do adults who stutter differ in their speech and language fluency profiles compared to normally fluent adults?
2. How do stuttered disfluencies impact on speech and language fluency profiles for adults who stutter?
3. How does the use of fluency techniques impact on speech and language fluency profiles for adults who stutter?

6.2 Method

6.2.1 Participants

Twelve adults who stutter aged 22 to 65 years, and age (+/- 2 years) and gender matched control adults participated. The participants who stuttered were part of a previous study where only males participated (Hennessey, et al., 2008). Speech samples for adults who stutter were collected as part of this previous study and used for speech and language fluency analysis for this study. The speech samples were not previously analysed as part of the study by Hennessey et al., (2008). The adults who stutter were recruited from The Speak Easy Association of Western Australia, a self-help organisation for people who stutter.

The control participants for this study were recruited by the examiner. They were recruited by word-of-mouth, through colleagues, family and friends of the examiner. No control participant had a previous history of stuttering, nor did they have difficulties with speech and language or any known history of neurological, psychological or intellectual impairments. English was the first language for all participants.

6.2.2 Materials and Apparatus

Pre-collected samples for stuttering participants from Hennessey et al., (2008), used a Sony TC-D5 PRO II cassette player with a Sony electret condenser lapel microphone for speech sample recording. The cassette tapes were digitised at a sampling rate of 44100Hz.

Speech samples collected for the control participants for this study were elicited using identical speech sampling procedures (see below, section 6.2.3) as the adults who stutter, and used similar equipment for recording. A digital recorder model SONY UX70 with a lapel microphone was used to record speech samples for the control participants at a sampling rate of 44100Hz and a bit depth of 16 bits. All speech samples were downloaded to a desktop PC in WAV files containing uncompressed PCM data, compatible with PRAAT acoustic analysis software.

As part of the previous study (Hennessey, et al., 2008) case-history information was gathered in regards to treatment histories and use of fluency techniques learned in speech pathology treatment for the stuttering adults. This served as an attempt to quantify some of the individual differences that may be present for the adults in regards to the techniques they employed to control their stuttering. Appendix N details the questions included in this case-history form.

6.2.3 Design and Procedure

Speech samples were collected in a single session. The speech sampling protocol was adapted from Nicholas and Brookshire (1993) and from Ciccone (2003). Speech samples were collected at the participants' homes or places of work, in a quiet room free from distractions.

Three spontaneous speaking tasks were employed for the purposes of speech and language fluency analysis. They were single picture description, personal narrative and procedural narrative. In accordance with Ciccone's (2003) speech sampling procedures and materials, the picture description task utilised four single pictures from "Far Side" comic book Larson (1989). Pictures were presented to participants and remained in front of them until they finished speaking. Participants also responded to two personal narrative questions and two procedural narrative questions. Participants were asked to speak for at least one minute per narrative question. Table 6.1 below gives the instructions and topics for each monologue task. See Appendix O for the picture description task stimuli.

Table 6.1: Speech sampling protocol for adult participants

Type of Monologue	Interview Question
Picture Description	"Describe as much as you can in this picture" (*n* = 4)
Personal Narrative	"Tell me all about what you did yesterday"
Personal Narrative	"Tell me where you live and describe it to me"
Procedural Narrative	"Tell me all the steps for how to make a cup of coffee"
Procedural Narrative	"Tell me all the steps for how to fill a car up with petrol"

6.2.4 Data Collection Procedures

See Chapter 3, General Methods for details relating to measures collected for clinical stuttering measures, the Fluency Profiling System analysis procedure, articulation rate and the procedure for removing stuttered disfluencies from speech. Details for Correct Information Unit (CIU) and Performance Deviation (PD) analyses are provided later in this section. The same speech samples were used for all analyses.

6.2.4.1 Clinical Stuttering Measures

A minimum 700 syllable sample was obtained to rate Percent Syllables Stuttered. On average, the adults who stutter had an average stutter rate of 6.87% syllables stuttered. The range was 1.5% to 21.7% syllables stuttered. Table 6.2 shows the individual stuttering measure for each of the adults who stutter.

Responses from the case-history questionnaires were collated to yield four clinical measures for the adults who stutter (a) months since last treatment (if participant was currently in treatment this equated to zero), (b) total number of months that a participant has used fluency techniques in speech to control stuttering, (c) the number of hours they use fluency techniques on average in a week, and (d) the number of hours they spent engaging in explicit practice of their fluency techniques in a week.

All participants had previous speech therapy and had previously used fluency techniques in their everyday communication. However, not all participants were currently practicing or explicitly using their techniques. One participant, participant number 5, had claimed that he used and practiced fluency techniques every time he spoke. Therefore, the number of hours for both the use and practice of fluency techniques equated to the number of hours he indicated for speaking. Table 6.2 shows the individual characteristics of adults who stutter, displaying their values for these four clinical measures.

Table 6.2: Individual characteristics and clinical stuttering measures for adults who stutter (*n* = 12)

Participant Number	Sex	Age (years)	%SS	Months Since Last Tx	Total Months Used FT	Use of FT (hrs/week)	Practice FT (hrs/week)
1	M	36	21.7	12	60	0.5	2
2	M	56	2.5	312	312	0	0
3	M	58	3.9	324	324	1	0
4	M	34	4.9	180	168	17.5	0
5	M	45	1.5	276	276	35	35
6	M	62	13.4	180	0	0	0
7	M	65	6.0	216	216	0	0
8	M	53	8.1	60	60	0	0
9	M	25	4.8	0	42	21	2
10	M	51	9.3	120	324	7	3.75
11	M	54	2.9	276	276	17.5	1.5
12	M	34	3.4	0	7	15	9

Note. %SS = Percent Syllables Stuttered, Tx = Treatment, FT = Fluency techniques.

6.2.4.2 The Fluency Profiling System Pause Measures

For the adults in this study, Proportion of Short Pauses was also gathered in addition to other measures described in Chapter 3, General Methods. This was gathered to make comparisons with Love and Jeffress' (1971) previous study investigating the frequency of pauses in the read speech of adults who stutter. However, a frequency count for the pauses was not appropriate for this study due to the varying lengths of speech samples for each speaker. Since there were only two types of pause durations, only Proportion of Short Pauses was reported. The measure informs about the proportions of both short and long pauses produced by a speaker.

With stutters included in the speech samples of the stuttering group, the *participant only* total speech times collected across *all* adults was on average 7.39 minutes (*SD* = 2.19). This sample time did not significantly differ between the groups (Stuttering: *M* = 8.11, *SD* = 2.20, Controls: *M* = 6.66, *SD* = 2.03). After the deletion of all pauses greater than 20 milliseconds from the *participant only* samples, a *speech only* sample remained. The average *speech only* sample time collected across *all* adults was 4.66 minutes (*SD* = 1.56). This *speech only* sample time did not differ between the groups (Stuttering: *M* = 4.87, *SD* = 1.56, Controls: *M* = 4.45, *SD* = 1.60).

6.2.4.3 Articulation Rate

The middle third portion of the speech sample was used to calculate articulation rate, expressed as Syllables Spoken per Second. For adults who stutter, this was calculated for speech samples with and without stuttered disfluencies. Across all participants an average sample of 478 syllables was used to calculate articulation rate (*SD* = 164) with no difference between the groups (Stuttering: *M* = 462 syllables, *SD* = 141, Controls: *M* = 494 syllables, *SD* = 190). For the samples with stuttered disfluencies deleted, the mean number of syllables for the stuttering group was 386 syllables (*SD* = 154). The group difference for the total number of syllables remained non-significant after stuttered disfluencies were deleted.

Long pauses were deleted for the calculation of articulation rate based on each adult's unique pause threshold. This threshold was on average 148 milliseconds across all speech samples, for the stuttering samples containing stutters.

6.2.4.4 Language Performance-Based Measures

To investigate the informativeness and efficiency of the speech of the adult speakers, Correct Information Unit (CIU: Nicholas & Brookshire, 1993) analysis was conducted. To investigate the types of extraneous language productions produced by speakers, analysis of Performance Deviation (PD: Brookshire & Nicholas, 1995) was conducted. Extraneous productions are units of speech that do not add new and/or relevant information in the context of the speaking task.

Measures were gathered in accordance to the instructions published by the authors. CIU and PD analyses were conducted separately for each monologue produced by a speaker. This included four picture description responses, two personal narratives and two procedural narratives. The average scores for each monologue *type* were obtained. The data was then collapsed across all monologue types to obtain averages for CIU and PD, for each participant.

Nicholas and Brookshire (1993) calculated a measure of Percent Correct Information Unit and Words Spoken per Minute as the main measures to determine informativeness and efficiency of speech. This study gathered mean Percent Correct Information Unit. However, instead of Words Spoken per Minute, Seconds per Correct Information Unit was gathered as a measure of how efficient the information was delivered according to time.

Any verbal production that did not qualify as a 'word' or a 'Correct Information Unit' from the CIU analysis was subsequently subjected to PD analysis. PD categorisations included two *non-word* categories: (a) part word or unintelligible productions, and (b) non-word filler. PD categorisations included seven *non-Correct Information Unit* categories: (a) inaccurate, (b) false start, (c) unnecessary exact repetition, (d) nonspecific or vague, (e) filler, (f) the word 'and', and (g) off-task irrelevant. An additional category was used in this study and was referred to as 'uncategoriseable.'

'Uncategoriseable' is a 'non-Correct Information Unit' PD category originally used by Brookshire and Nicholas (1995) but it was deleted after they found that they could reliably code PDs without this category. However, for this study, it was felt that some productions were not reflected in the existing categories. Therefore, 'uncategoriseable' was utilised. For example, it was unclear as to which category the following non-CIUs would fit into: (a) repeated information that is not new but not repeated exactly, (b) self-monitoring errors and corrections, (c) commentary by the participant when they were thinking out loud and/or revising their own speech related to the task, and (d) participants asking themselves questions out loud.

The total number of PDs was counted per participant. Thereafter, a proportion for each type of PD category was calculated. A rate of occurrence of PD (collapsed across different PD types), Seconds per Performance Deviation, was also gathered.

In accordance with Brookshire and Nicholas (1995), proportions of each PD category were calculated by dividing the number of productions or words in each category by the total number of productions or words that the speaker had produced. The proportions of the two non-word categories were calculated by dividing the number of productions in each of those categories by the total words *plus* non-words produced by that participant. The percentages of the eight non-CIU categories were calculated by dividing the number of words in each of those categories by the total words produced by that participant.

Speech samples were transcribed into the PRAAT program for the Fluency Profiling System pause analysis. The Long Pause Speech Segment Transcript (see Chapter 3, section 3.1.2.2) from the MATLAB output was used as the platform to count CIUs and PDs. However, the 'time' of the speech sample used to calculate the efficiency measures of Seconds per Correct Information Unit and Seconds per Performance Deviation *included* long pauses.

Language performance-based measures were not examined specifically for samples where stuttered disfluencies were removed in this study. See Chapter 3, General Methods for explanation (section 3.1.5). The CIU analysis for this study categorised repeating stuttered disfluencies and other disfluencies such as filled pauses, false starts, as 'non-words' (see also, Nicholas & Brookshire, 1993). A word categorised as a CIU or non-CIU could have been stuttered or not. The PD analysis procedure conducted on 'non-words' and 'non-Correct Information Units' served as a measure of extraneous language production and what these units constituted.

6.2.4.5 Reliability of Language Performance-Based Measures

See Chapter 3 General Methods for information on reliability for clinical stuttering (section 3.1.1.1), and Fluency Profiling System pause measures (section 3.1.2.4).

For CIU and PD measures, an undergraduate speech pathology student was trained to implement the procedures to establish the reliability of the language performance-based measures. A training phase was used to identify and resolve discrepancies in coding. The student received as much support and practise as required during this training phase. The student completed analyses during the training phase for three speech samples. The first of these samples was developed for the purposes of training only. The remaining two samples were participants in the control group of this study.

For the reliability checks, approximately twenty percent (n = 5 speech samples) of the total speech samples were randomly selected for CIU and PD analysis. Samples used in the training phase were excluded from this reliability check. The same five speech samples were used for both CIU and PD analyses. The speech pathology student did not complete the transcription of speech to gather these measures. The same Long Pause Speech Segment Transcripts from the MATLAB output were used and were transcribed by the examiner.

The inter-rater reliability for mean percentage of CIUs was 0.85. The inter-rater reliability for PD analysis according to the number of counts per PD category, and across all speech samples, ranged from 0.79 to 1.00. Some categories of PD, such as the word 'and', were identified and categorised with perfect accuracy. Other categories were not as obvious to identify due to some subjective interpretation, such as for the category 'non-specific or vague' which scored 0.79.

6.3 Results

Please refer to Chapter 3, General Methods (section 3.2) for background information regarding the statistical tests. This includes information regarding the independent samples *t*-tests, ANCOVA, paired samples *t*-tests and regression analyses.

There were some measures gathered for the adults that were not gathered for the children in Experiments 1 and 2. These were Proportion of Short Pause, measures from Correct Information Unit (CIU) and Performance Deviation (PD) analyses, and clinical stuttering measures for the use of fluency techniques.

6.3.1 Between-Groups Comparisons: **t**-*Tests*

Table 6.3 shows the means and standard deviations for the pause measures, articulation rate and language performance-based measures for both the adults who stutter and the control participants. For the adults who stutter, figures for pre-stutter and post-stutter removal are also presented. In accordance with Brookshire and Nicholas (1995), the ten PD categories were also individually tested for between-groups differences using independent samples *t*-tests.

6.3.1.1 Group Differences with Stutters in Samples

There were significant differences for Short Pause Mean, $t(22) = 2.163$, $p = .042$, Syllables Spoken Per Second, $t(22) = 2.09$, $p = .048$ and Seconds per Correct Information Unit, $t(22) = 2.19$, $p = .039$. Adults who stutter produced longer short pauses (Figure 6.1) and they were slower with articulation (Figure 6.2) and slower in producing CIUs in speech compared to control participants when stutters were included in their speech samples (Figure 6.3).

Table 6.3: Descriptive data for FPS pause, articulation rate, and language performance-based measures for adults who stutters (AWS) pre-stutter and post-stutter removal (*n* = 12), and control participants (*n* = 12)

	AWS With Stutters		AWS No Stutters		Controls	
	M	SD	*M*	SD	*M*	SD
FPS Pause Measures						
Proportion of Pause Time	40.26	6.82	41.68	5.01	33.59	10.30
Short Pause Mean	3.92	0.21	3.89	0.18	3.78	0.09
Long Pause Mean	6.24	0.24	6.33	0.16	6.06	0.43
Misclassification Rate	2.59	2.11	1.75	1.03	2.48	1.98
Speech Segment Mean	7.05	0.42	7.15	0.34	7.13	0.36
Proportion Short Pause	71.90	0.08	78.30	0.08	74.60	0.10
Articulation Rate						
Syllables Spoken Per Sec	4.07	1.00	4.13	0.95	4.79	0.65
Language Measures						
CIU Percent	80.94	5.49	-	-	81.29	3.87
Seconds per CIU	0.69	0.30	-	-	0.49	0.11
PD Total	236.75	119.72	-	-	239.67	93.28
Seconds per PD	2.20	0.78	-	-	1.70	0.57

Note. FPS = Fluency Profiling System, CIU = Correct Information Unit, PD = Performance Deviation, dash indicates no data gathered for this condition. Short Pause Mean, Long Pause Mean, and Speech Segment Mean are in log.

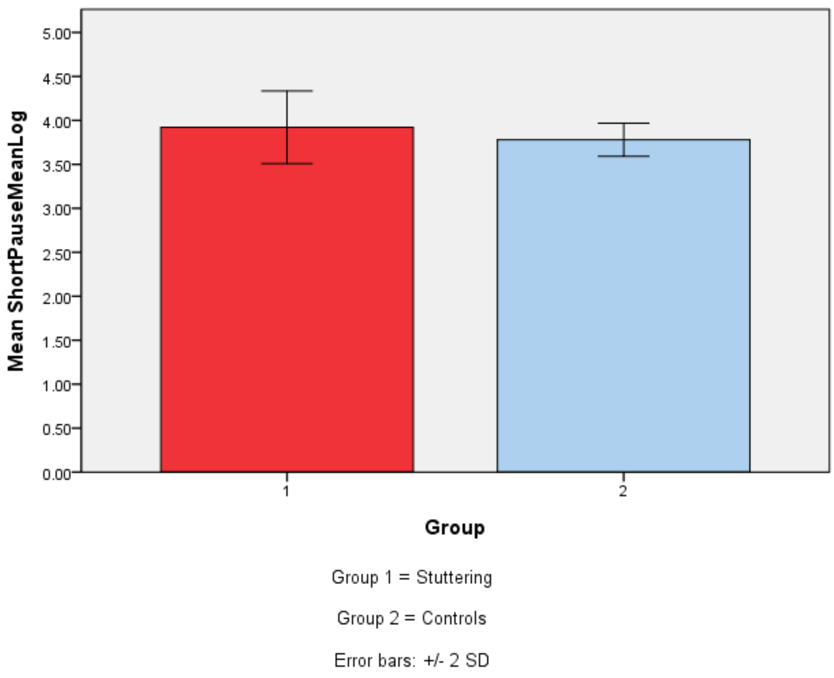


Figure 6.1: Between-groups means for the adults for Short Pause Mean (log) pre-stutter removal

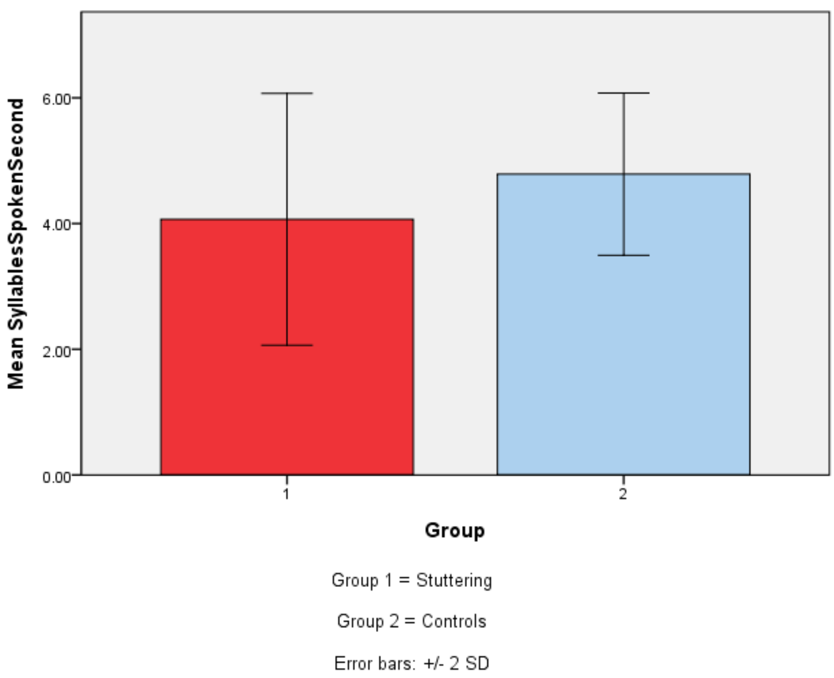


Figure 6.2: Between-groups means for the adults for Syllables Spoken per Second pre-stutter removal

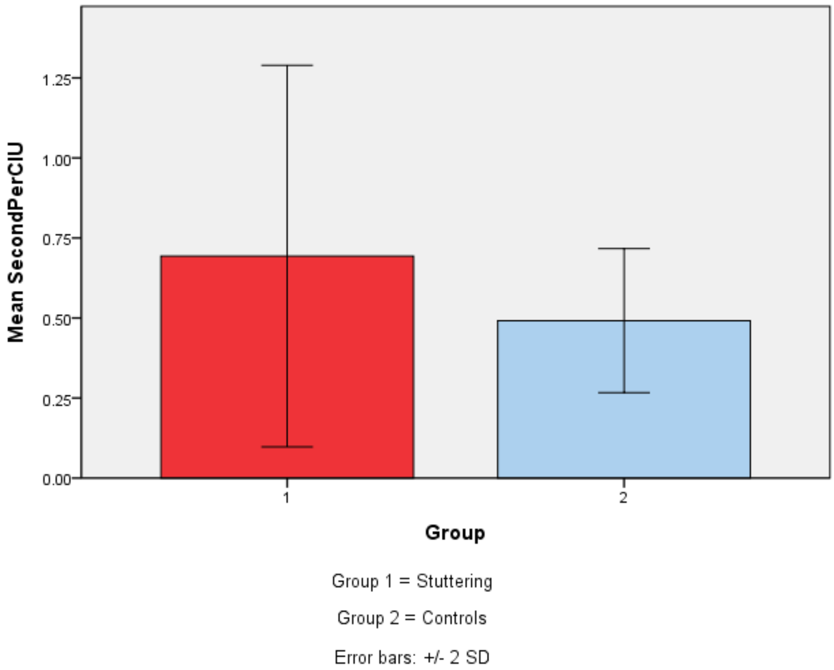


Figure 6.3: Between-groups means for the adults for Seconds per Correct Information Unit pre-stutter removal

The ten categories of PD were examined individually for both the stuttering and control groups. The proportions of each type of PD were examined for group comparisons using independent samples *t*-tests. There were no significant differences between the groups for any PD category. Table 6.4 shows the means and standard deviations for the percentage of each PD category counted for each group.

Table 6.4: Group means and standard deviations for the percentage of each category of performance deviation for adults who stutter (*n* = 12) and control participants (*n* = 12)

	AWS		Controls	
	M	*SD*	*M*	*SD*
Nonword Category				
Part-word or unintelligible production	2.34	3.47	0.49	0.35
Nonword filler	4.65	2.73	3.86	2.46
Word Category & Non CIU				
Inaccurate	0.43	0.72	0.57	0.71
False start	3.48	2.15	3.25	1.56
Unnecessary exact repetition	1.13	1.28	1.11	0.82
Nonspecific or vague	1.85	1.55	2.92	1.53
Filler	1.48	1.43	1.78	1.91
And	3.91	1.71	4.85	1.51
Off-task or irrelevant	3.60	4.03	2.05	1.99
Uncategoriseable	1.19	1.20	1.58	1.23

Note. AWS=Adults who Stutter, CIU=Correct Information Unit.

6.3.1.2 Group Differences No Stutters in Samples

There was a significant difference for Proportion of Pause Time, $t(22) = 2.44$, $p = .027$. Adults who stutter had a higher proportion of pause time in their speech (M = 41.68) compared to controls (M = 33.59) when stutters were removed from their sample (Figure 6.4). The means and standard deviations for measures by group and for pre- and post-stutter removal can be seen in Table 6.3.

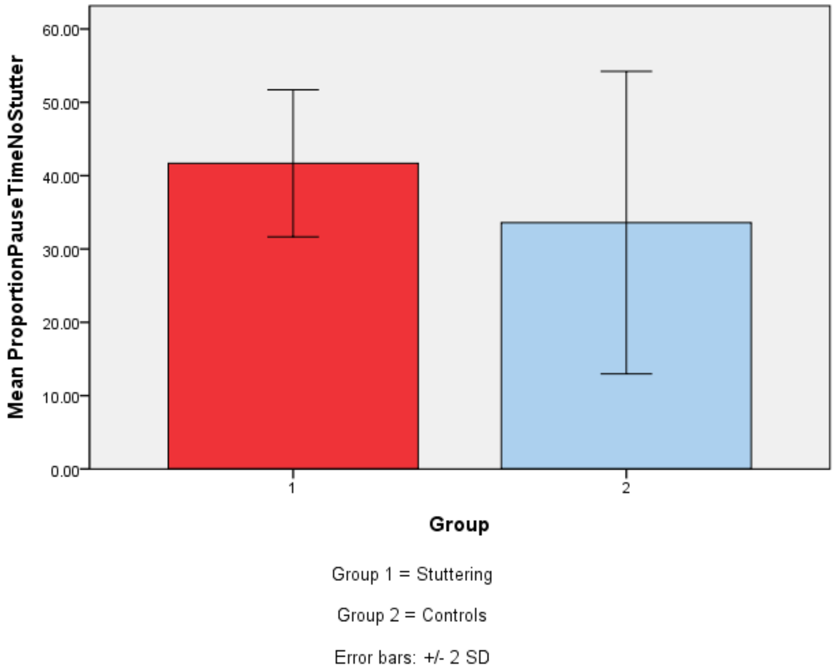


Figure 6.4: Between-groups means for the adults for Proportion of Pause Time (%) post-stutter removal

6.3.2 Between-Groups Comparisons: Associated measures

Analysis of Covariance (ANCOVA) for this study followed the general procedures detailed in Chapter 3, General Methods (section 3.2.1.2). The language-based measures for the adults in this study were CIU and PD measures. Significant group interactions and group main effects are presented in the following format 'Covariate Variable *with* Dependent Variable.'

6.3.2.1 Group Interactions

Significant group interactions are presented in Table 6.5. The table also presents the significance values and the direction for the associations per group, per group interaction.

There were significant group interactions for the following associations Seconds per Correct Information Unit *with* Proportion of Pause Time (p = .002), Seconds per Correct Information Unit *with* Long Pause Mean (p = .010), Seconds per Performance Deviation *with* Long Pause Mean (p = .007), Syllables Spoken per Second *with* Seconds per Performance Deviation (p = .028) and Short Pause Mean *with* Seconds per Performance Deviation (p = .037). See Figures 6.5 to 6.9 for the scatterplots of significant group interactions.

The significant group interactions were examined separately for each group in Table 6.5. The control participants showed significant associations for all significant group interactions. The stuttering adults did not show any significant relationships.

Table 6.5: ANCOVA significant group interactions for adults who stutter (AWS) (n = 12) and controls (n = 12)

Covariate Measure	Dependent Measure	GI p Value	AWS ME p Value (Direction)	Control ME p Value (Direction)
Seconds Per CIU	Proportion Pause Time	.002	.796 (+)	.003 (+)
Seconds Per CIU	Long Pause Mean	.010	.840 (-)	.025 (+)
Seconds Per PD	Long Pause Mean	.007	.220 (+)	.001 (+)
Syllables Spoken per Second	Seconds Per PD	.028	.229 (+)	.036 (-)
Short Pause Mean	Seconds Per PD	.037	.271 (-)	.036 (+)

Note. GI=Group Interaction, Short Pause Mean and Long Pause Mean are in log.

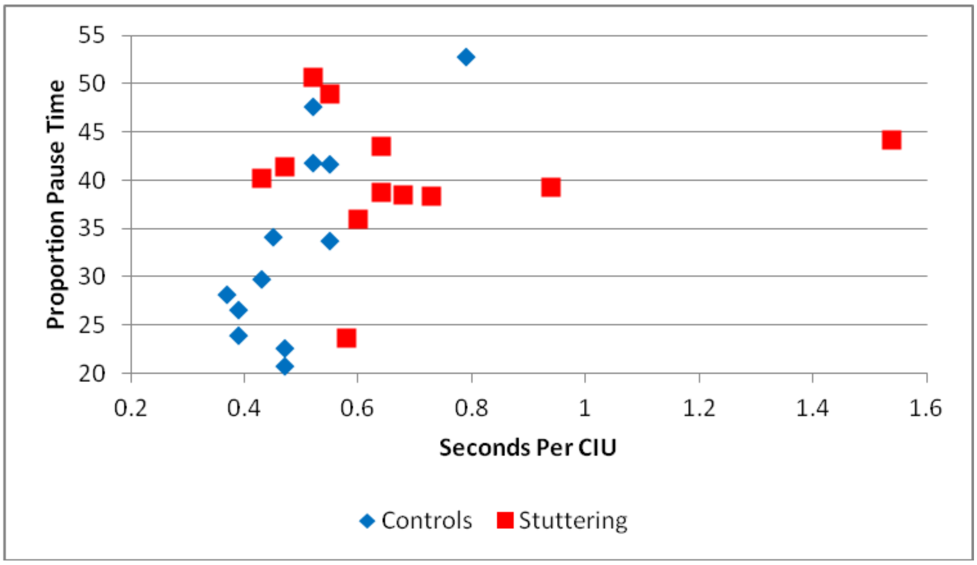


Figure 6.5: Group interaction for Seconds per Correct Information Unit (CIU) (*x*-axis/covariate) *with* Proportion of Pause Time (%) (*y*-axis/dependent variable) with stutters in stuttering samples. Adults who stutter (main effect, *p*=.796), control participants (main effect, *p*=.003).

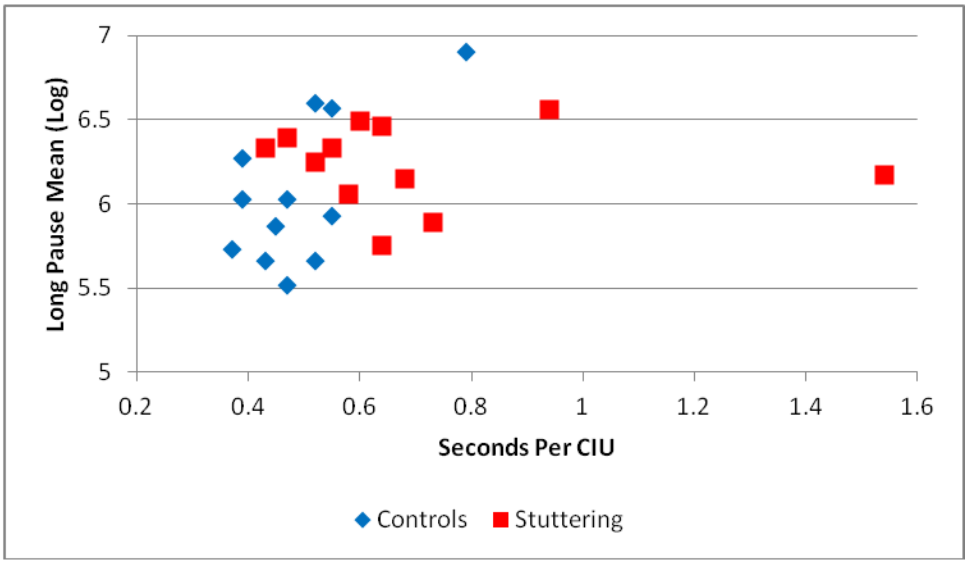


Figure 6.6: Group interaction for Seconds per Correct Information Unit (CIU) (*x*-axis/covariate) *with* Long Pause Mean (*y*-axis/dependent variable) with stutters in stuttering samples. Adults who stutter (main effect, *p*=.840), control participants (main effect, *p*=.025).

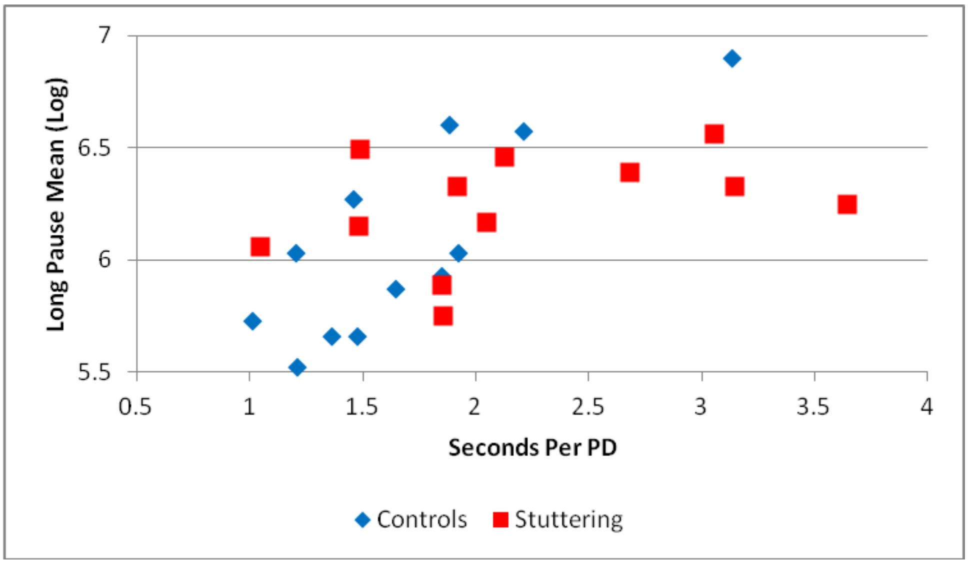


Figure 6.7: Group interaction for Seconds per Performance Deviation (PD) (*x*-axis/covariate) *with* Long Pause Mean (*y*-axis/dependent variable) with stutters in stuttering samples. Adults who stutter (main effect, *p*=.220), control participants (main effect, *p*=.001).

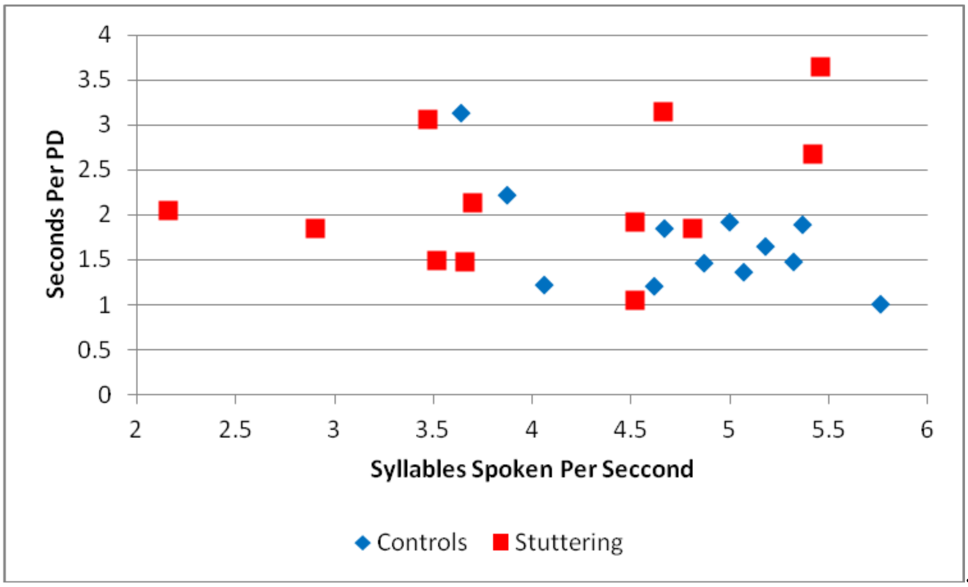


Figure 6.8: Group interaction for Syllables per Second (*x*-axis/covariate) *with* Seconds per Performance Deviation (PD) (*y*-axis/dependent variable) with stutters in stuttering samples. Adults who stutter (main effect, *p*=.229), control participants (main effect, *p*=.036).

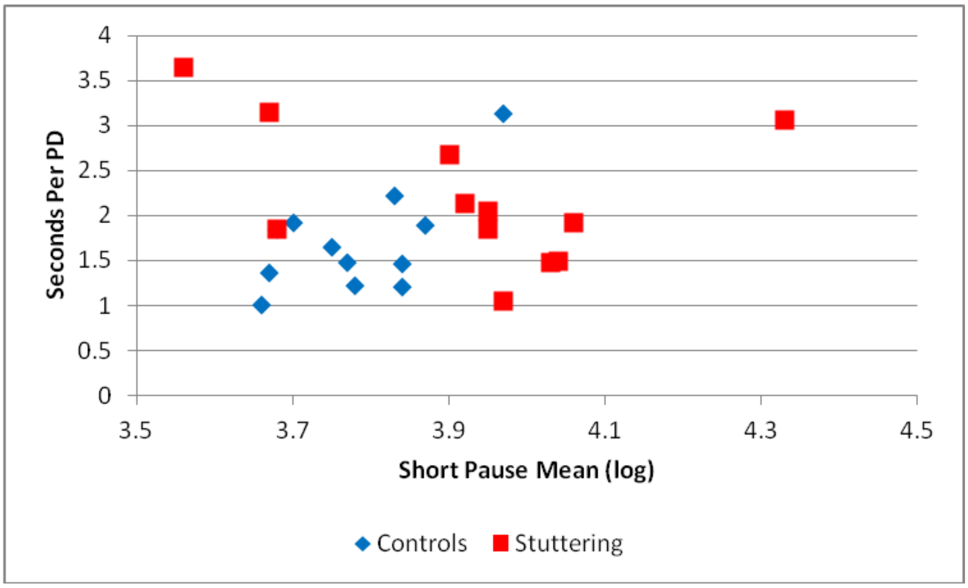


Figure 6.9: Group interaction for Short Pause Mean (*x*-axis/covariate) *with* Seconds per Performance Deviation (PD) (*y*-axis/dependent variable) with stutters in stuttering samples. Adults who stutter (main effect, *p*=.271), control participants (*p*=.036).

6.3.2.2 Group Main Effects

The significant group main effects can be seen in Table 6.6. The dependent variables for significant group main effects were Seconds per Correct Information Unit, Syllables Spoken per Second, Short Pause Mean and Proportion of Pause Time. These measures were also found to be significantly different between the groups as indicated by the independent samples *t*-tests (section 6.3.1).

Table 6.6: ANCOVA Significant group main effects for adults who stutter (AWS) (n = 12) and controls (n = 12)

Covariate Measure	Dependent Measure	GME p Value	AWS ME p Value (Direction)	Control ME p Value (Direction)
Proportion of Short Pauses	Seconds Per CIU	.008	.010 (-)	.972 (+)
Proportion of Short Pauses	Syllables Spoken per Second	.042	.198 (+)	.393 (-)
Percent CIU	Short Pause Mean	.047	.487 (-)	.499 (+)
Percent CIU	Proportion Pause Time	.048	.026 (+)	.352 (+)
Total PD	Short Pause Mean	.044	.364 (+)	.464 (-)
Total PD	Proportion Pause Time	.018	.002 (-)	.008 (-)
Seconds per PD	Short Pause Mean	.043	.271 (-)	.036 (+)

Note. GME=Group Main Effect, Short Pause Mean is in log.

6.3.2.3 Measure Main Effects

Measure main effects indicate significant relationships between variables with no group factor. Table 6.7 displays the measure main effects. In addition, regression analyses were conducted for each speech and language fluency measure with age in years with no group factor. No significant associations were present.

Table 6.7: ANCOVA significant measure main effects with no group factor (*n* = 24)

Measure 1	Measure 2	*p* Value	Direction
Proportion Pause Time	Percent CIU	.041	(+)
Proportion Pause Time	Total PD	.000	(-)
Proportion Pause Time	Seconds per PD	.000	(+)
Proportion of Short Pauses	Seconds per CIU	.011	(-)
Short Pause Mean	Syllables Spoken Second	.008	(-)
Long Pause Mean	Seconds per PD	.004	(+)
Speech Segment Mean	Total PD	.023	(+)

Note. CIU=Correct Information Unit, PD=Performance Deviation, Long Pause Mean, Short Pause Mean and Speech Segment Mean are in log.

6.3.3 Within-Group Comparisons: Adults who stutter only

6.3.3.1 Univariate Regression Analyses with Clinical Stuttering Measures

Regression analyses were conducted to investigate correlations between clinical stuttering measures and speech and language fluency measures. Percent Syllables Stuttered was negatively correlated with Proportion of Short Pauses (p = .022), Syllables Spoken per Second, (p = .001) and with Seconds per Correct Information

Units (p = .000). The scatterplots for all of the above associations are presented in Figures 6.10, 6.11 and 6.12.

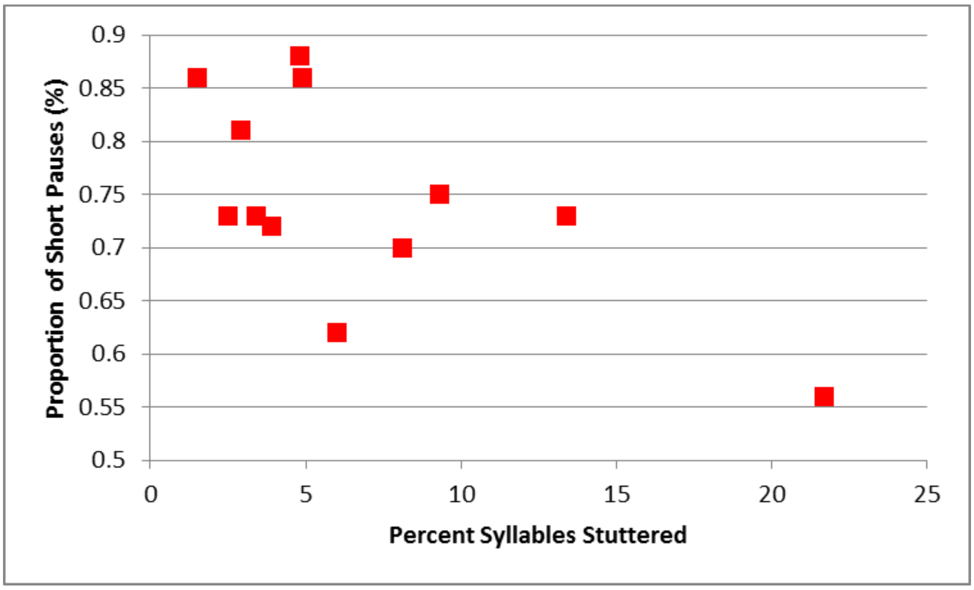


Figure 6.10: Proportion of Short Pauses (y-axis) as a function of Percent Syllables Stuttered (x-axis) for adults who stutter (main effect, p = .022)

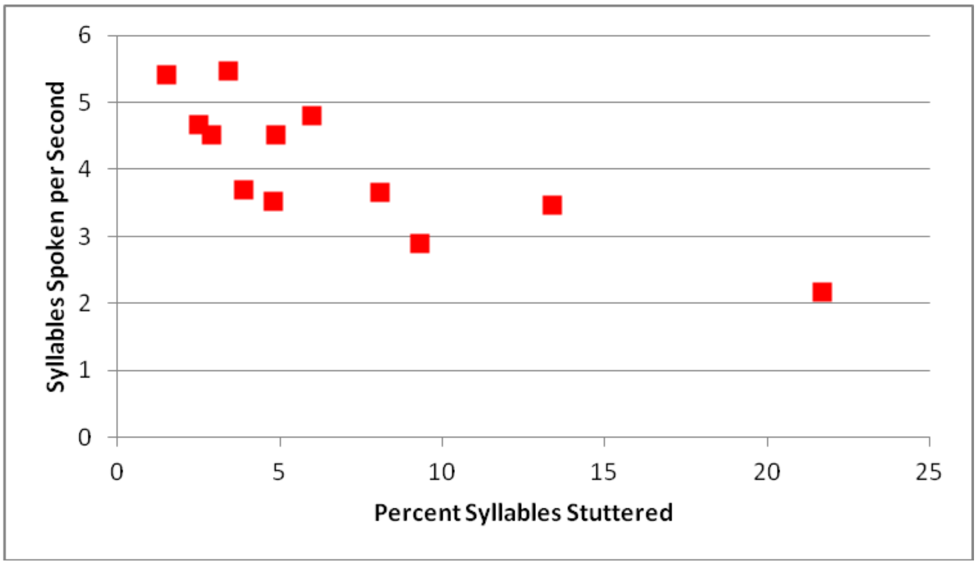


Figure 6.11: Syllables Spoken per Second (y-axis) as a function of Percent Syllables Stuttered (x-axis) for adults who stutter (main effect, p = .001).

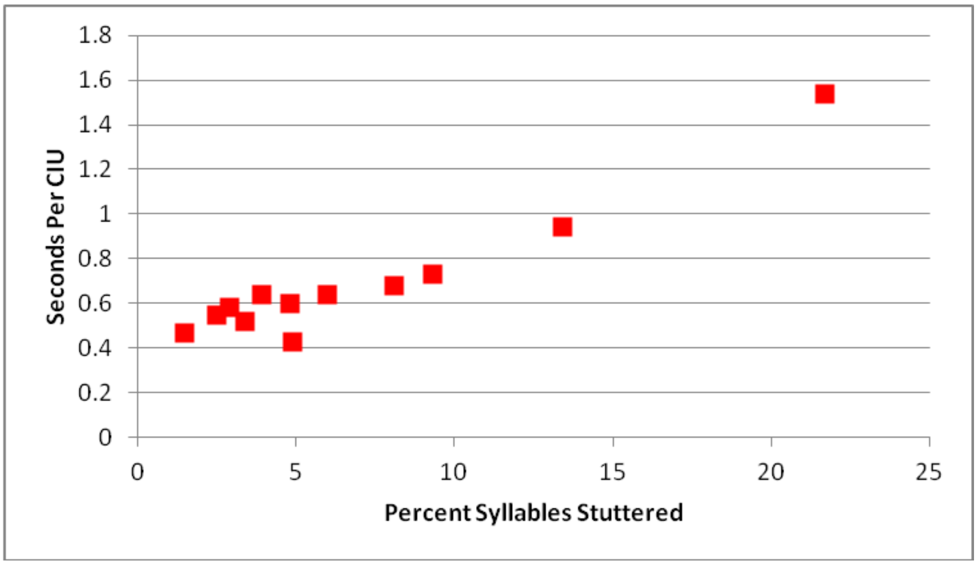


Figure 6.12: Seconds per Correct Information Unit (*y*-axis) as a function of Percent Syllables Stuttered (*x*-axis) for adults who stutter (main effect, p = .000).

Significant positive associations were present for Use of Fluency Techniques (hours per week) with Proportion of Short Pauses (p = .002) and for Use of Fluency Techniques (hours per week) with Speech Segment Mean (p = .012). The scatterplots can be seen in Figures 6.13 and 6.14, respectively. It is noted that the associations present with Use of Fluency Techniques (hours per week) were only representative for half of the participants because half of the participants had a zero value for this measure.

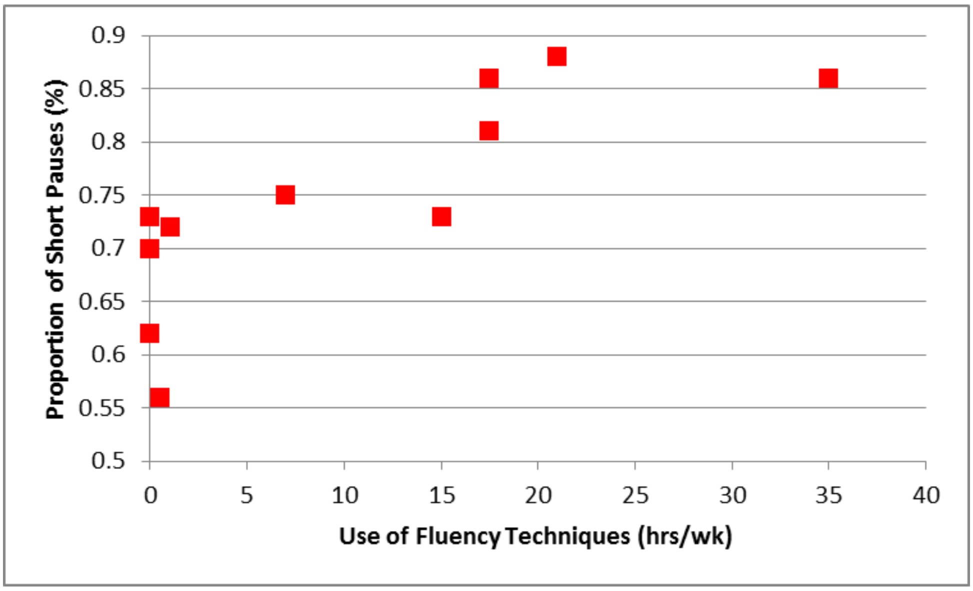


Figure 6.13: Proportion of Short Pauses (*y*-axis) as a function of the Use of Fluency Techniques per Week (hrs/wk) (*x* -axis) for adults who stutter (main effect, p = .002).

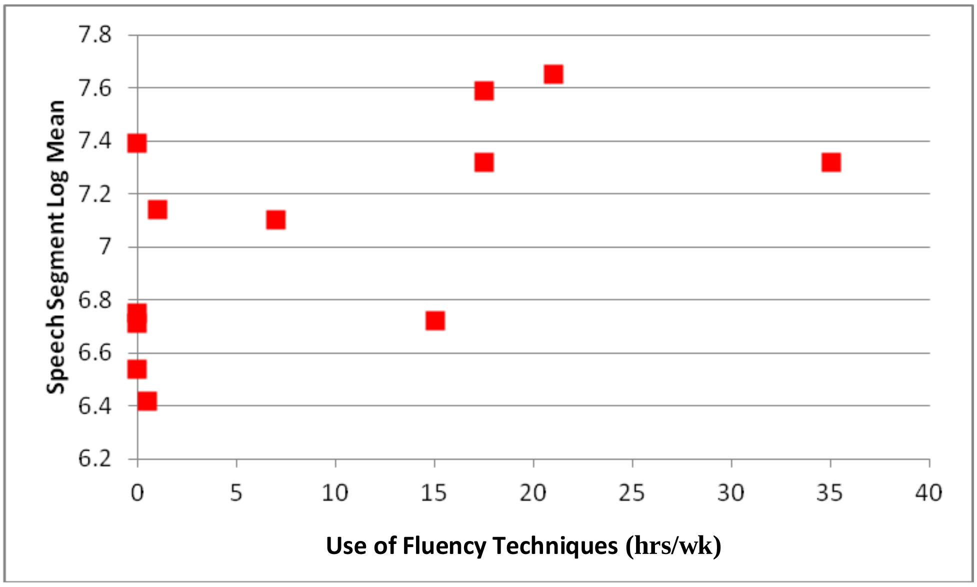


Figure 6.14: Speech Segment Mean (*y*-axis) as a function of the Use of Fluency Techniques per Week (hrs/wk) (*x* -axis) for adults who stutter (main effect, p = .012).

6.3.3.2 Paired Samples t-Tests for Pre-stutter and Post-stutter Removal

Paired-samples *t*-tests for the two conditions of pre-stutter removal and post-stutter removal were conducted to examine the impact of stuttered disfluencies on pause and articulation rate measures for the stuttering group only. Post- removal of stutters resulted in one significant outcome. After stutters were removed Short Pause Mean was shorter in duration compared to the pre- removal stutter condition (Pre- M = 3.92, Post- M = 3.89), $t(11) = 2.25$, p = .046.

The Short Pause Mean for adults who stutter decreased towards the mean of the control group after stuttered disfluencies were removed. Measures which moved towards and beyond the means of the control group were Proportion of Short Pause, Speech Segment Mean and Misclassification Rate. Proportion of Pause Time and Long Pause Mean increased further from the mean of the controls after stutters were removed.

The deleted pause and speech segment data lines had on average pause segments of 299 milliseconds and speech segments of 341 milliseconds. See Table 6.8 for the means per participant.

Table 6.8: Characteristics of pause-speech data lines removed as part of the stutter removal procedure for adults who stutter (n = 12)

Participant Number	Pause Segment Duration (*M*) (milliseconds)	Speech Segment Duration (*M*) (milliseconds)
1	320.99	358.31
2	561.14	295.91
3	361.76	397.55
4	143.97	147.69
5	125.14	227.71
6	290.27	475.72
7	203.22	292.61
8	316.28	385.44
9	164.07	228.93
10	331.91	355.41
11	175.96	640.81
12	467.61	282.26

Note. Each pause-speech data line consists of a pause segment duration and speech segment duration

6.4 Discussion of Speech and Fluency Profiles in Adults who do and do not Stutter

6.4.1 Summary of Findings

The results suggest that differences seen in the speech of adults who stutter compared to control participants were largely a consequence of stuttering. That is, differences found in speech and language measures between those who stutter and those who do not, were due to the presence of stuttered disfluencies.

When the perceptually fluent speech of adults who stutter were compared to controls, adults who stutter had slower speech production processes. This was indicated by an increase in Proportion of Pause Time. There was evidence for the use of compensatory techniques by people who stutter to be the reason for this slower execution of speech.

6.4.2 Group Differences for Absolute Means

The first question posed in this study asked whether adults who stutter differed in their speech and language fluency profiles compared to their normally fluent peers. With stuttered disfluencies present in the speech of the adults who stutter, significant differences existed between the groups for Short Pause Mean, Syllables Spoken per Second and Seconds per Correct Information Unit.

After stuttered disfluencies were removed, a significant group difference was only present for Proportion of Pause Time. No between-groups difference was present for Short Pause Mean or Syllables Spoken per Second. A measure of Seconds per

Correct Information Unit was not calculated for the post-stutter removal condition. Please see Chapter 3, General Methods (section 3.1.5) for more information.

6.4.2.1 Speech Motor Activity Differences: Impact of Stuttering

Adults who stutter were slower with speech motor activity as indicated by the significant results for Short Pause Mean and Syllables Spoken per Second when stuttered disfluencies remained in the speech samples of the adults who stutter. The real-time mean group difference for short pauses was 6.6 milliseconds. For articulation rate, the adults who stutter were on average 0.72 syllables per second slower than control participants. But since there were no significant differences for these measures after stuttered disfluencies were removed, they do not appear to have stemmed from underlying speech production processes. Instead, the timing differences have been impacted by the presence of stuttered disfluencies as a consequence of stuttering.

Results from the regression analysis suggest that adults who stutter are slower in speech production because of stuttered disfluencies. The production of disfluencies interfered with the forward flow of speech. Production of more stutters in speech (Percent Syllables Stuttered) was significantly associated with slower articulation rates and also with slower delivery of CIUs.

Adults who stutter did not differ in the frequency of pauses they produced compared to controls. This is inconsistent with Love and Jeffress’ study (1971), which demonstrated that adults who stutter had more brief pauses in their read speech than control participants. There was no group difference for Proportion of Short Pause between the groups.

6.4.2.2 More Time Required by Adults who Stutter

The only significant group difference found after removing stuttered disfluencies from analysis was Proportion of Pause Time. This result is indicative of adults who stutter requiring more time for general speech production processes even when they produced perceptually fluent speech. Adults who stutter had a greater Proportion of Pause Time compared to control participants, with a mean difference of 8.09%.

Proportion of Pause Time increased by 1.42% for the adults who stutter after stutters were removed compared to their pre-stutter removal mean. This indicates that the production of stuttered disfluencies cannot explain the greater proportion of pauses in the speech of adults who stutter. The increase in proportion of pauses was a function of the duration and frequency of long and short pauses produced by the stuttering adults. Even though not statistically significant, adults who stutter produced on average longer mean duration of short and long pauses and had a higher proportion of short pauses in their speech after stutters were removed.

It is likely that the group difference of Proportion of Pause Time was a result of a cumulative effect of a number of different processes. There were no significant group differences for primary pause measures of Short and Long Pause Means, or for articulation rate, after stuttered disfluencies were removed. There were also no significant group differences for any language-based measure. Therefore, the results in this study indicate that adults who stutter required extra time for broad speech production processes, for both linguistic planning processes *and* speech motor control processes.

Difficulties with speech planning processes do not appear to be the sole reason for the difference found for Proportion of Pause Time because adults who stutter did not differ in their content of language production for communicative effectiveness. That is, adults who stutter did not differ in their production of Percent Correct Information Unit and Total Performance Deviations. The results of this study show that adults who stutter only differed in the manner in which the information was delivered according to time.

Specifically, adults who stutter were found to be significantly slower (0.2 seconds) than control participants as indicated by Seconds per Correct Information Unit. This difference for Seconds per Correct Information Unit was a result of an overall slower articulation rate for the adults who stutter. Further, the production of stuttered disfluencies was found to be a significant contributor to the slowness observed for this measure. Percent Syllables Stuttered was found to negatively associate with Seconds per Correct Information Unit. This indicates that the more frequent a speaker produced stutters in speech, the slower they were with production of CIUs in speech.

In regards to measures of Performance Deviations (PD), adults who stutter did not produce more, or less, of any other type of PD in speech, nor did they produce PDs significantly quicker in spontaneous speech when compared to the control participants (Seconds per PD). Therefore it appears that they did not compensate for stuttering through the production of PDs. Adults who stutter produced PDs on average 0.5 seconds slower than controls, which was a non-significant result. The slower production of PDs by adults who stutter was due to a general slower articulation rate.

Adults who stutter did not differ significantly for articulation rate or Short Pause Mean compared to controls when stutters were removed from their speech samples. Therefore, an exclusive speech motor theory for why they required extra time for speech production is not well supported.

The extra time required in speech for the adults who stutter could have been related to the use of compensatory mechanisms used to help control stuttering. There are indications of this from the regression analysis. The Use of Fluency Techniques positively correlated with Proportion of Short Pauses. Fluency techniques include attempts to prevent, stop or change a stutter and it is reasonable to expect that those who used fluency techniques more frequently were more likely to have also used the techniques for the speech samples collected for this study.

Based on this, the implementation of fluency techniques was likely related to the increased production of short pauses. Also, there was a higher Proportion of Short Pauses in the perceptually fluent speech of adults who stutter compared to speech that included stuttered disfluencies. This further suggests that short pauses are related to processes of fluency techniques that are employed to maintain fluency in speech.

It takes time for an individual to implement conscious strategies to constantly control stuttering. This can be a highly taxing task, particularly for a speaker who is less skilled and/or less experienced at implementing these strategies in their speech. Such strategies may result in an increased physical and emotional exhaustion (Kalinowski & Dayalu, 2002). It would be reasonable to speculate that the production of pauses, particularly long pauses, may also be associated with conscious strategies to control stuttering. Although not significantly different, adults who stutter produced longer long pauses post-stutter removal compared to the control participants. The longer long pauses produced by adults who stutter could have contributed to the overall increase in proportion of pause time observed for the adults who stutter.

Slower initiation times found for stuttering adults' perceptually fluent speech samples relate to timing differences in speech production (De Nil, Kroll, & Houle, 2001). This could be related to compensation for difficulties with sensorimotor control (De Nil, et al., 2001; Max & Gracco, 2005). Max and Gracco (2005) found that adults who stutter did not differ in their ability to coordinate oral-laryngeal durations for speech production but they did have slower initiation of phonation, or longer movement durations. The authors had concluded that this slower initiation may have served to provide additional time to deal with the multiprocessing requirements involved in speech production, for adults who stutter.

Therefore, a cumulative effect of generally slower speech production skills for both linguistic and speech motor control, as well as the additional time required for compensatory mechanisms, is a plausible explanation for the increase in Proportion of Pause Time observed for the stuttering adults. However, the specific role of pauses in the use of fluency techniques cannot be determined without objective measurement.

6.4.3 Group Differences for Associated Measures

The dependent variables from the significant group main effects (ANCOVA) were also measures that were found to be significant for the independent samples *t*-tests. This included Seconds per Correct Information Unit, Syllables Spoken per Second, Short Pause Mean and Proportion of Pause Time. As dependent variables of significant group main effects, this further confirms that these measures were deviant for the adults who stutter.

The group interactions observed for this study did not reveal any possible use of speech and language trade-offs by the adults who stutter. Rather, the group interactions involved only timing measures as both covariate and dependent variables. When the group interactions were examined separately per group, only the control participants showed significant associations in all cases. The lack of associated measures for the adults who stutter shows that they had unusual patterns of performance. This further suggests that adults who stutter deviated from controls in the timing aspects of speech production.

Adults who stutter in this study did not show expected patterns for the following associations: (a) Seconds per Correct Information Unit *with* Proportion of Pause Time, (b) Seconds per Correct Information Unit *with* Long Pause Mean, (c) Seconds per Performance Deviation *with* Long Pause Mean, and (d) Short Pause Mean *with* Seconds per Performance Deviation. These associations were expected to be positive. CIUs and PDs are produced as ‘speech’ units according to the pause segmentation procedure.

Therefore, the more pauses a speaker produces, the less they speak. This results in a slower production of CIUs and PDs in speech. Furthermore, Percent Syllables Stuttered was found to positively associate with Second per Correct Information Unit. This indicates that stuttered disfluencies had likely contributed to the reason as to why adults who stutter did not show expected patterns for the associations involving this measure.

There was also a group interaction for Syllables Spoken per Second *with* Seconds per Performance Deviation. For control participants, as expected, Syllables Spoken per Second was a predictor of how quickly PDs were produced in speech. For the adults who stutter, articulation rates did not associated significantly with the production of PDs. As articulation rate was also found to be negatively related to Percent Syllables Stuttered, this suggests that stuttered disfluencies likely have resulted in slower articulation rates for adults who stutter. This in turn has resulted in the slower production of PDs.

6.4.4 Impact of Stuttered Disfluencies on Speech and Language Fluency Profiles

To address the research question of how stuttering and stuttered disfluencies impact on pause and articulation rate measures, it was previously discussed that Short Pause Mean and Syllables Spoken per Second were deviant as a result of stuttered disfluencies in speech. The measures were found to have a significant group difference when stuttered disfluencies were not removed, but they ‘normalised’ to the point where group differences became non-significant after stuttered disfluencies were removed.

Also as previously discussed, Syllables Spoken per Second, Proportion of Short Pauses and Seconds per Correct Information Unit were found to associate with Percent Syllables Stuttered. Syllables Spoken per Second and Proportion of Short Pauses were found to be negatively correlated with Percent Syllables Stuttered. Percent Syllables

Stuttered was found to be positively correlated with Seconds per Correct Information Unit. These associations support the notion that stuttering impacts negatively on speech output by slowing the rate of speech production.

The Use of Fluency Techniques was found to correlate with Proportion of Short Pause and Speech Segment Mean. Both of these associations showed positive relationships. These results indicate a possible link between the explicit use of techniques in speech and how they affect speech and language output. These associations were only observed for approximately half of the stuttering participants, therefore the results should be interpreted with caution.

Those who used fluency techniques for more time during the week produced a greater proportion of short pauses. They also produced longer speech segments. This suggests that the production of short pauses may be related to the types of fluency techniques that adults who stutter use in their perceptually fluent speech. A longer duration of Speech Segment Mean gives an indication of the speech segments planned in relation to the production of long pauses. The positive association with the Use of Fluency Techniques shows that those who used fluency techniques more often also had longer speech segments. This means that they also produced fewer long pauses in their speech, resulting in the production of longer speech segments. It is possible that the use of fluency techniques reduced the number of long pauses produced in speech. This is plausible given that speech restructuring techniques emphasise the continuous vocalisation of speech to reduce the frequency of stutters. Hence, the number of pauses a speaker produces would be expected to decrease when these fluency techniques are successfully applied.

An examination of pause and articulation measures post-stutter removal compared to the pre-stutter removal condition further demonstrate the negative impact of stuttered disfluencies on speech and language output. After stutters were removed, measures became more normalised. Misclassification Rate decreased and Speech Segment Mean increased. These effects were not statistically significant; however, they still indicate that stuttered disfluencies resulted in more deviant patterns.

Proportion of Pause Time and Long Pause Mean were two measures which did not ‘normalise’ post-stutter removal. Both of these measures increased to deviate more from the means of the control participants. As previously discussed, Proportion of Pause Time was the only measure to demonstrate a *between-groups* significant difference post-stutter removal.

The only measure which showed a significant *within*-group difference, when comparing pre-stutter and post-stutter removal conditions was Short Pause Mean. Short Pause Mean was shorter for the post-stutter removal condition compared to the pre-stutter removal condition, with a mean real-time difference of 1.5 milliseconds. This result indicates that stuttered disfluencies largely contributed to the group difference observed for this measure.

The analyses for pre-stutter and post-stutter removal were expected to be more reliable in Study 3 than for Study 1 or 2. The adults in Study 3 had more stuttering data to remove from samples compared to the children in Experiments 1 and 2. Children in Study 1 had the least number of stuttered data lines. Across Experiments 2 and 3, Proportion of Pause Time was the only measure which did not show the same pattern post-stutter removal. This measure decreased for the children in Study 1 and 2, but increased for the adults in this study. This further provides evidence that extra time was required for speech production processes and for compensatory techniques used by adults who stutter.

An examination of the deleted stuttering segments further informs about the composition of the stuttered disfluencies. The stuttering segments had a pause duration average of 299 milliseconds; this measurement included the immediate subsequent pause-speech segment data line. The average speech segment duration was 341 milliseconds, which was between the mean short pause duration (50 milliseconds) and the mean long pause duration (513 milliseconds) for stuttering adults. After stuttered disfluencies were removed, the remaining short pauses were on average shorter, and the remaining long pauses were on average longer. As such, the short pause distribution shifted to the left and the long pause distribution shifted to the right. The two pause duration distributions became more separable, indicated by a lower misclassification rate compared to when stutters remained in the speech samples. The speech segment duration increased by an average of 122 milliseconds after stutters were removed. The increase in Proportion of Pause Time after stutters were removed was a function of the longer *speech* segment durations being deleted relative to the *pause* segment durations.

6.4.5 Study Limitations and Future Research

The significant between-groups difference in Proportion of Pause Time for this study has been hypothesised to reflect the general delay in speech production processes and compensatory mechanisms employed by adults who stutter. The fact that none of the stuttering clinical measures were associated with Proportion of Pause Time questions the validity of the stuttering clinical measures gathered. It is possible that these measures did not appropriately reflect the composition of the compensatory mechanisms.

The measures of fluency techniques were based on the participants’ subjective recollections and estimates of how often they use and practice techniques. They served as an attempt to quantify the use of compensation by the adults but they did not give any indication of how successful a speaker was at using fluency techniques to control their stutter. The measures did not provide information about the quality or quantity of the fluency techniques used during the speech sampling sessions gathered for this study.

In order to develop more valid and reliable methods of measurement, there is a need to further explore the speech production changes that occur due to certain therapeutic techniques, covert behaviours and compensatory techniques used. Perhaps there is a way to measure such entities in the speech production of people who stutter. It may be feasible to use an acoustic analysis program to assist in the identification of changes in speech relating to compensatory techniques. If this is possible, this would lead to a better understanding of the mechanisms of change commonly adopted as strategies to control stuttering in speech therapy.

All stuttering adults who participated in this study have had prior therapy for their stutter. A high percentage (67%) of the participants claimed to use fluency techniques in their speech every week. It may be that an investigation of adults who do not use fluency techniques, or an investigation of adults with no prior therapy experience, may help with elucidating the origin for the differences observed between the groups for Proportion of Pause Time. However, it would be a challenge to find and recruit adults who have not undergone any form of therapy due to the debilitating consequences of the disorder. In addition, many adults who stutter may develop compensatory techniques on their own without formal therapy.

Future studies need to investigate the speech and language processes of females who stutter. The speech samples of only males who stutter were investigated in this study as they were recorded as part of a previous study (Hennessey, et al., 2008). Males who stutter were more readily available for research and easier to recruit. This reflects the greater ratio of males who stutter compared to females at approximately 4:1 (Guitar, 2006). For more detailed investigation of possible gender differences for adults who stutter is it important that future participant samples are more representative of the stuttering population.

Even though no speech and language fluency measure was found to significantly associate with age of participants in years, a more representative sample of the adult population with a better spread of ages could be useful. Participants in this study were on average 48 years of age for the stuttering group and 47 years of age for the control group with a wide range of 22 years to 65 years of age.

For this study, each participant completed three genres of spontaneous speech sampling tasks in one session: picture description, personal narrative, and procedural narrative. Speech and language measures have been averaged across all tasks. Future research may find it worthwhile to investigate how the different tasks for speech sampling result in differences in speech and language output. Different speaking tasks may have differing profiles for the pauses typically used to execute them. For example, it has been found that a picture description task is more cognitively taxing than a conversation task, resulting in longer and more frequent pauses (Deputy, et al., 1982). Also, tasks requiring explanation and interpretation have more pauses and longer pauses than tasks requiring description (Goldman-Eisler, 1968; Levin, et al., 1967).

Though not tested statistically, it was found that for adults who stutter, Seconds per Correct Information Unit for the picture description task was slower than the personal narrative tasks and procedural narrative tasks. The picture description task may be more challenging for some adults who stutter because there is less flexibility around word choice. The subsequent use of avoidance strategies to compensate is more difficult and cognitively demanding.

Even though measures from The Fluency Profiling System and articulation rate were common across all studies of this study, the language measures differed for children compared to adults. As a result, the language-based measures were not directly comparable for the different age groups. It could be worthwhile for future research to investigate if it would be possible to collect the same language measures for all participants and use age and gender matched controls to serve as the first point of comparison. The cross-sectional nature of the data from Experiments 2 and 3 limits the strength of the conclusions drawn about the different stages of stuttering.

6.4.6 Study Summary

In Study 1, the results showed that differences in the speech and language performance of young children who stutter became apparent only after stuttering had started. The way speech and language measures were associated with each other differed between children who stutter and children who continued to develop typically. In Study 2, the results showed that stuttering had globally impacted the ongoing speech and language skills of school-aged children who stutter. This was supported by differences for the between-groups absolute means for both Short and Long Pause Mean measures. This was also supported by changes in the way speech and language measures associated with each other. However, for adults who stutter in this study there was no strong evidence to suggest that stuttering is a disorder of speech timing (De Nil, et al., 2001). The origin for timing deficits were largely related to the presence of stuttering disfluencies in speech, and not to an underlying difference in speech motor control.

The second major finding of this study was that, even when stuttered utterances were removed from the speech of adults who stutter, the adults who stutter continued to require additional time for speech production processes. This was demonstrated by a significant group difference for Proportion of Pause Time, a measure which includes all pauses produced by a speaker (long and short). The data indicate that the stuttering adults gained extra time by producing more and/or longer pauses in speech, particularly by producing longer *long* pauses than control participants. Though this finding may indicate the role of speech motor control difficulty contributing to the underlying cause of stuttering, it is more likely to relate to compensatory mechanisms used by stuttering adults in order to avoid, delay, or change their stuttering (van Leishout, et al., 1996; Zimmerman, 1980). Alternatively, it is also possible that adults who stutter have difficulty with general aspects of speech motor control (Peters, et al., 2000), *in addition* to the time related to the use of compensatory strategies. Thus it is the combination of such processes and factors that have resulted in the general increase in time required for speech production in adults who stutter.

CHAPTER 7: GENERAL CONCLUSIONS

This chapter presents the overall conclusions for the study and takes into account the implications of the findings across all three studies.

7.1 Summary

The first major aim of this thesis was to ascertain whether any differences in speech and language fluency profiles are a reflection of the cause of stuttering, or if they are instead a consequence of stuttering. The thesis also aimed to investigate factors associated with stuttering, such as factors relating to familial history and speech and language fluency profiles at different stages of stuttering.

Findings from Study 1 may indicate a positive familial history of stuttering but the study did not have sufficient power to confirm this. The study showed that the speech and language skills of children with and without familial history do not differ and differences in speech and language ability as causes of stuttering onset could not be confirmed. Rather, subtle changes in speech and language observed in young children appear to occur *due to* stuttering. For school-aged children in Study 2 who had been stuttering longer, there was evidence for underlying differences in speech motor and language ability in addition to differences for associated speech and language variables compared to controls. For adults who stutter in Study 3, group differences in measures of timing aspects of speech motor activity were due to the consequence of stuttered disfluencies in their speech. Stuttering adults did however exhibit a general delay in speech production processes for their perceptually fluent speech.

The findings of this study indicate that the relationship between speech and language processes and stuttering differ during development (Watkins, et al., 1999). In addition, the role of speech motor control in the cause of stuttering was more apparent in school-aged children who stutter rather than adults who stutter. It may be possible that different factors for the cause of stuttering are at play at different stages of stuttering development.

Specifically, younger individuals during a skill *acquisition phase* showed different patterns compared to older individuals during a skill *maintenance phase* on the same measures (Conture, et al., 2006). For school-aged children who stutter, differences in speech and language functioning suggest co-development of such skills with stuttering. Stuttering has a greater impact for children because their speech production systems are less stable than that of adults, hence the adults mostly showed perturbations due to the production of stuttered disfluencies in speech. From this finding, it is speculated that for those whose stutters persist, their speech and language skills recover to levels comparable to their fluent peers. This recovery may occur as their stuttering patterns stabilise. It is unknown as to how this happens or what facilitates or hinders this, and is an area for future research. For example, communication through other modes, literacy ability and/or the treatment for stuttering may be factors that can facilitate or maintain language development.

7.2 Clinical Implications

The results of this study could be useful for the assessment and monitoring of speech and language skills in young children who start to stutter.

In Study 1, group differences for associated speech and language measures began to emerge within six months of stuttering onset, which demonstrates the impact of stuttering on speech production output. This could have implications for how young children who stutter are facilitated for developing speech and language skills. This need not be in the form of formal treatment but could instead be through parent education. The importance of supporting the ongoing skill development for children who start to stutter in their everyday environment, regardless of whether the child may or may not spontaneously recover from stuttering should be highlighted. This would complement the notion that early intervention is important to reduce the negative impact of stuttering on communicative skills, and more broadly for social, psychological and cognitive development (Davis, et al., 2002).

The differences found in the language ability for school-aged children who stutter compared to the control children highlight the importance for clinicians to consider the assessment of speech and language skills other than stuttering. This is consistent with the conclusions drawn from a recent meta-analysis of the language abilities of children who stutter, stating that "...children known or suspected of stuttering should receive the same comprehensive speech-language assessment received by other children with known or suspected speech-language problems" (Ntourou, et al., 2011, p. 175). Information about a child's relative speech and language skills (subcomponents of speech and language) should also be considered. Absolute differences may not provide the full picture of what may be happening within a stuttering child's speech and language system. Relative strengths and weaknesses, together with the specific factors that affect the fluency levels of a child, could assist in providing a more individually tailored speech therapy program.

Study 3 found no differences in language performance between individuals with chronic stuttering and control participants. This reinforces that people who stutter do know what they want to say and how to say it, but they differ in the timing of their output *because* of their stuttering. Continual education and awareness is required to highlight this aspect of stuttering. Negative stereotypes of people who stutter are often reported. People who stutter have been described to be inferior to those who do not stutter in the areas of intelligence and general competence (e.g., Craig, Tran, & Craig, 2003).

7.3 Concluding Remarks

The program of research presented here has utilised different methodologies to help ascertain the causes and consequences of stuttering. The ideas presented in this thesis have offered further insight into the nature of stuttering and have provided a base upon which future research can build. With the acknowledged limitations of this thesis noted, there are notable strengths of this thesis.

Comprehensive speech and language fluency profiles were defined for participants. This was achieved through the collection of measures from natural speaking contexts to reflect the multidimensional concept of fluency. There were common measures gathered across the different age groups to make comparisons across different developmental stages of stuttering. This allowed for the examination of speech and language relationships with each other and with stuttering.

The investigation of the perceptually fluent speech of people who stutter was possible without manipulating speech targets or using decontextualised tasks. The stutter removal procedure gathered perceptually fluent speech in the natural speech of people who stutter. The use of clinical stuttering measures gave additional insight into the relationship of stuttering measures with speech production measures.

The longitudinal study of young children collected data prior to any stuttering onset. Studies to date using the same methodology have been limited. It has been demonstrated here that defining speech and language profiles in conjunction with a longitudinal schedule is potentially a fruitful avenue to pursue for investigating factors that relate to the onset and development of stuttering.

This study was novel in its investigation of the speech and language fluency profiles related to the presence or absence of a familial history of stuttering. With a major interest in the genetics of stuttering and how they interact with environmental factors, it is foreseeable and hopeful that such studies will become more frequent in the near future. It would be interesting to see if a genetic predisposition results in differences regarding how the brain processes speech and language functions.

APPENDICES

Appendix A: Data Output from MATLAB

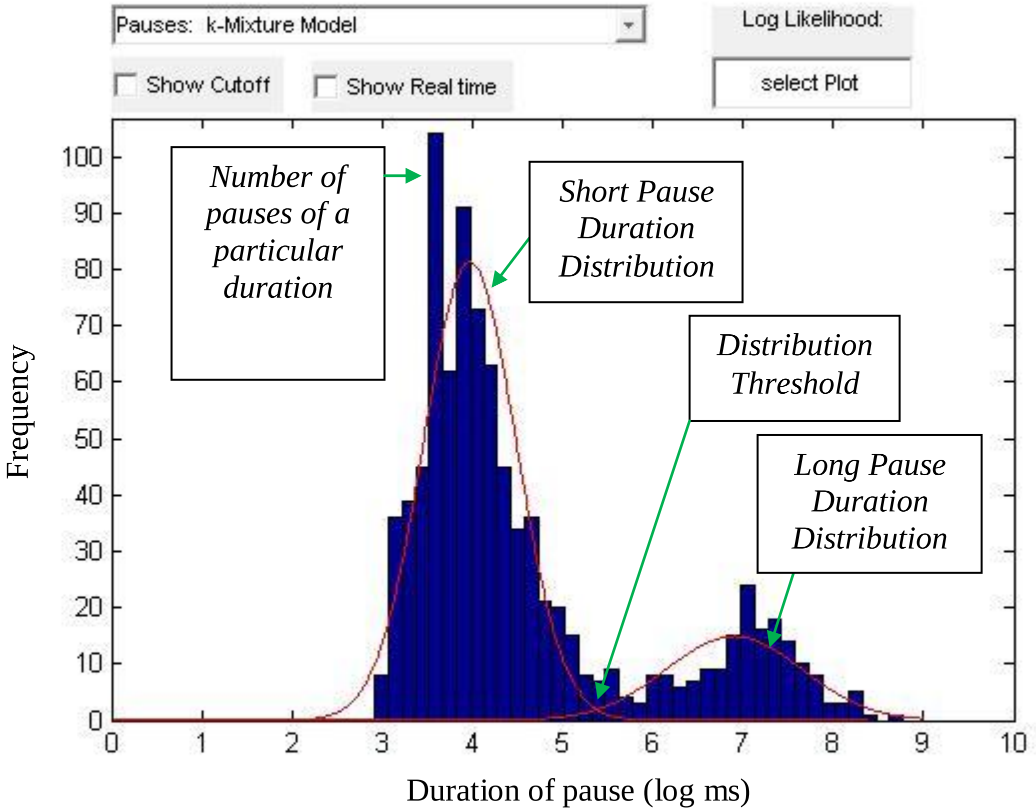


Figure A.1: An example of the visual display of the *pause* frequency data plotted against duration (log).

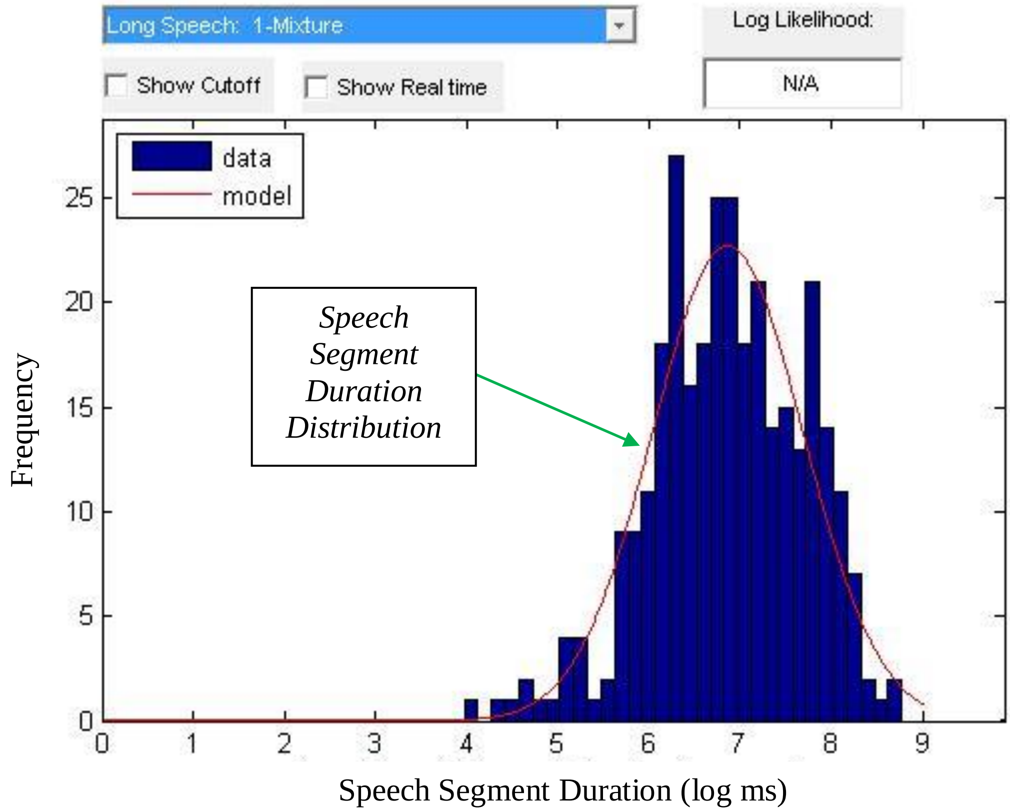


Figure A.2: A visual display of the *speech segment* frequency data plotted against duration (log).

No. of lines of data = 330
Total time = 4.56 mins.
Pause analysis:
Total pause time = 1.79 mins. (39.3%) **Proportion of Pause Time**

	Min.	*Max.*	*Mean*	*Stdev*
Log:	2.71	8.60	5.12	1.16
Real:	15	5435	325.54	476.59

Log-likelihood = -517.153
Log space:

Comp.	*Mean*	*Stdev*	*Prob.*	
1	3.97	0.47	0.40	**Short Pause Mean (log)**
2	5.88	0.80	0.60	**Long Pause Mean (log)**

Real space:

Comp.	*Mean*	*Stdev*	*Prob.*	
1	52.9	1.59	0.40	*Short Pause*
2	357.5	2.22	0.60	*Long Pause*

Log-likelihood = -490.172
Speech analysis:
Total speech time = 2.77 mins. (60.7%)

	Min.	*Max.*	*Mean*	*Stdev*
Log:	3.40	7.69	6.01	0.67
Real:	30	2195	503.21	339.45

Log-likelihood = -335.868
Classification analysis:
Optimal cutoff 1: 4.70 (log) 109.5 (real) **Distribution Threshold**
Short pause error rate: 0.0237
Long pause error rate: 0.0419
Total error rate: 0.0656 **Misclassification Rate**
Long pause speech segments:

	Min.	*Max.*	*Mean*	*Stdev*	
Log:	4.16	7.77	6.55	0.74	**Speech Segment Mean (log)**
Real:	64	2379	881	545.88	

Figure A.3: An output with descriptive pause data. Measures included the mean and standard deviation of short and long pause distributions, the percentage of misclassifications of pauses into distributions and the speech segment mean and standard deviation durations.

Pause	Speech	Text
402	111	t
3671	1642	C I lite {like}/Mitty {Miffy}
1375	1312	C o/pen/a
453	896	gain
1294	815	hmm {sighs}
2642	912	hm
555	1296	x/x
363	1796	a/foo {fruit}/thaler/t {salad}
4181	1377	C foot {fruit} salan/d {salad}
537	1320	the/foot {fruit}/plaland {salad}
681	546	C yeah
1843	470	C dad
318	1271	need some/for/k
3219	522	and/the s
214	587	poon
2462	381	C e
204	173	/s {eggs}
1063	787	C da/t {dad}
546	1358	C here we/go/dad
694	404	C yeah
838	1071	C you want/some?
1341	1222	C myou {you}/want/tome {some}?
2034	1104	C a/pi/ssa {pizza}
1449	1101	and/pizz/a

Figure A.4: A Long Pause Speech Segment transcript. This is where the transcript is displayed with short pauses folded signified by a forward slash and each line of speech segment data is bound by a long pause determined by the distributional analysis.

Appendix B: Study 1 Paediatric Case History Information Form

The information you provide on this form will provide us with some background information to ensure that we take all information into consideration when considering your child's speech and language skills. All material and information will be kept strictly confidential. This form will be stored in secured departmental facilities, at The School of Animal Biology, University of Western Australia. Data will be accessed only by the listed researchers.

Date:
Person (s) Completing this form:
Relationship to child (parent, teacher):

General Information about the child:
Name: Date of Birth:
Current Age:
School and Grade:

Mother's Name: Father's Name:
Address:
Phone:
Email:

Please indicate mother's highest education level:

1. Highest Educational Level (please tick):
   - ☐ Primary School
   - ☐ High School (year 10)
   - ☐ High School (year 12)
   - ☐ TAFE or other further training institute
   - ☐ University
   - ☐ Other ___________________________

Please indicate father's highest educational level:

1. Highest Educational Level (please tick):

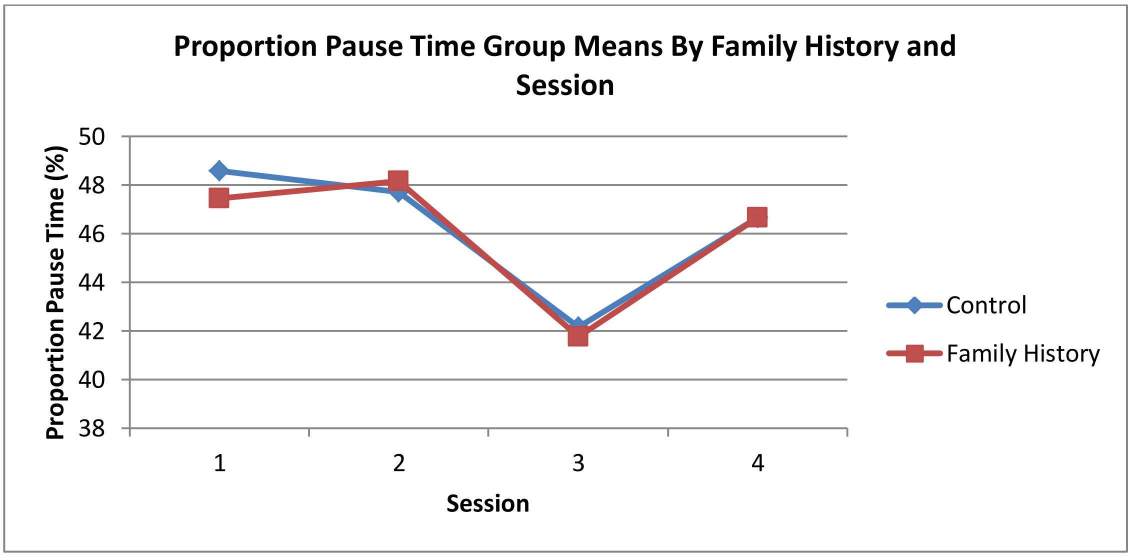
- ☐ Primary School
- ☐ High School (year 10)
- ☐ High School (year 12)
- ☐ TAFE or other further training institute
- ☐ University
- ☐ Other ______________________________

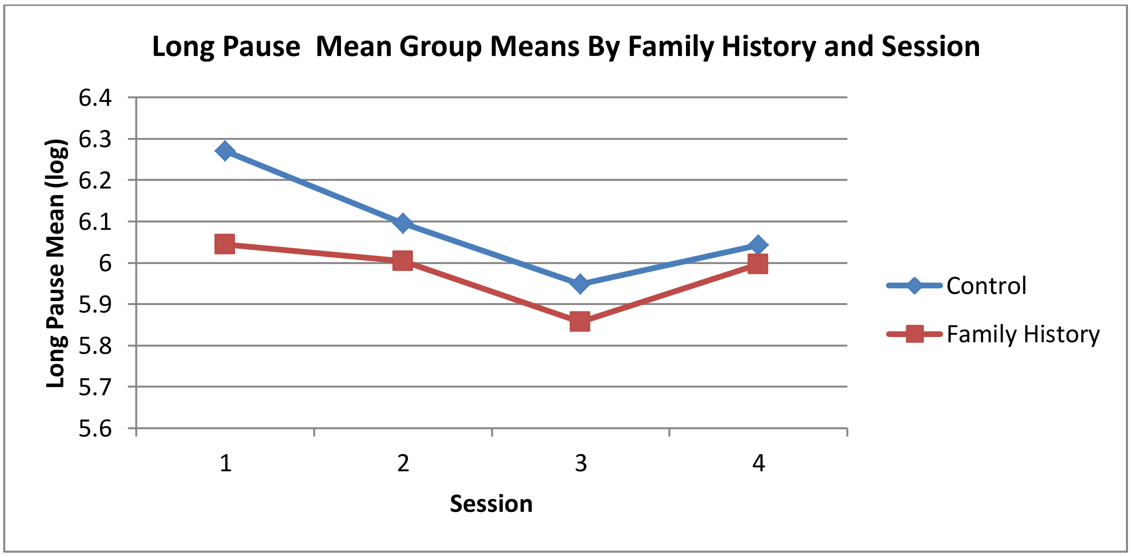
Family History:

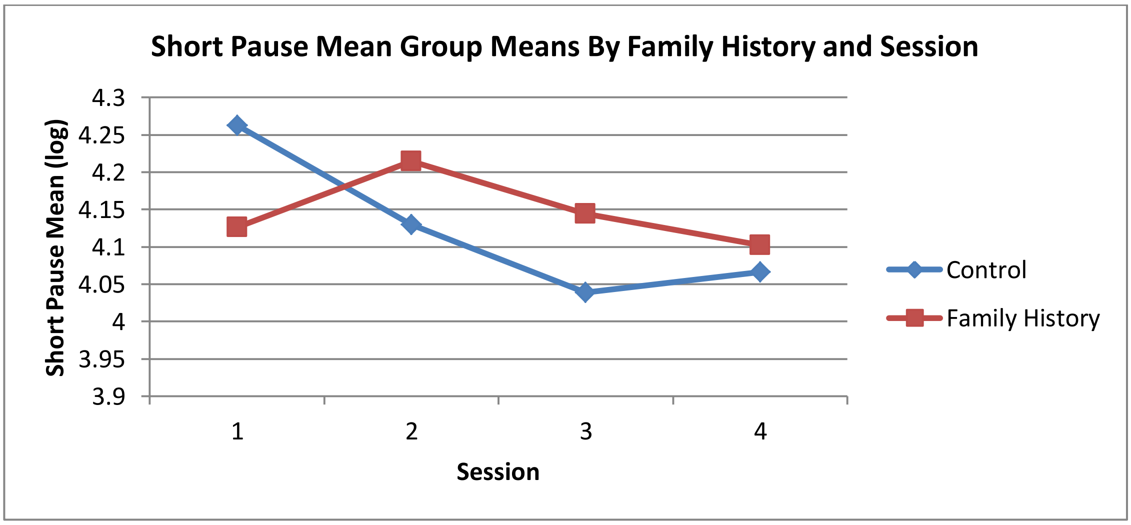
1. What are your child's living arrangements (e.g., living with both parents)?
2. Please list any siblings and their ages:
3. Is there a family history of stuttering or any other speech, language, learning, reading, attention or hearing problems? If yes, please indicate (to the best of your knowledge) all family members and their relationships to the child as well as the nature of their difficulties:
4. Is English your child's primary language? If no, please indicate the primary language and any other languages that the child uses frequently:
5. Have any other specialists (physicians, psychologists) seen your child? If yes, please indicate the type of specialist, when your child was seen, for how long and the reason why:
6. As far as you know, did your child's speech and language develop in the same way as other children of similar age?
7. Please describe any differences in their developmental pattern when learning to talk:
8. How has your child's general health been in the past? Good_____ Fair_____ Poor____
   If poor, please give details.
9. How is your child's health presently? Good_____ Fair_____ Poor____
   If poor please give details.
10. Has your child ever been hospitalised? If yes, please state when, how old your child was, for how long he/she was hospitalized and state the reason:
11. Has your child had any feeding/eating problems? (E.g., any problems with sucking, tolerating specific food textures, swallowing etc…) If yes, please describe when and for how long the problems lasted:

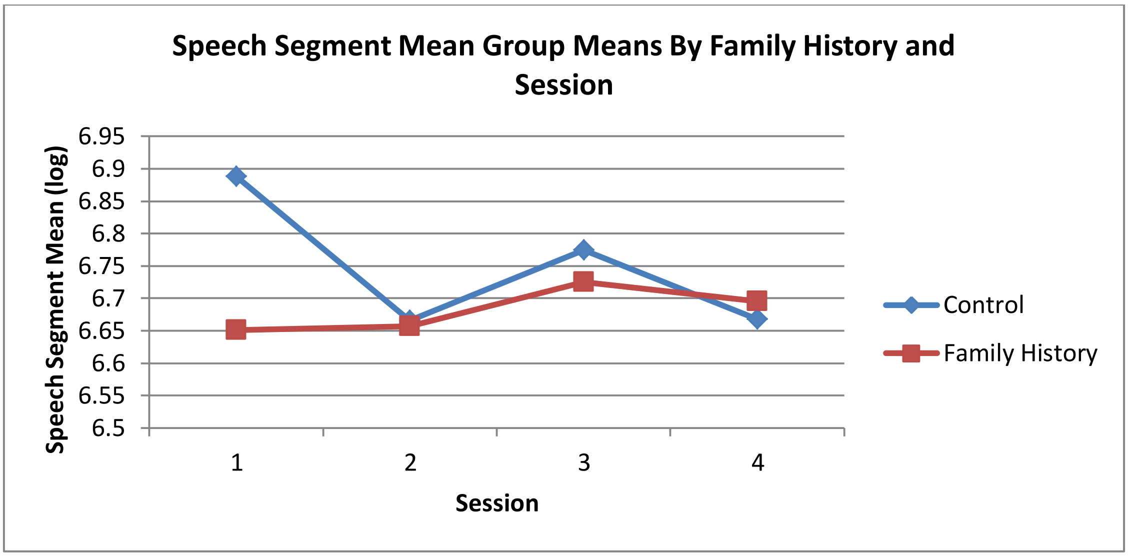
12. Has your child had any ear infections? If yes, please indicate when and what measures were taken to remediate that and if their ears are clear how long has this been?
13. When did your child last have their hearing tested? Please state when and the outcome:
14. Do you have any other health related developmental concerns regarding your child?

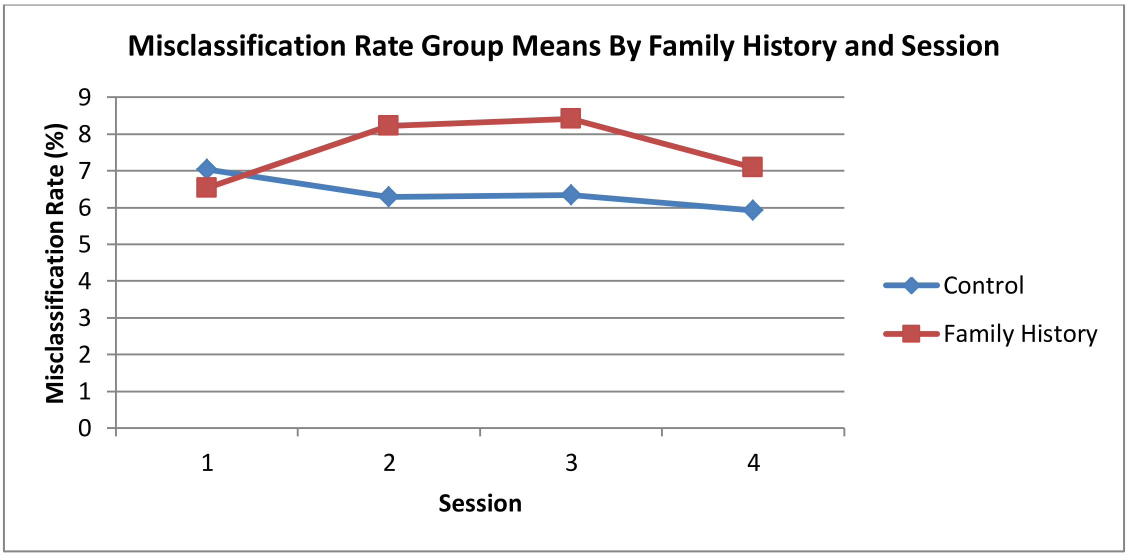
Appendix C: Study 1 Group Means for Speech and Language Measures by Family History and Session

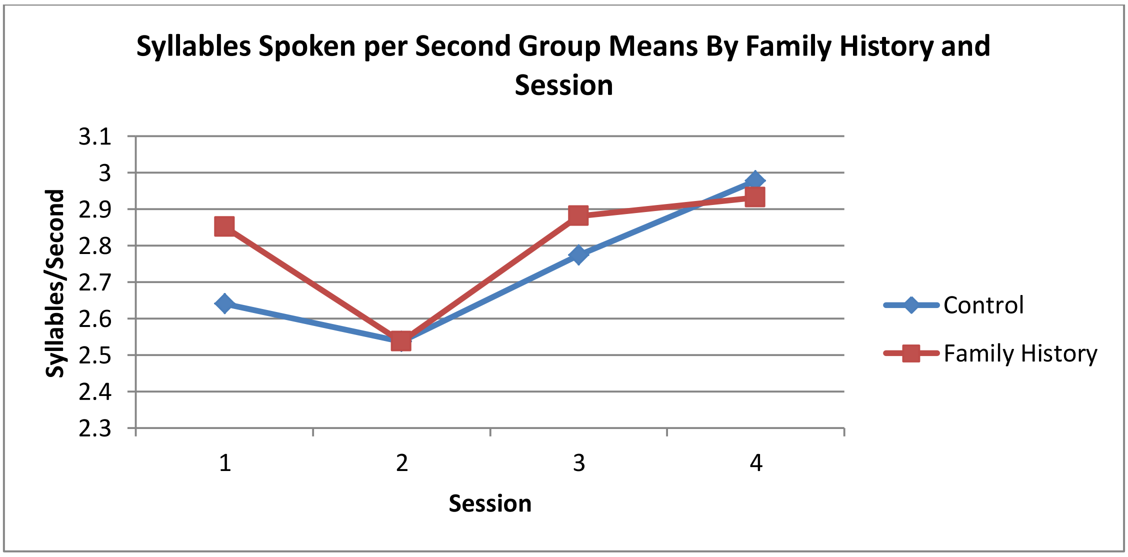


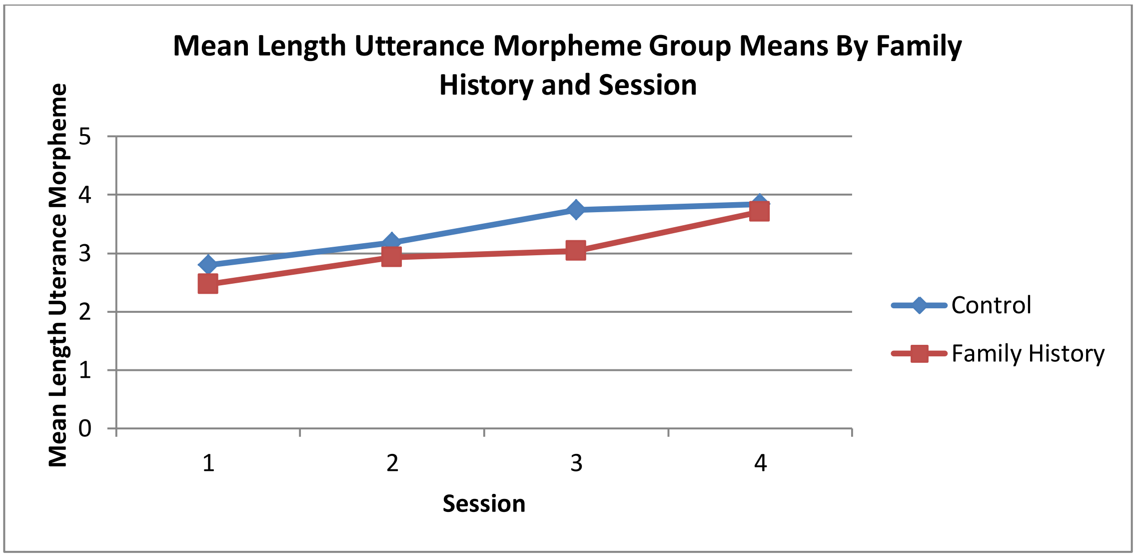


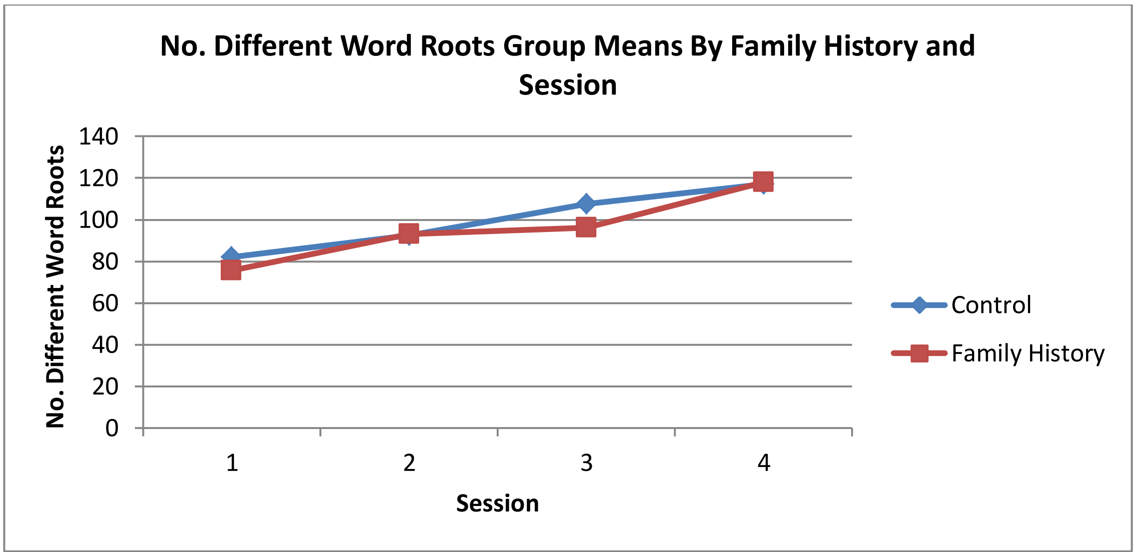


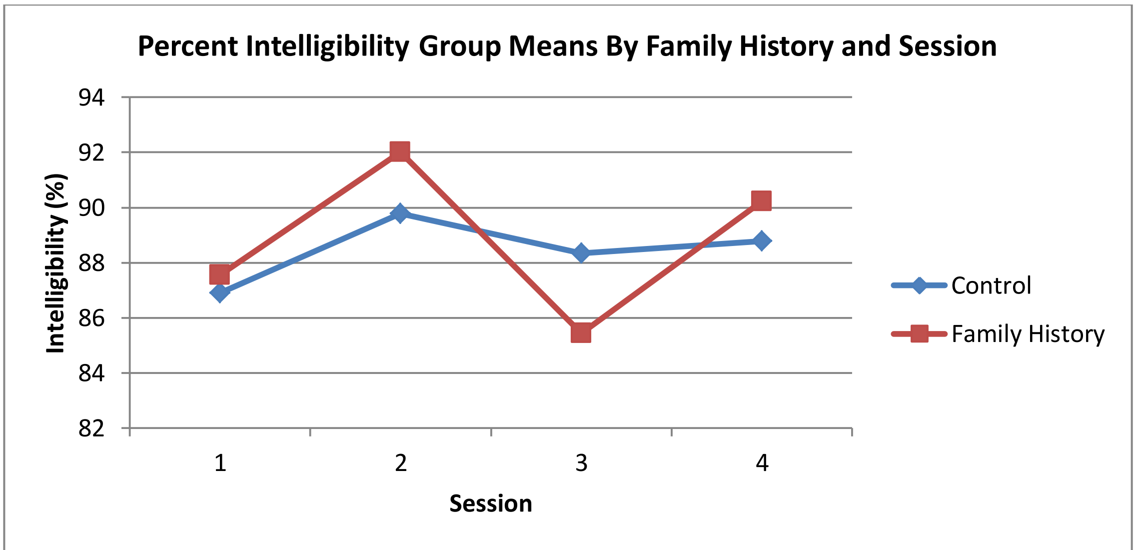

Speech Segment Mean Group Means By Family History and Session
Speech Segment Mean (log)
6.95
6.9
6.85
6.8
6.75
6.7
6.65
6.6
6.55
6.5
1
2
3
4
Session
Control
Family History

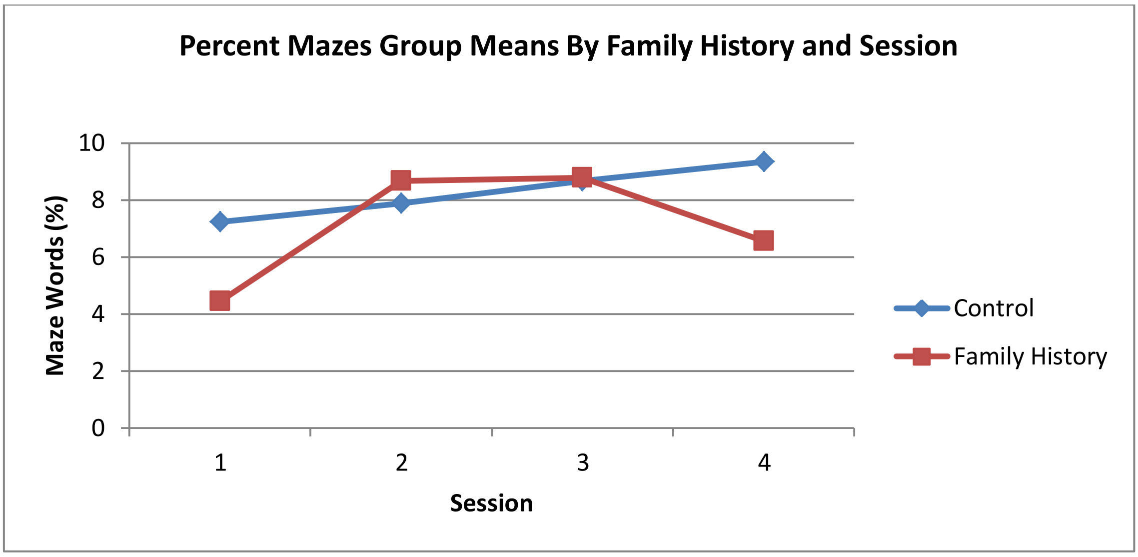

Misclassification Rate Group Means By Family History and Session
Misclassification Rate (%)
9
8
7
6
5
4
3
2
1
0
1
2
3
4
Session
Control
Family History


Syllables Spoken per Second Group Means By Family History and Session
Syllables/Second
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
1
2
3
4
Session
Control
Family History


Mean Length Utterance Morpheme Group Means By Family History and Session
Mean Length Utterance Morpheme
0
1
2
3
4
5
1
2
3
4
Session
Control
Family History

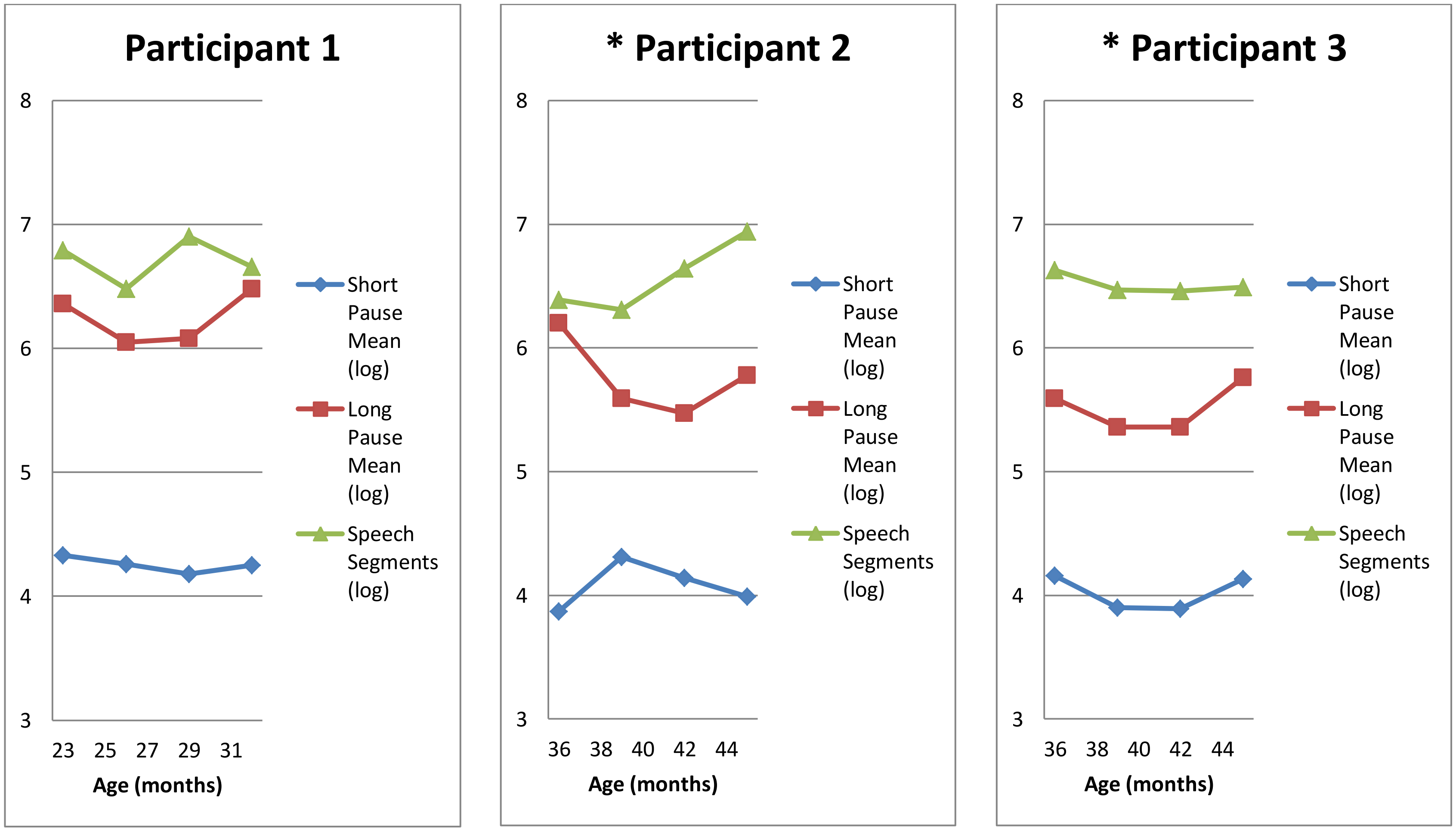

No. Different Word Roots Group Means By Family History and Session
No. Different Word Roots
0
20
40
60
80
100
120
140
1
2
3
4
Session
Control
Family History


Percent Intelligibility Group Means By Family History and Session
Intelligibility (%)
82
84
86
88
90
92
94
1
2
3
4
Session
Control
Family History

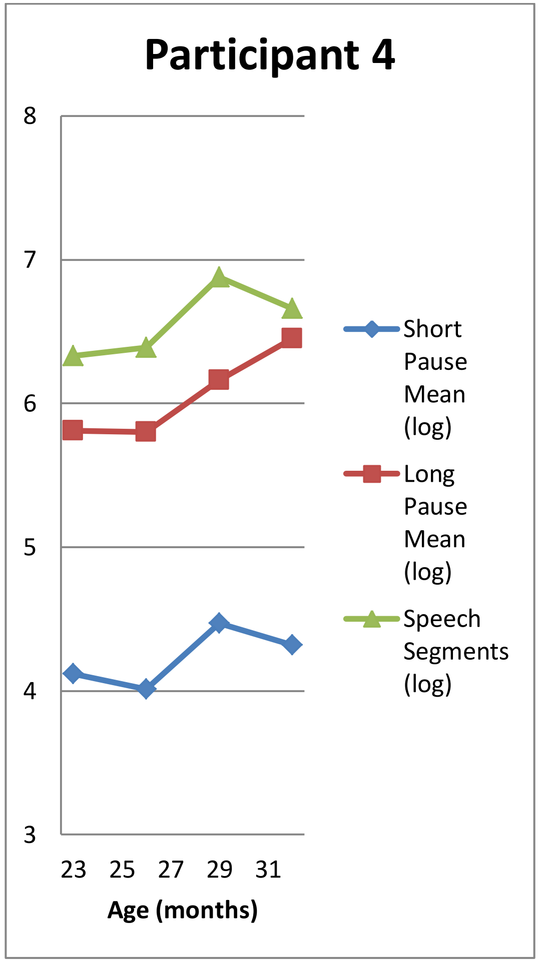

Percent Mazes Group Means By Family History and Session
Maze Words (%)
10
8
6
4
2
0
1
2
3
4
Session
Control
Family History

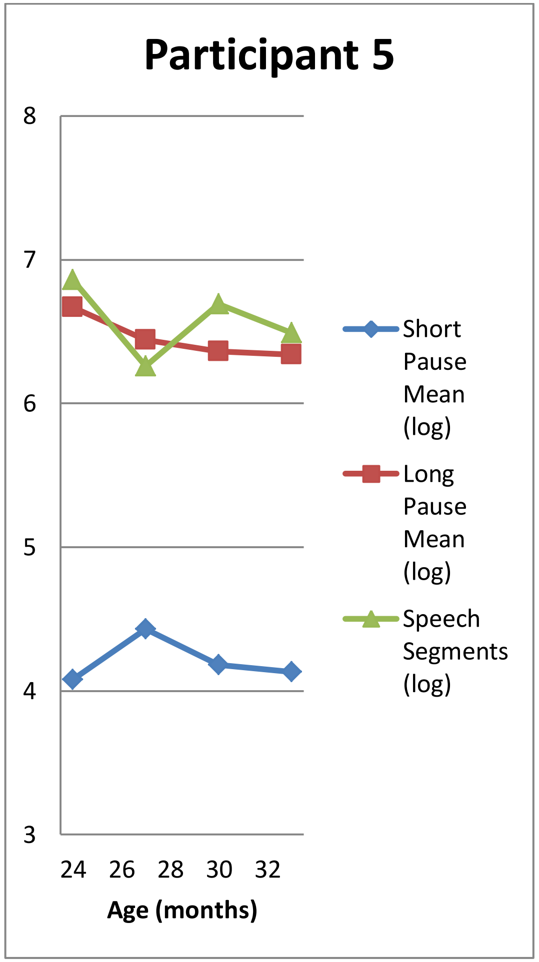
Appendix D: Study 1 Plots per Child Across Four Sessions for Short and Long Pause Mean, and Speech Segment Mean

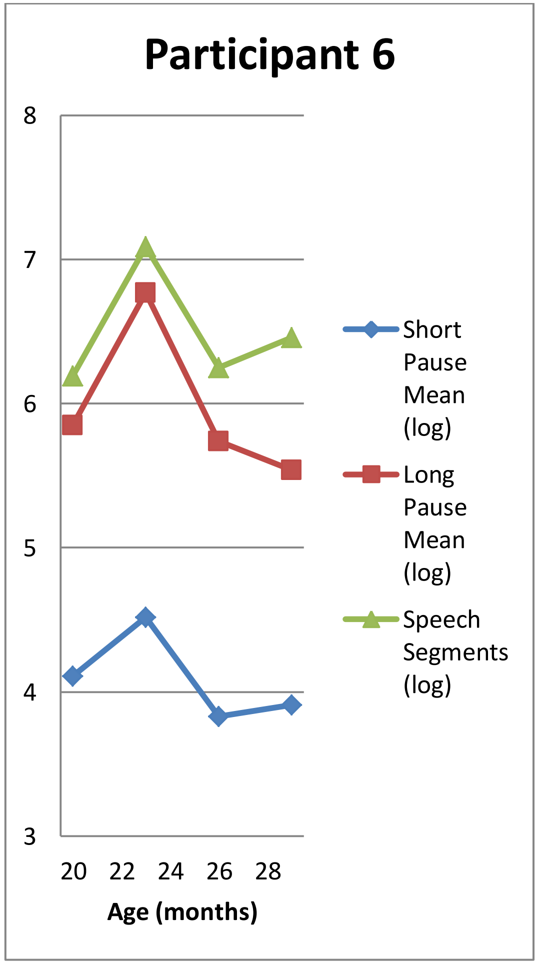
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

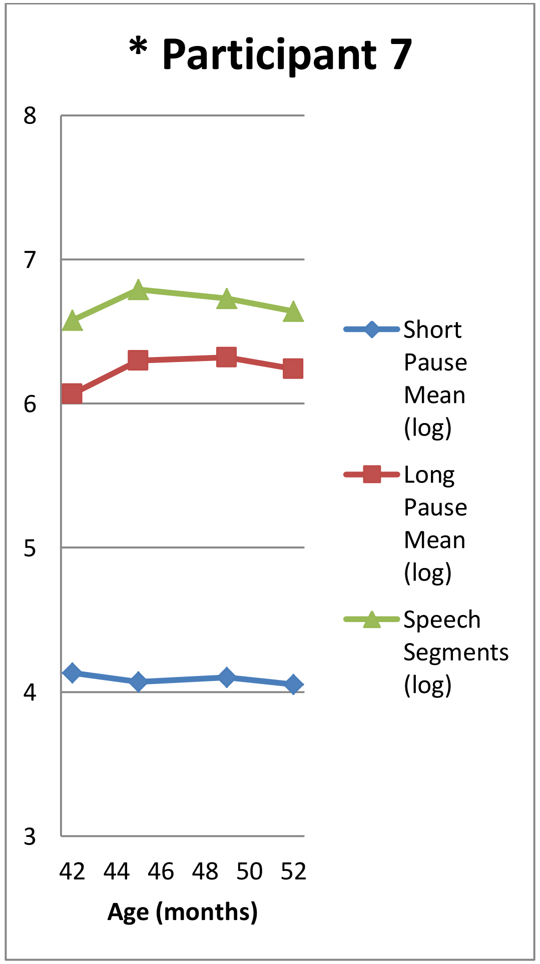


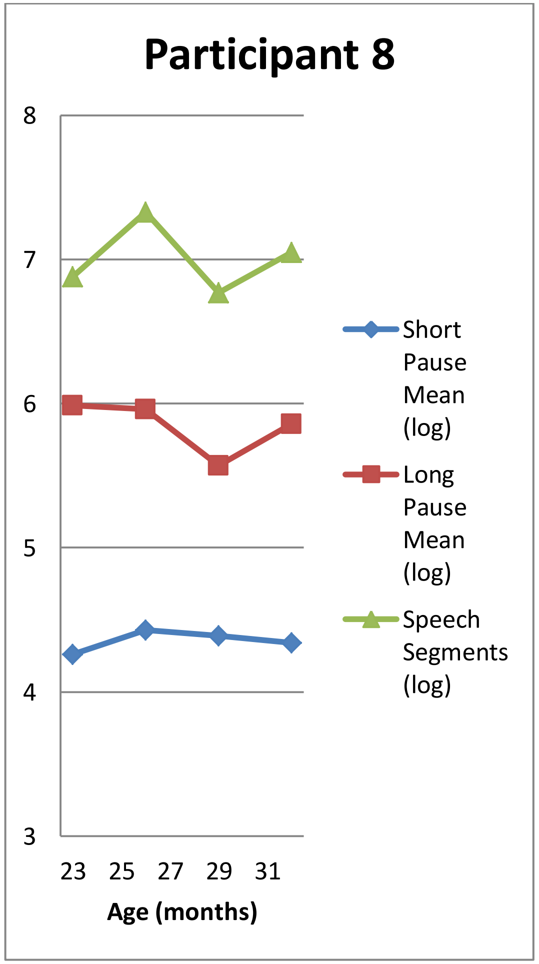
Participant 1
8
7
6
5
4
3
23 25 27 29 31
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)
* Participant 2
8
7
6
5
4
3
36 38 40 42 44
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)
* Participant 3
8
7
6
5
4
3
36 38 40 42 44
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

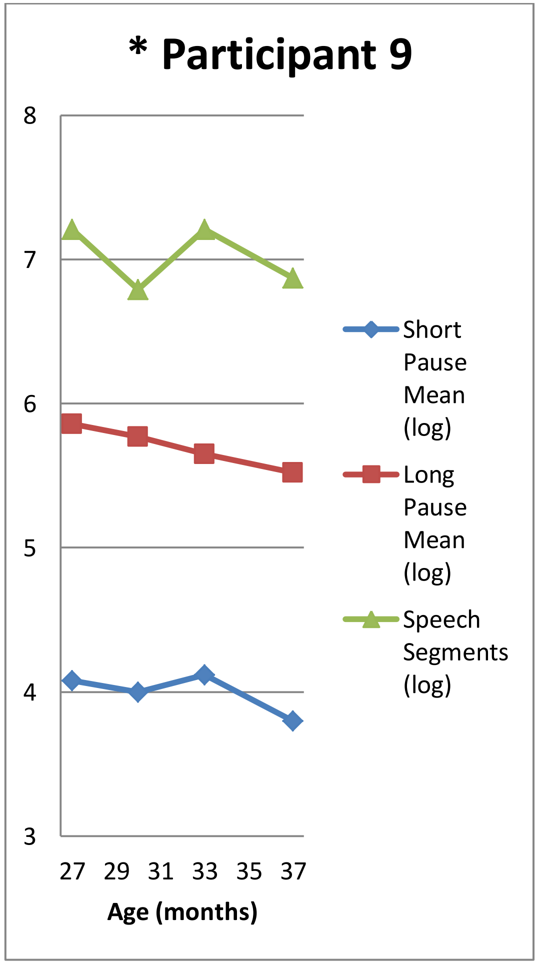

Participant 4
8
7
6
5
4
3
23 25 27 29 31
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

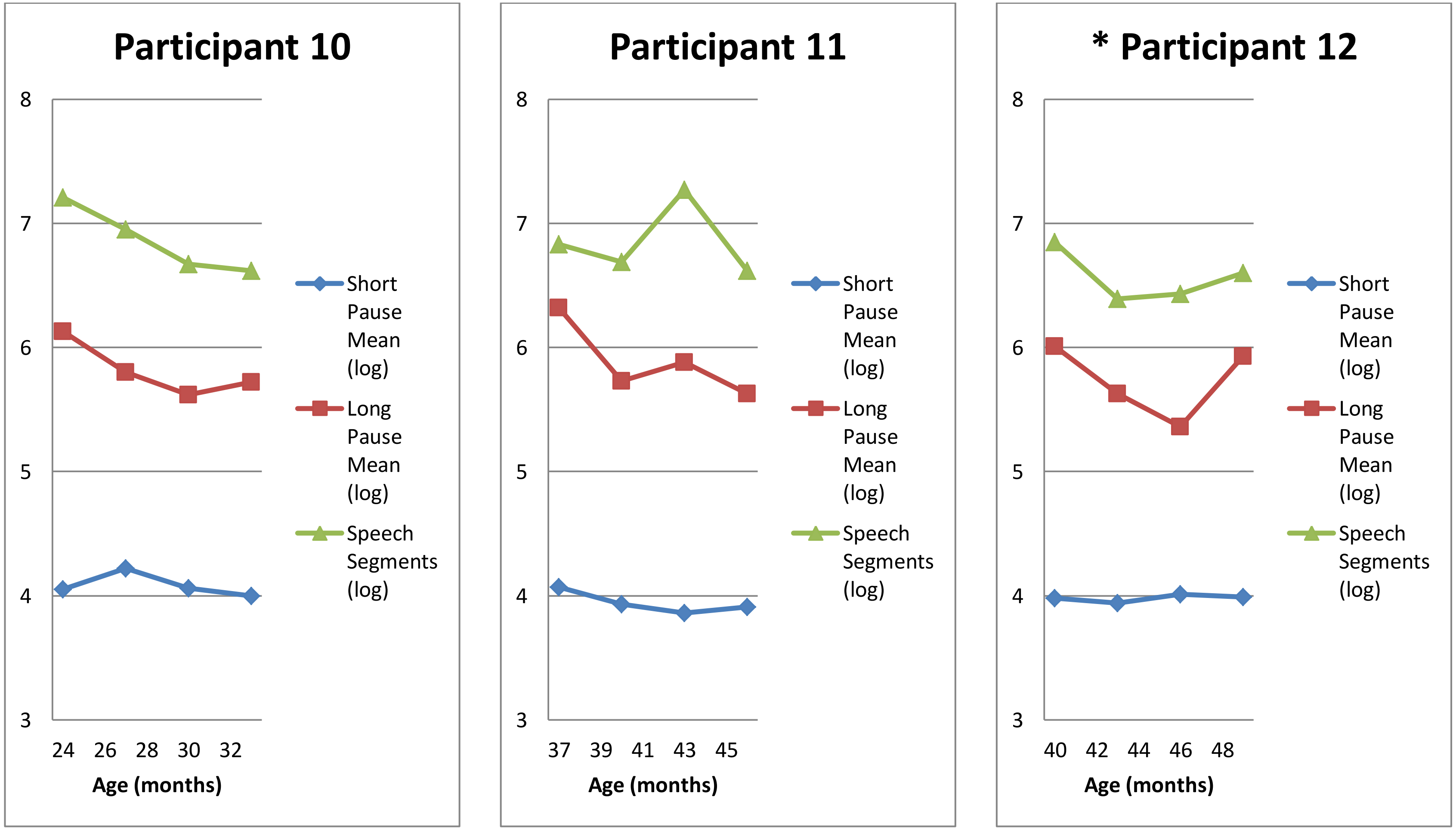

Participant 5
8
7
6
5
4
3
24 26 28 30 32
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

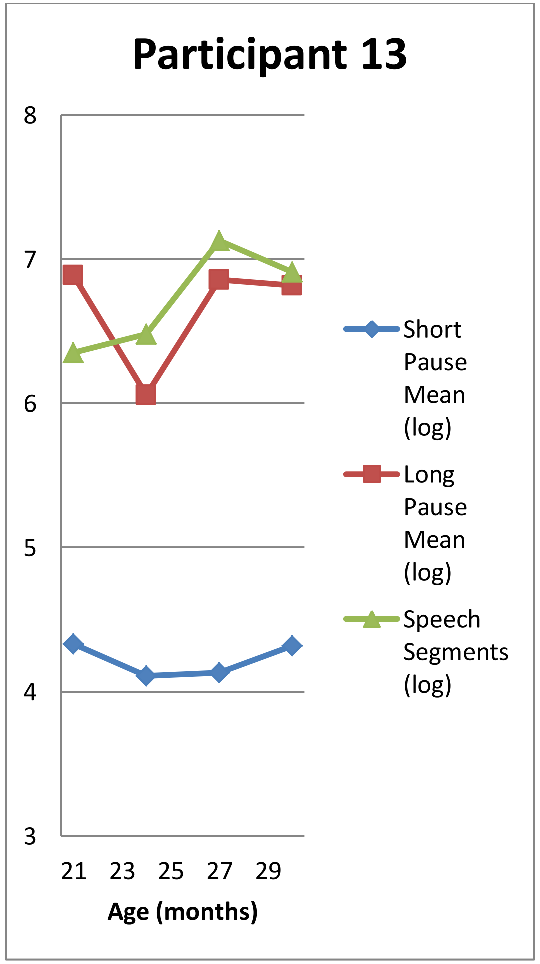

Participant 6
8
7
6
5
4
3
20 22 24 26 28
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

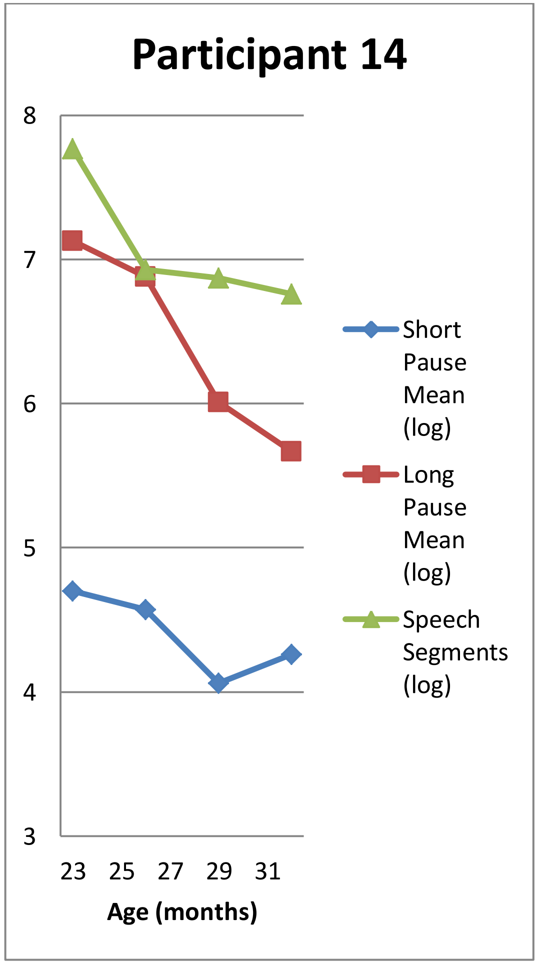

* Participant 7
8
7
6
5
4
3
42 44 46 48 50 52
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

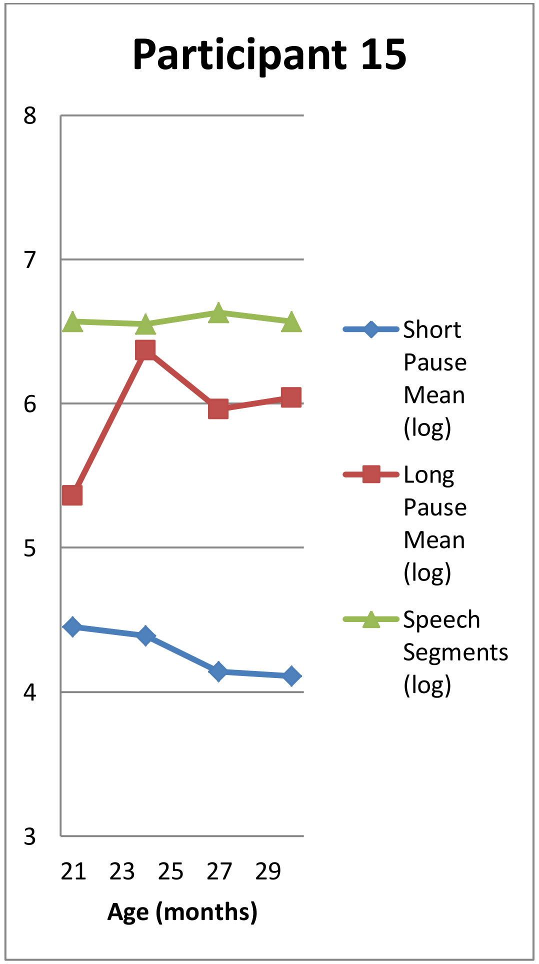

Participant 8
8
7
6
5
4
3
23 25 27 29 31
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

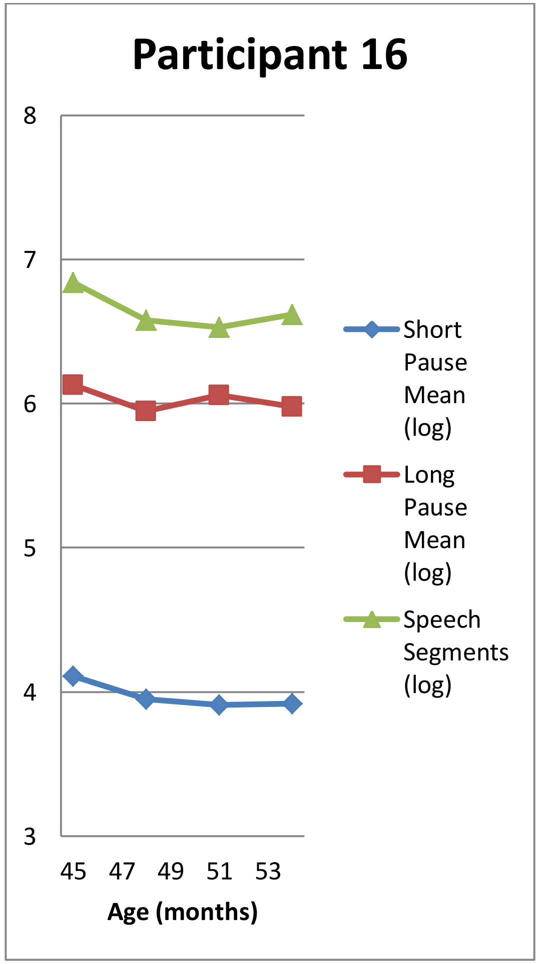

* Participant 9
8
7
6
5
4
3
27 29 31 33 35 37
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

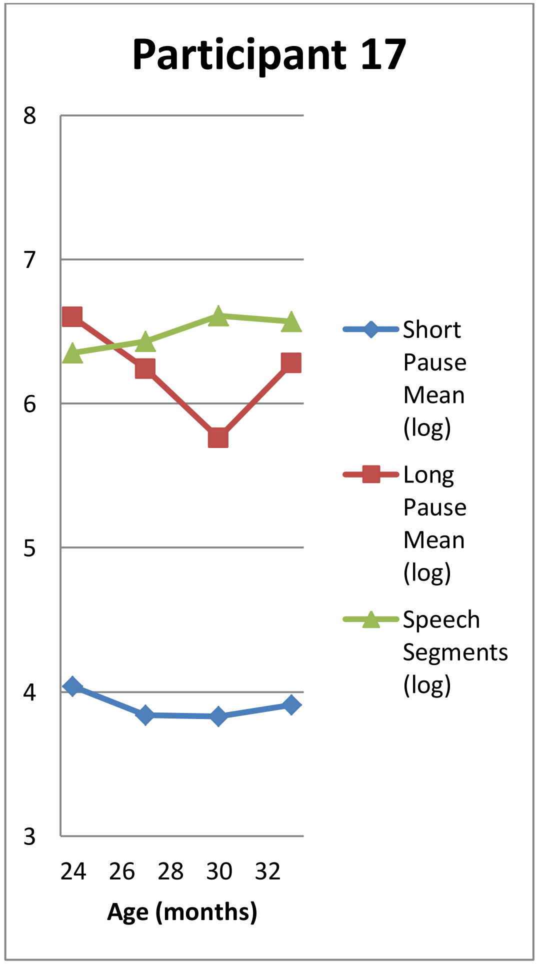

Participant 10
8
7
6
5
4
3
24 26 28 30 32
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)
Participant 11
8
7
6
5
4
3
37 39 41 43 45
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)
* Participant 12
8
7
6
5
4
3
40 42 44 46 48
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

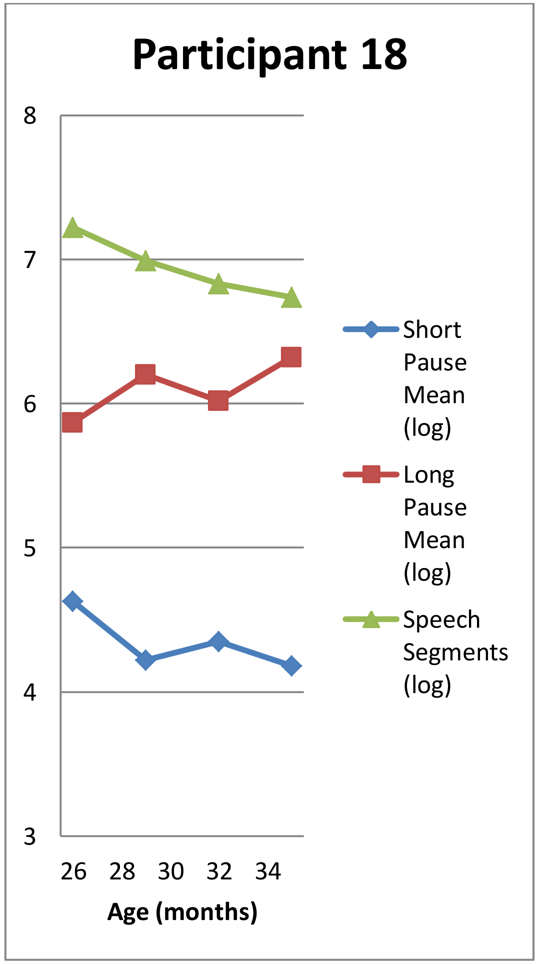

Participant 13
8
7
6
5
4
3
21
23
25
27
29
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)


Participant 14
8
7
6
5
4
3
23
25
27
29
31
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)


Participant 15
8
7
6
5
4
3
21
23
25
27
29
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

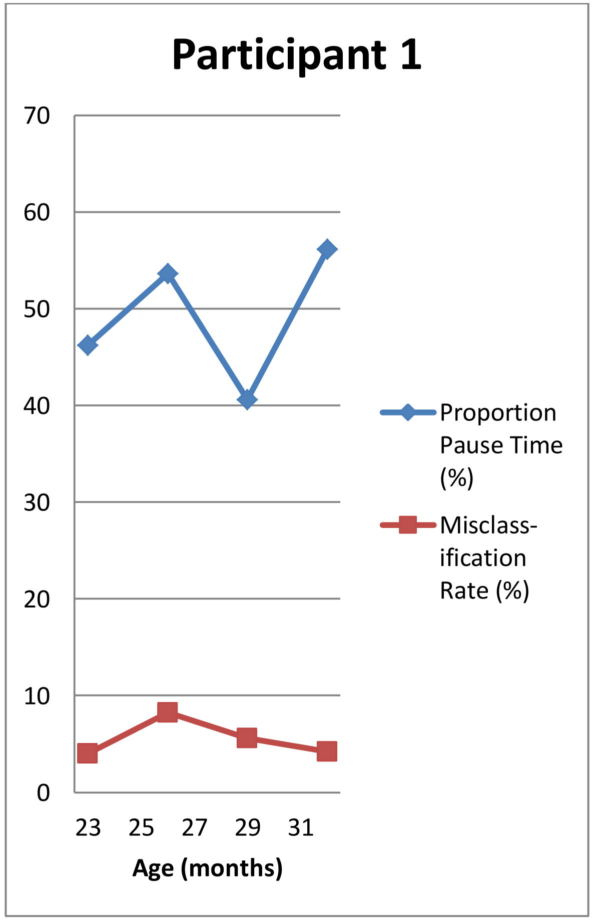

Participant 16
8
7
6
5
4
3
45 47 49 51 53
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

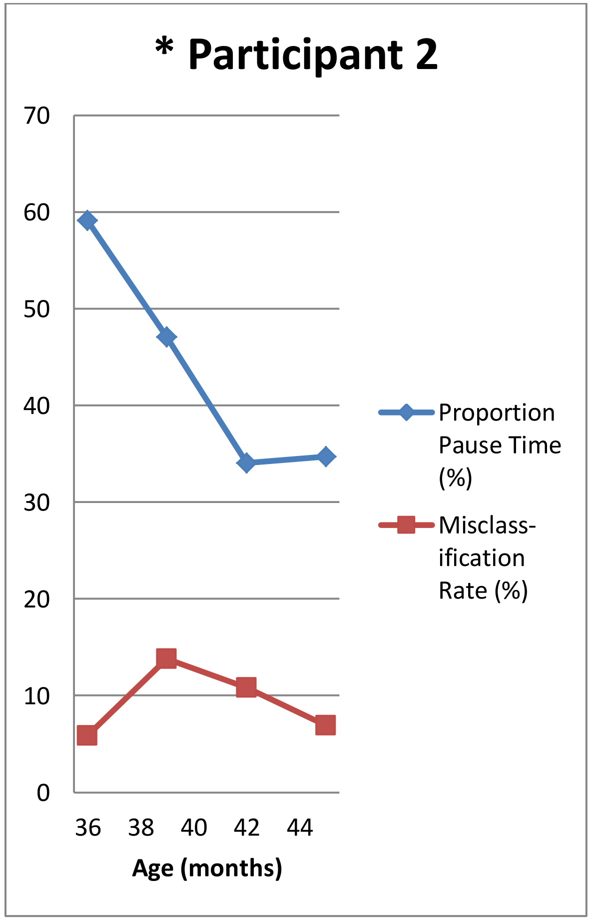

Participant 17
8
7
6
5
4
3
24 26 28 30 32
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

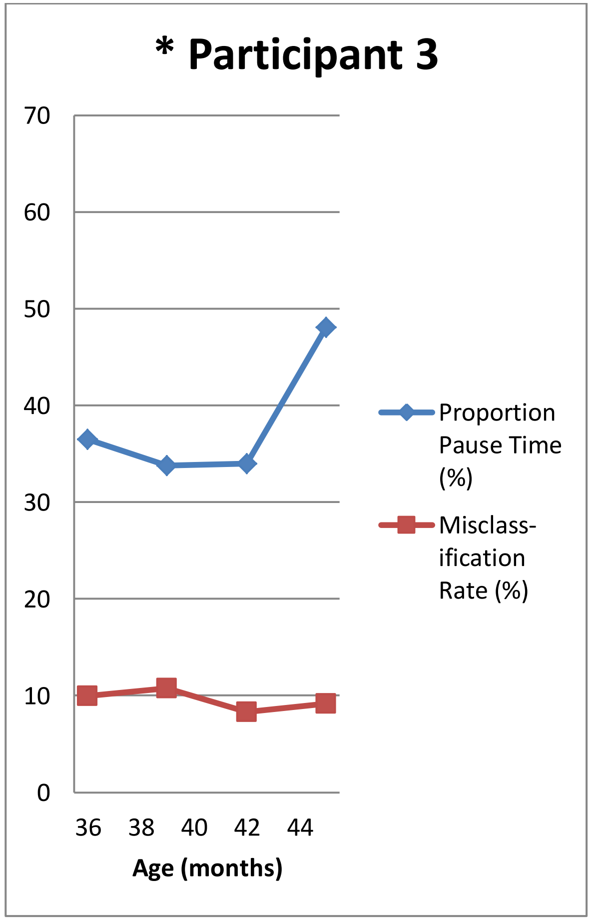

Participant 18
8
7
6
5
4
3
26 28 30 32 34
Age (months)
Short Pause Mean (log)
Long Pause Mean (log)
Speech Segments (log)

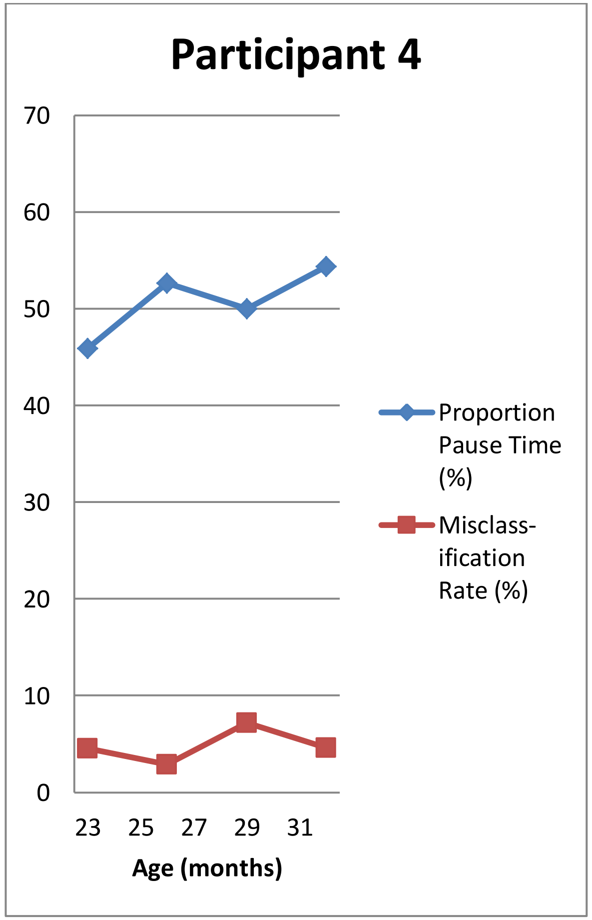
Appendix E: Study 1 Plots per Child across Four Sessions for Proportion of Pause Time and Misclassification Rate

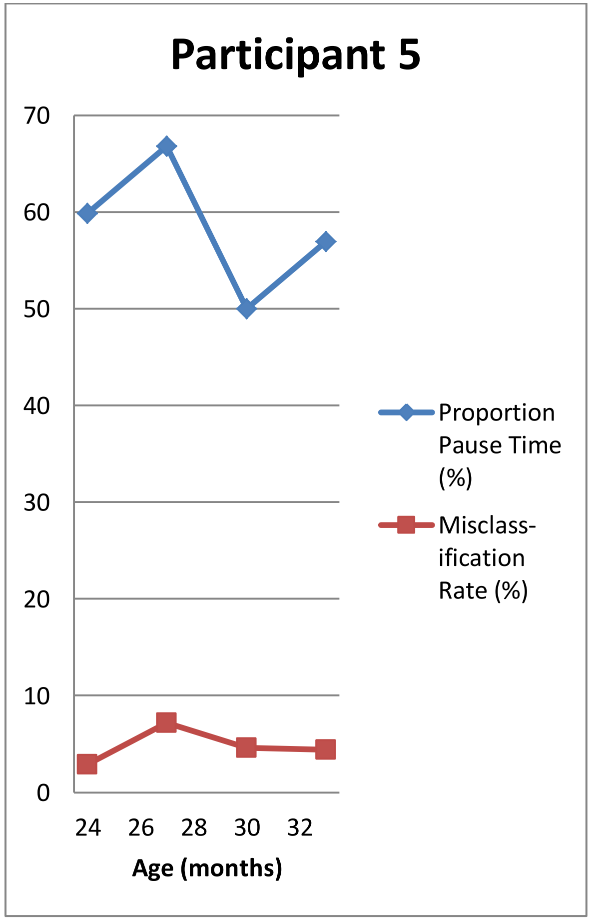
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

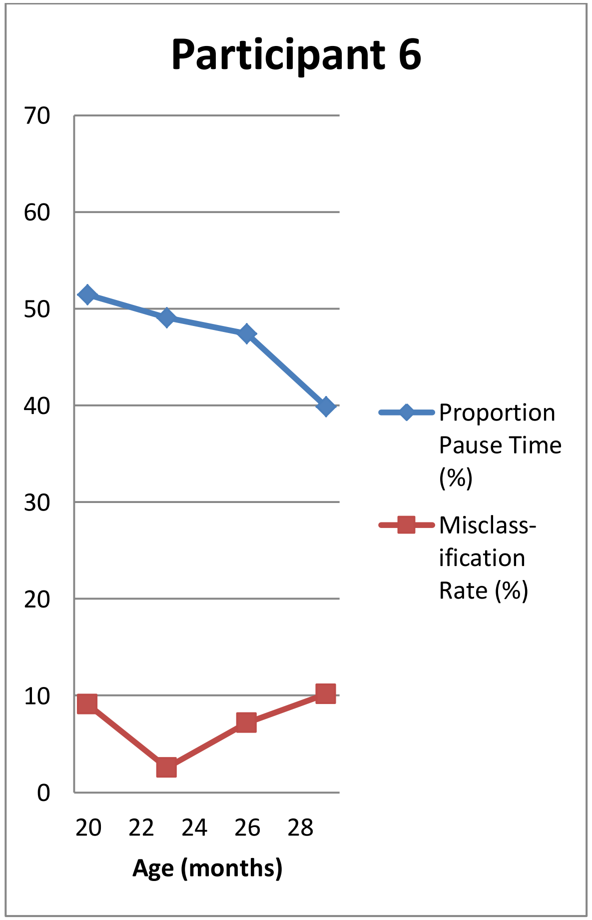

Participant 1
70
60
50
40
30
20
10
0
23 25 27 29 31
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

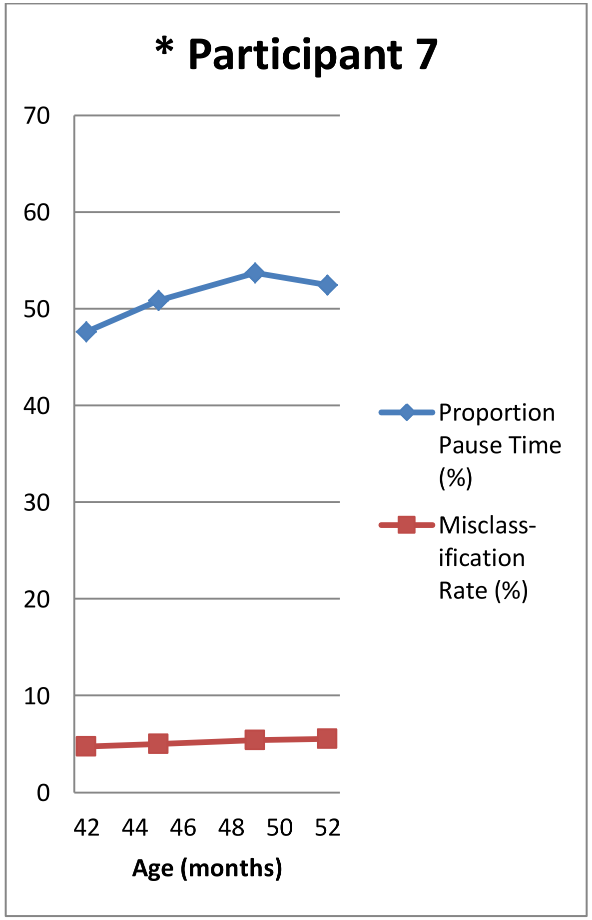

* Participant 2
70
60
50
40
30
20
10
0
36 38 40 42 44
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

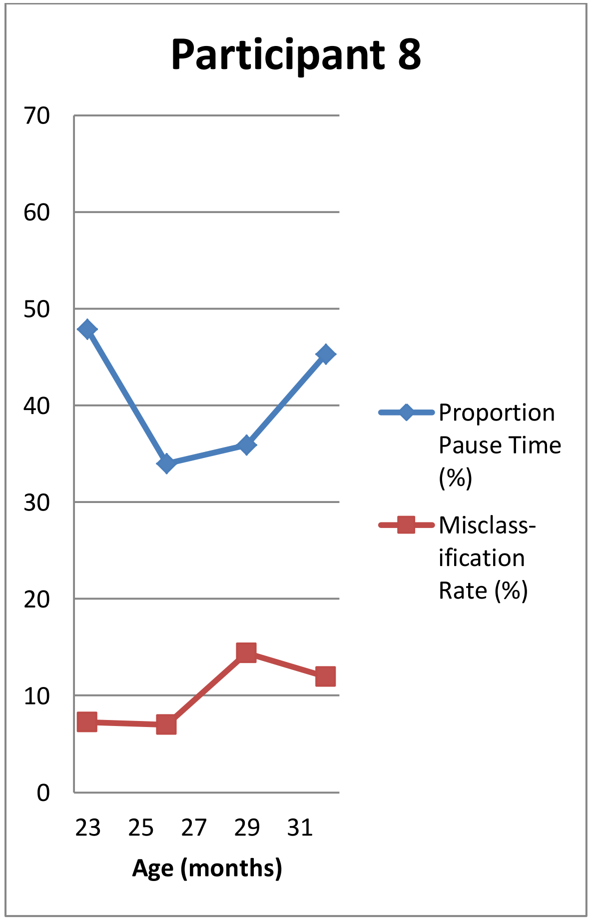

* Participant 3
70
60
50
40
30
20
10
0
36 38 40 42 44
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

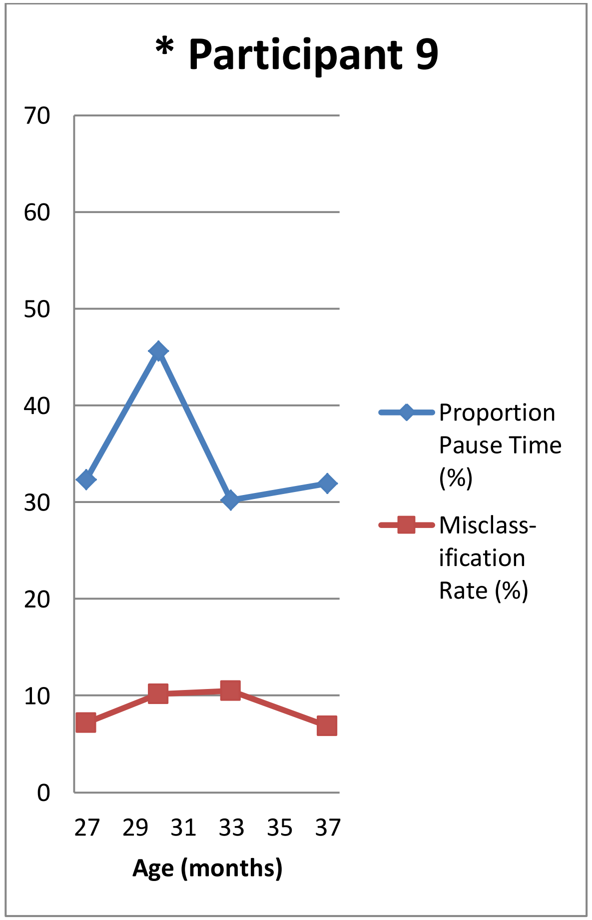

Participant 4
70
60
50
40
30
20
10
0
23 25 27 29 31
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

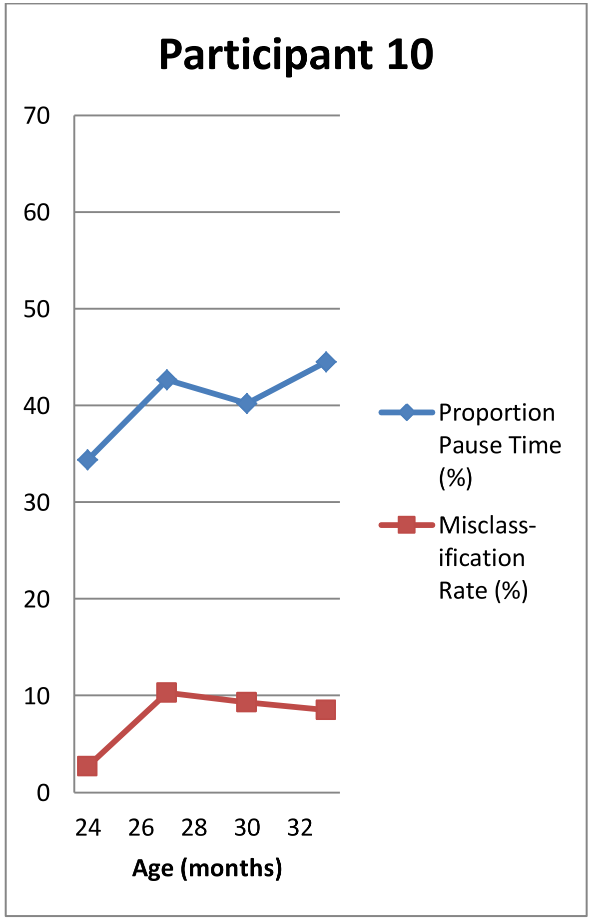

Participant 5
70
60
50
40
30
20
10
0
24 26 28 30 32
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

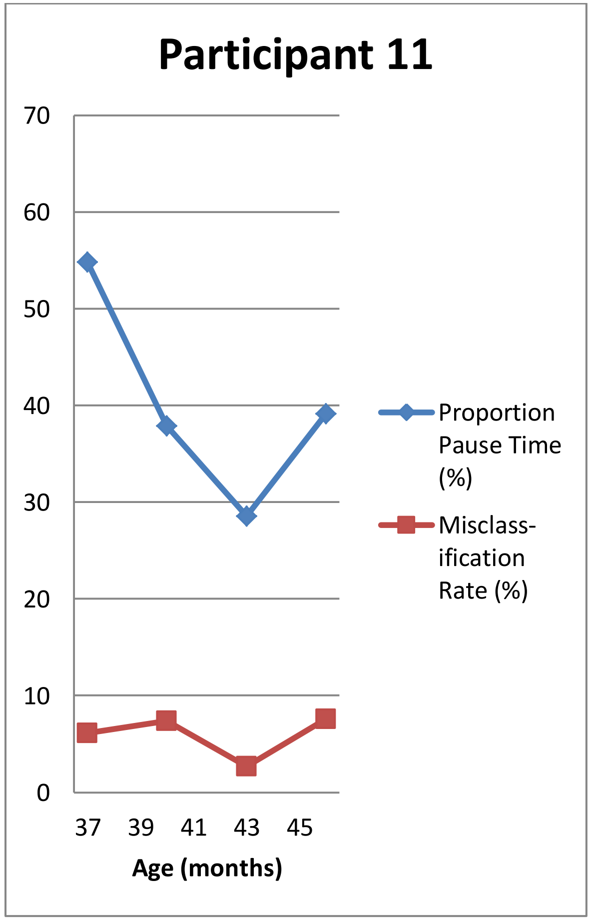

Participant 6
70
60
50
40
30
20
10
0
20 22 24 26 28
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

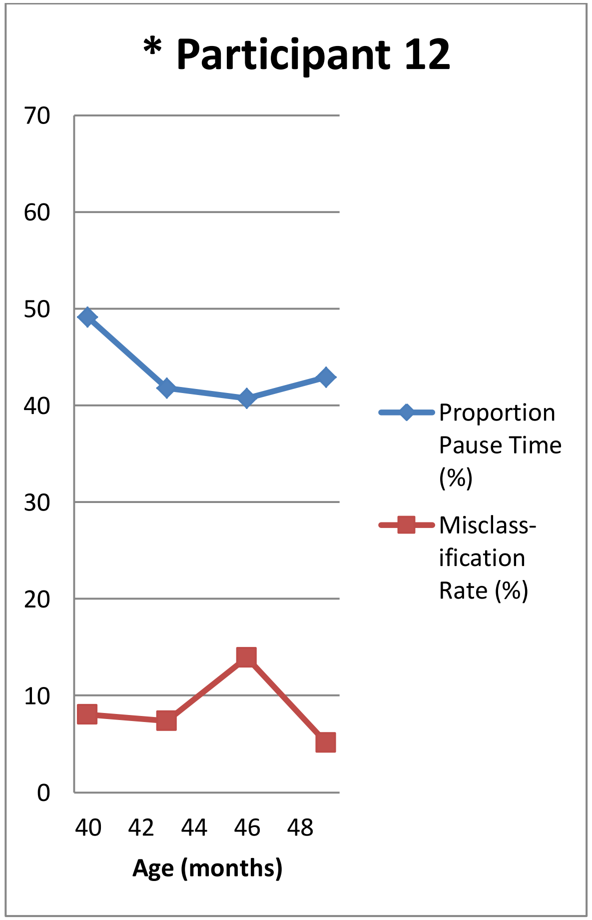

* Participant 7
70
60
50
40
30
20
10
0
42 44 46 48 50 52
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

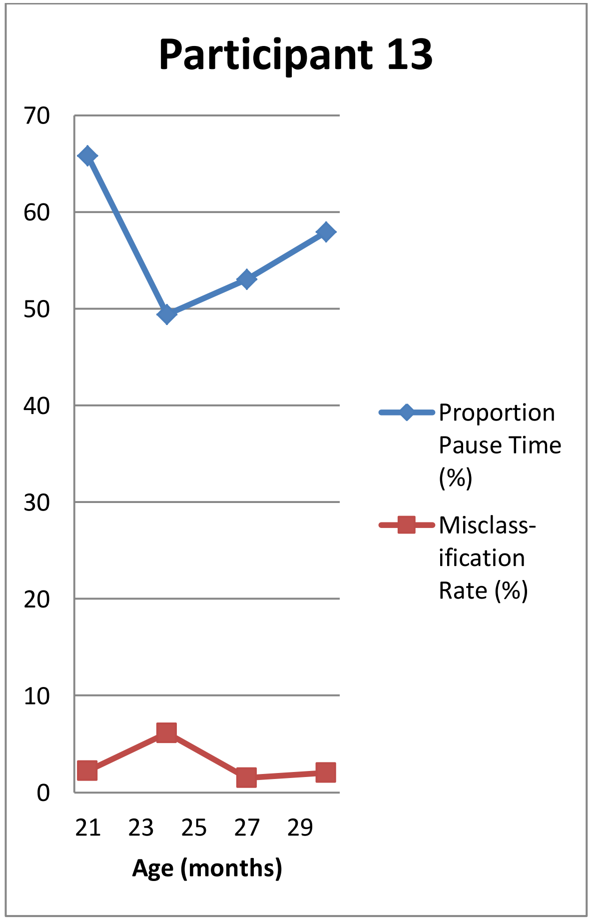

Participant 8
70
60
50
40
30
20
10
0
23 25 27 29 31
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

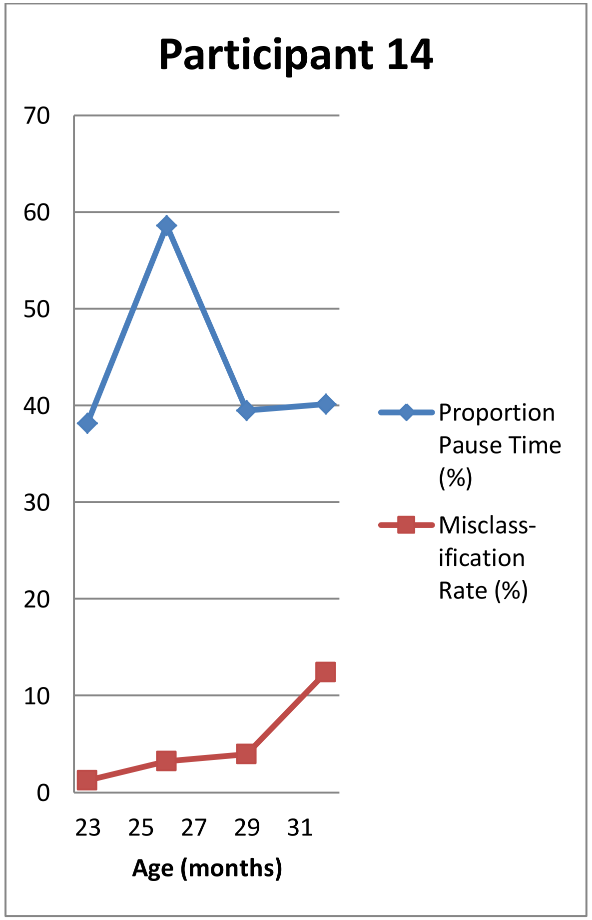

* Participant 9
70
60
50
40
30
20
10
0
27 29 31 33 35 37
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

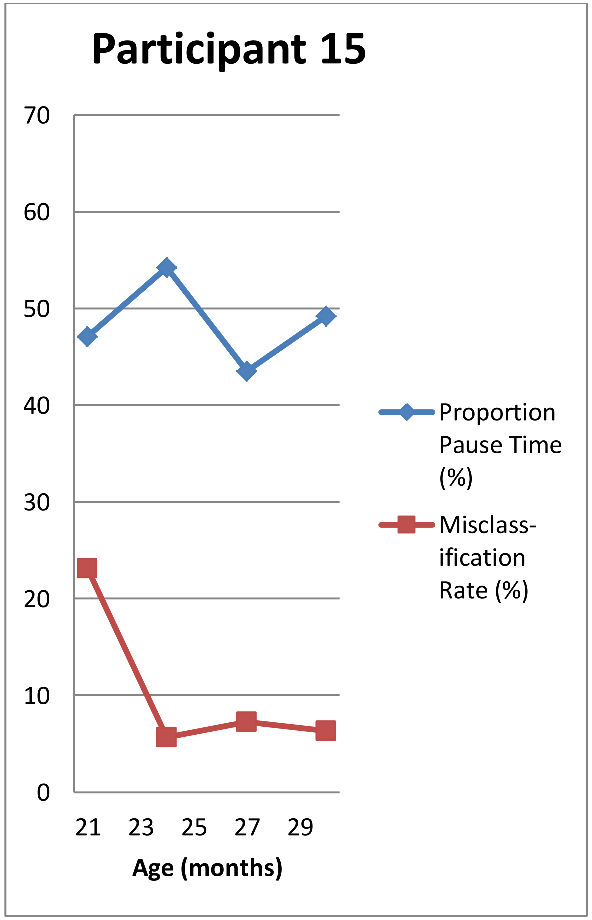

Participant 10
70
60
50
40
30
20
10
0
24 26 28 30 32
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

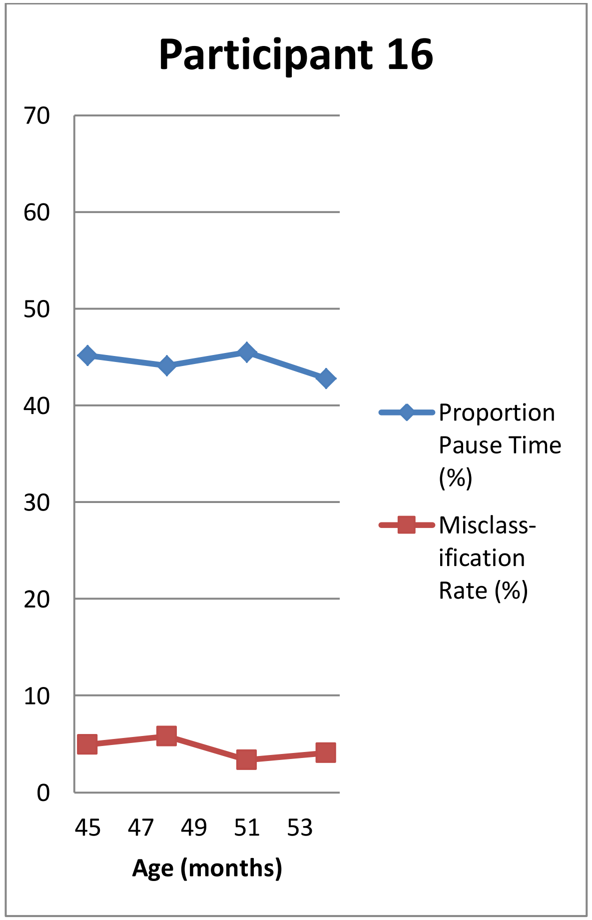

Participant 11
70
60
50
40
30
20
10
0
37 39 41 43 45
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

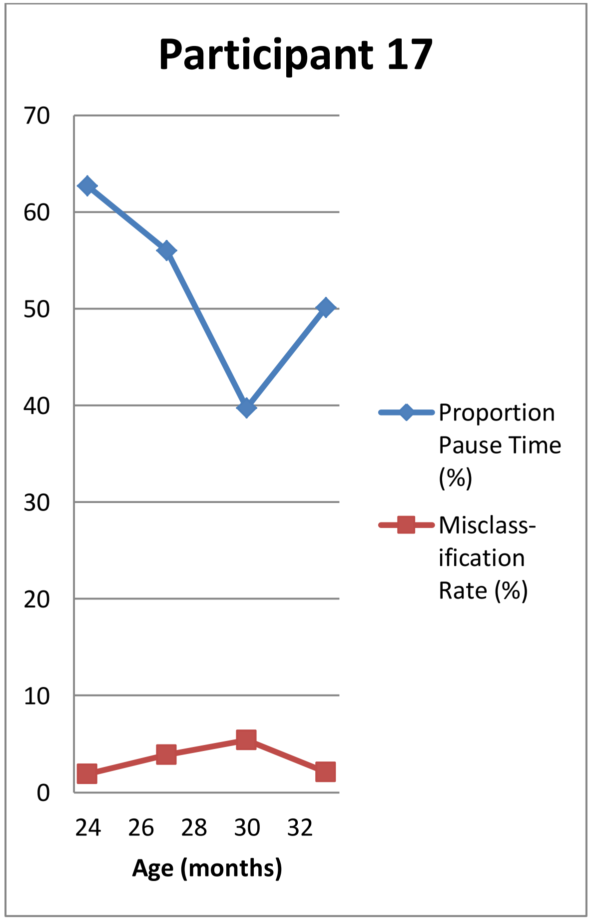

* Participant 12
70
60
50
40
30
20
10
0
40 42 44 46 48
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

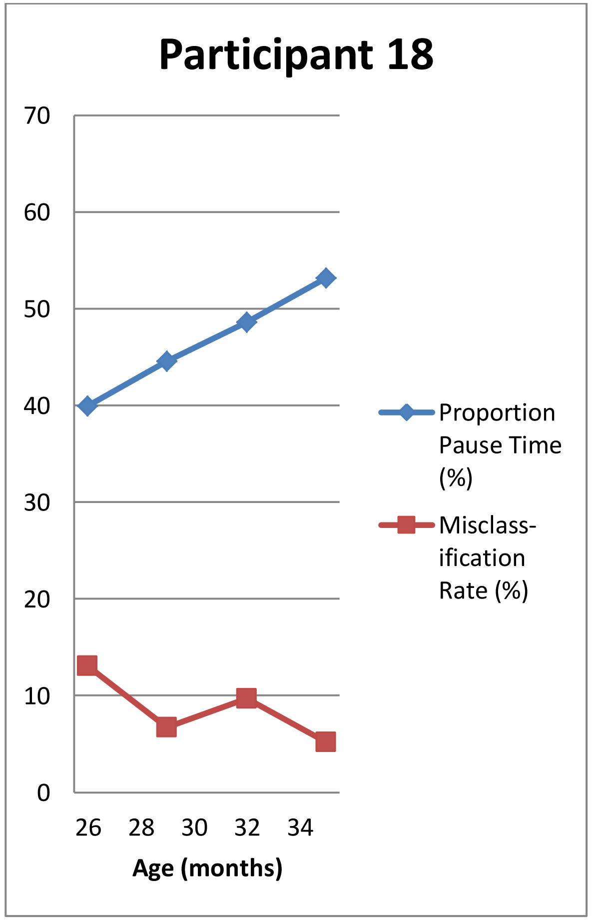

Participant 13
70
60
50
40
30
20
10
0
21 23 25 27 29
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)


Participant 14
70
60
50
40
30
20
10
0
23 25 27 29 31
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)


Participant 15
70
60
50
40
30
20
10
0
21 23 25 27 29
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

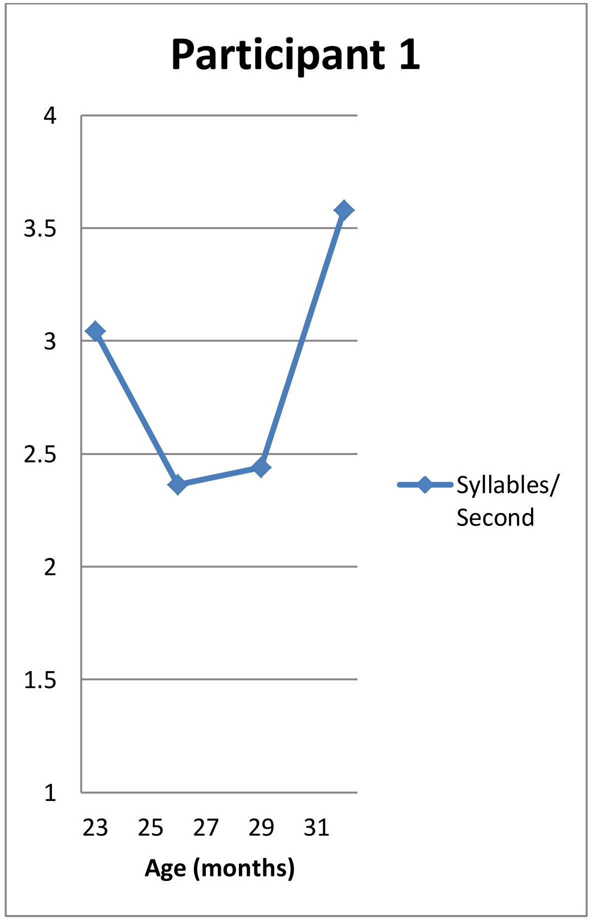

Participant 16
70
60
50
40
30
20
10
0
45 47 49 51 53
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

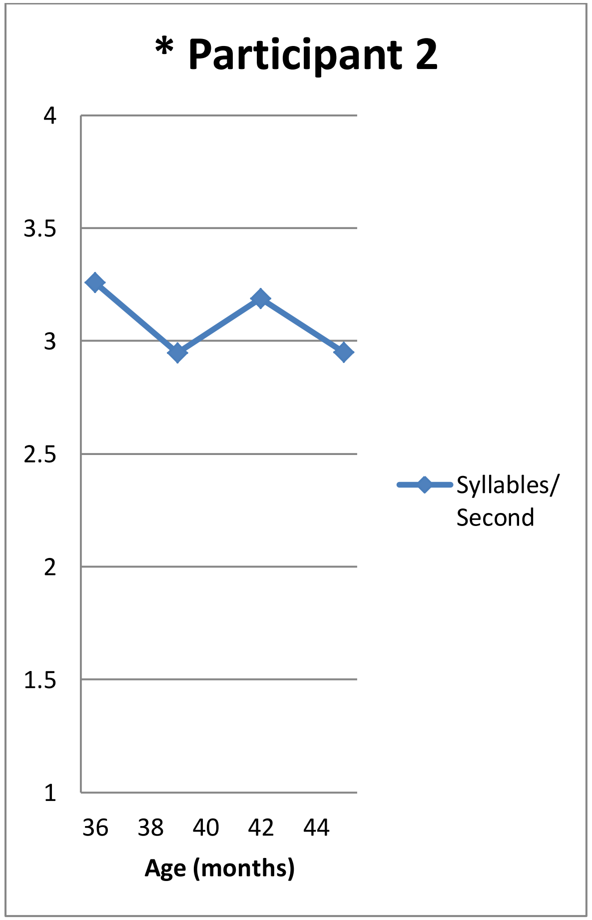

Participant 17
70
60
50
40
30
20
10
0
24 26 28 30 32
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

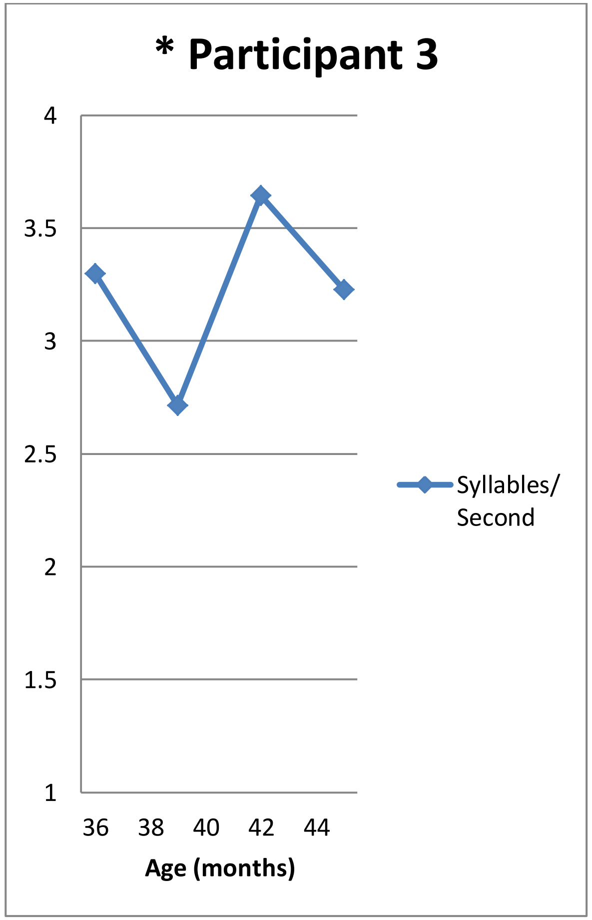

Participant 18
70
60
50
40
30
20
10
0
26 28 30 32 34
Age (months)
Proportion Pause Time (%)
Misclass-ification Rate (%)

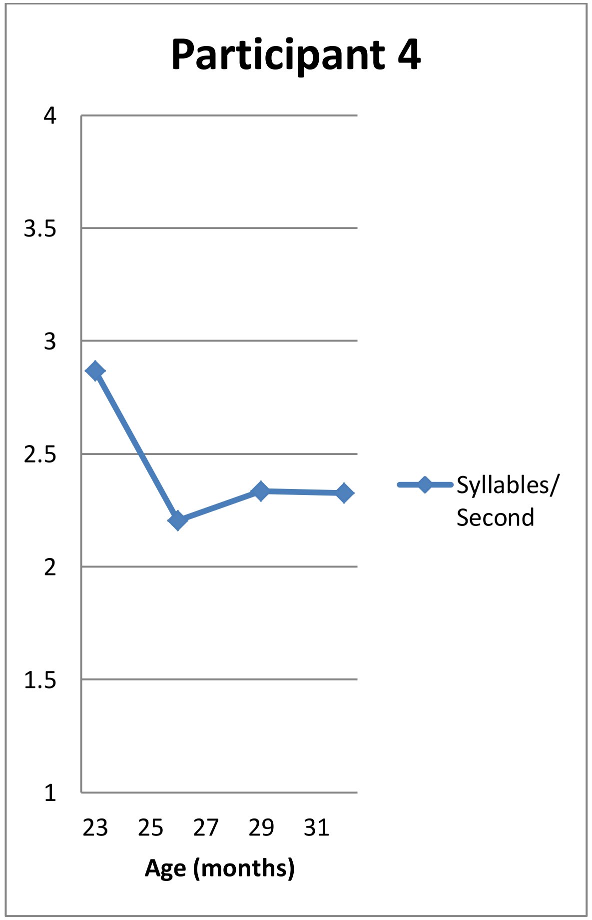
Appendix F: Study 1 Plots per Child across Four Sessions for Syllables Spoken Per Second

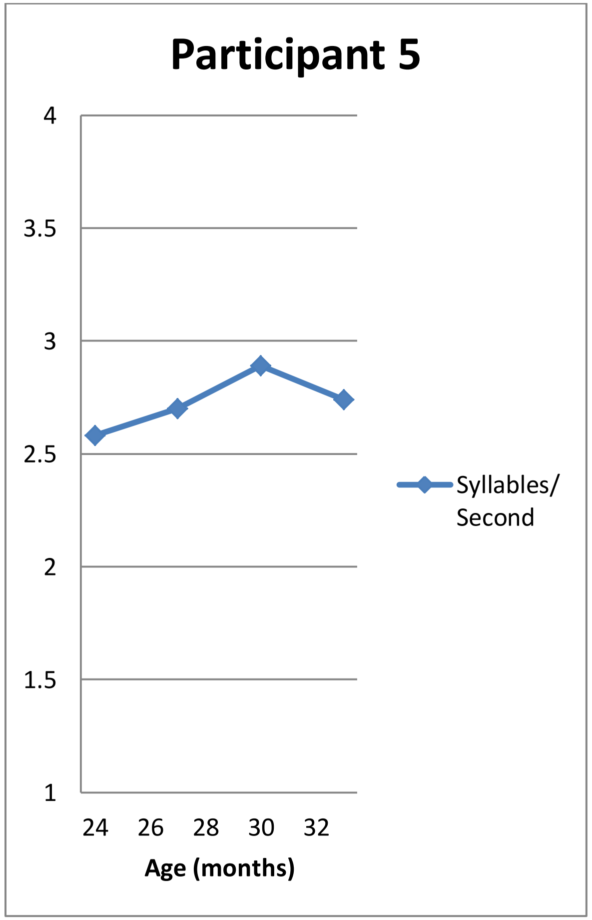
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

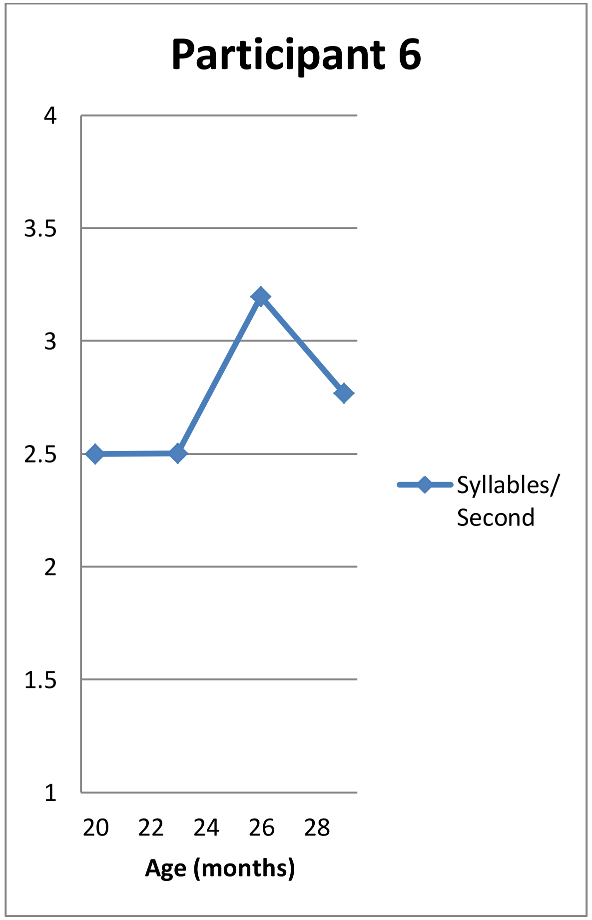

Participant 1
4
3.5
3
2.5
2
1.5
1
23 25 27 29 31
Age (months)
Syllables/
Second

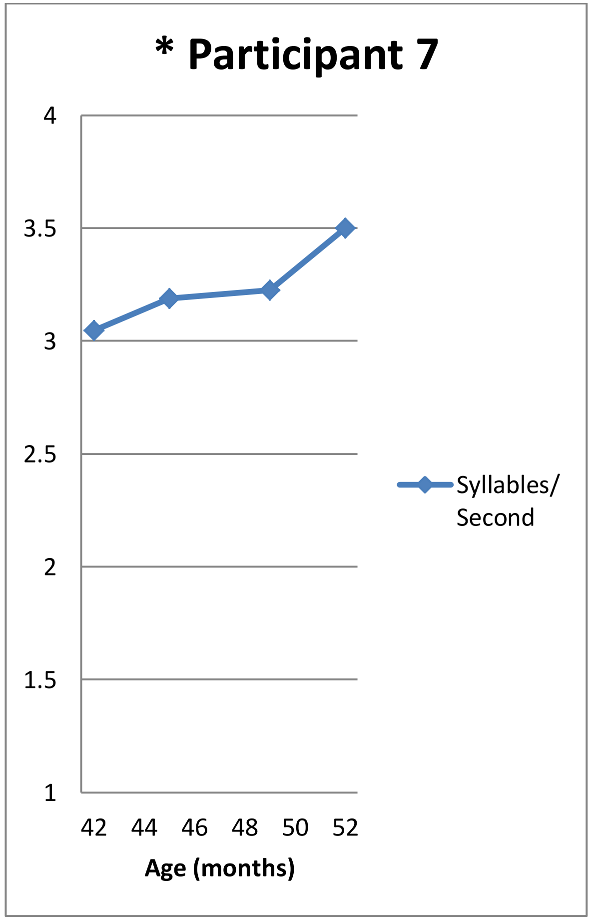

* Participant 2
4
3.5
3
2.5
2
1.5
1
36 38 40 42 44
Age (months)
Syllables/
Second

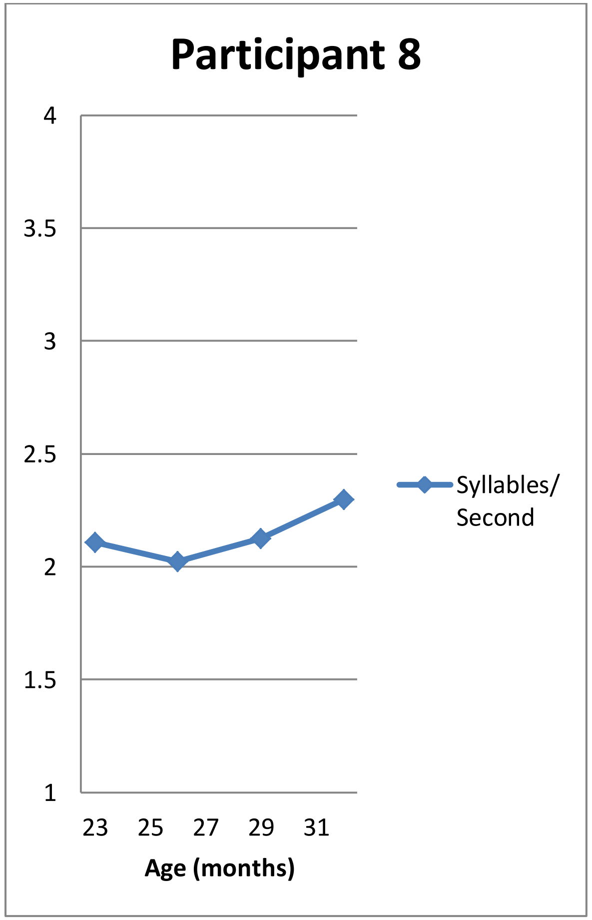

* Participant 3
4
3.5
3
2.5
2
1.5
1
36 38 40 42 44
Age (months)
Syllables/
Second

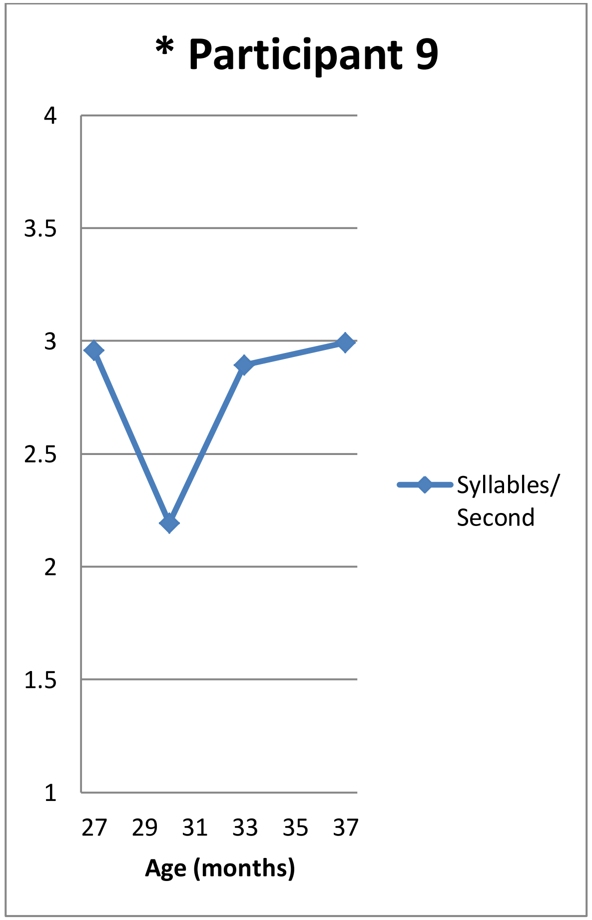

Participant 4
4
3.5
3
2.5
2
1.5
1
23
25
27
29
31
Age (months)
Syllables/ Second

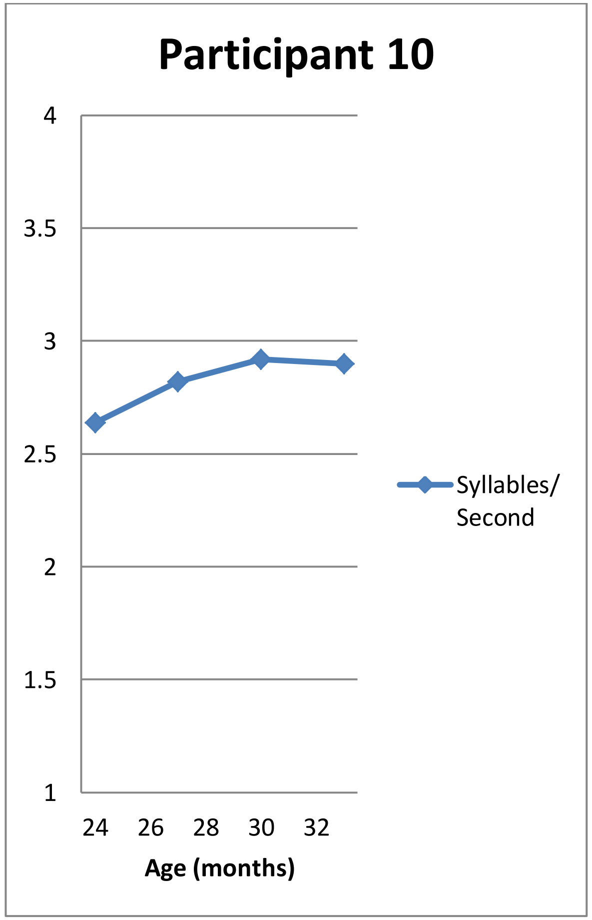

Participant 5
4
3.5
3
2.5
2
1.5
1
24
26
28
30
32
Age (months)
Syllables/ Second

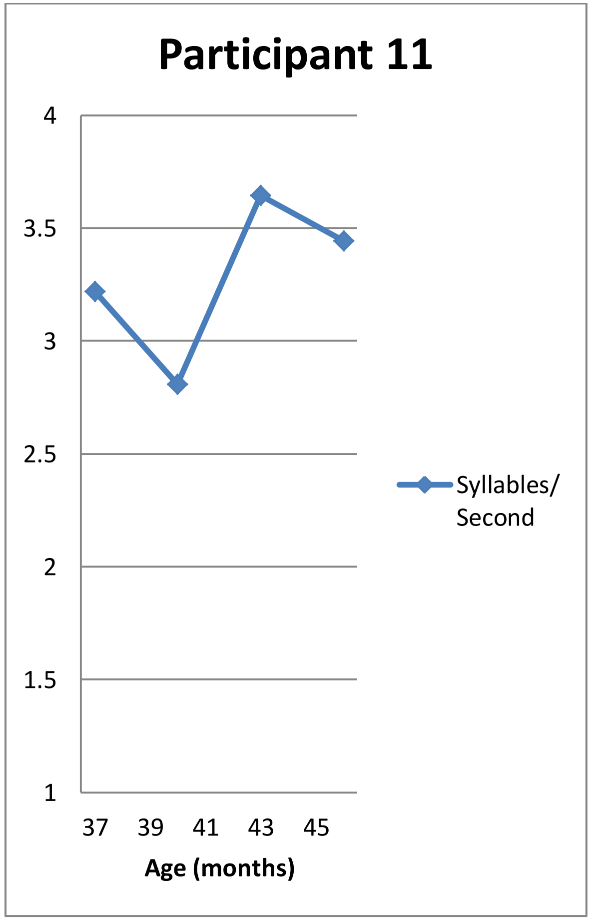

Participant 6
4
3.5
3
2.5
2
1.5
1
20
22
24
26
28
Age (months)
Syllables/ Second

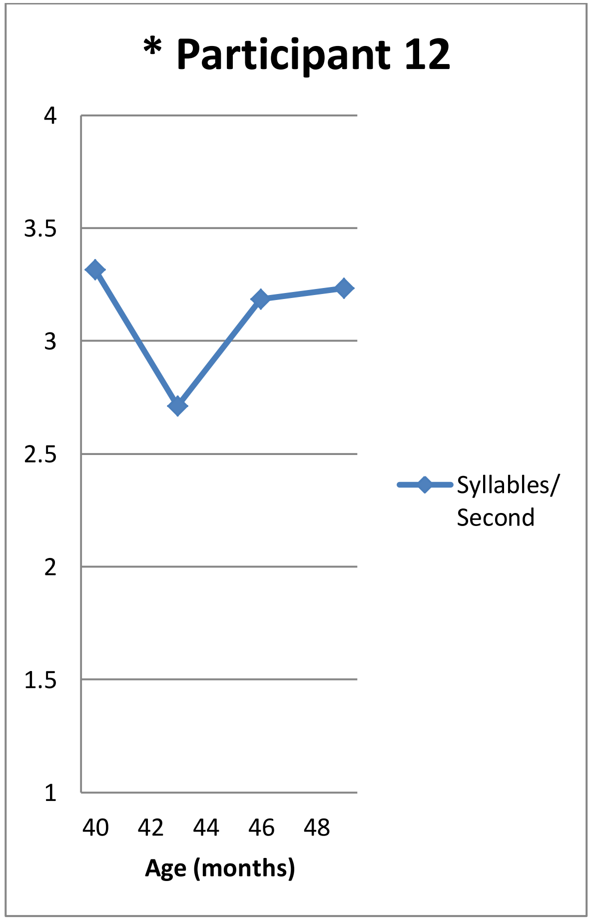

* Participant 7
4
3.5
3
2.5
2
1.5
1
42 44 46 48 50 52
Age (months)
Syllables/ Second

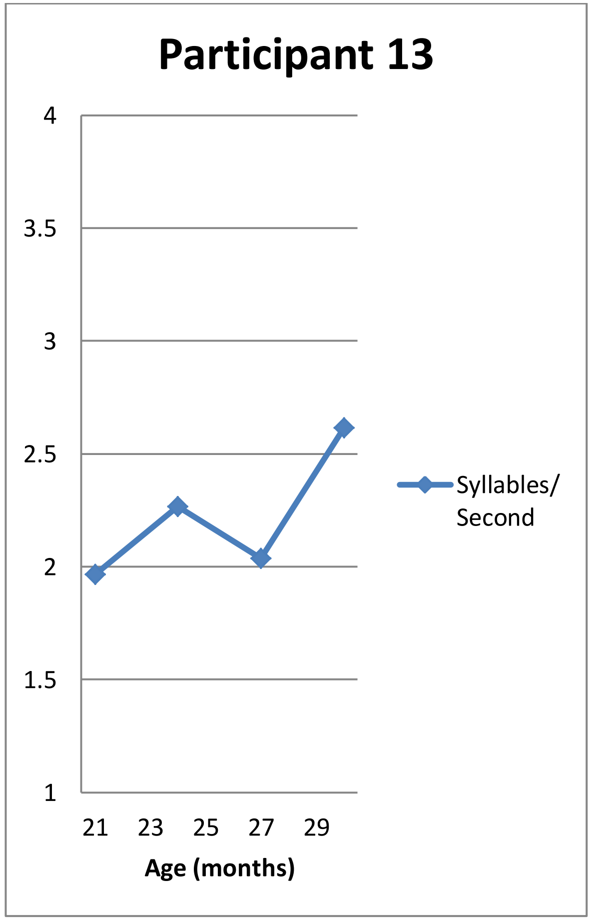

Participant 8
4
3.5
3
2.5
2
1.5
1
23 25 27 29 31
Age (months)
Syllables/ Second

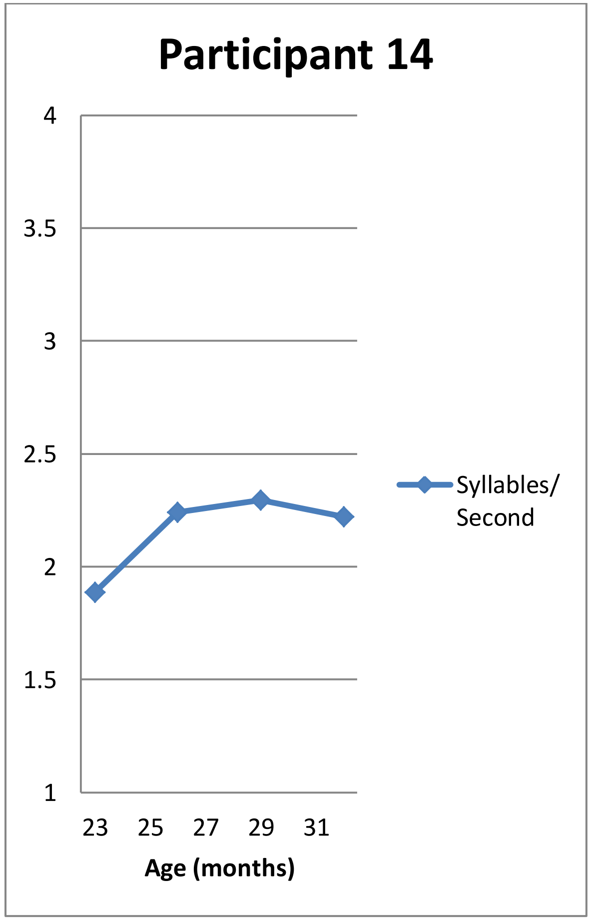

* Participant 9
4
3.5
3
2.5
2
1.5
1
27 29 31 33 35 37
Age (months)
Syllables/ Second

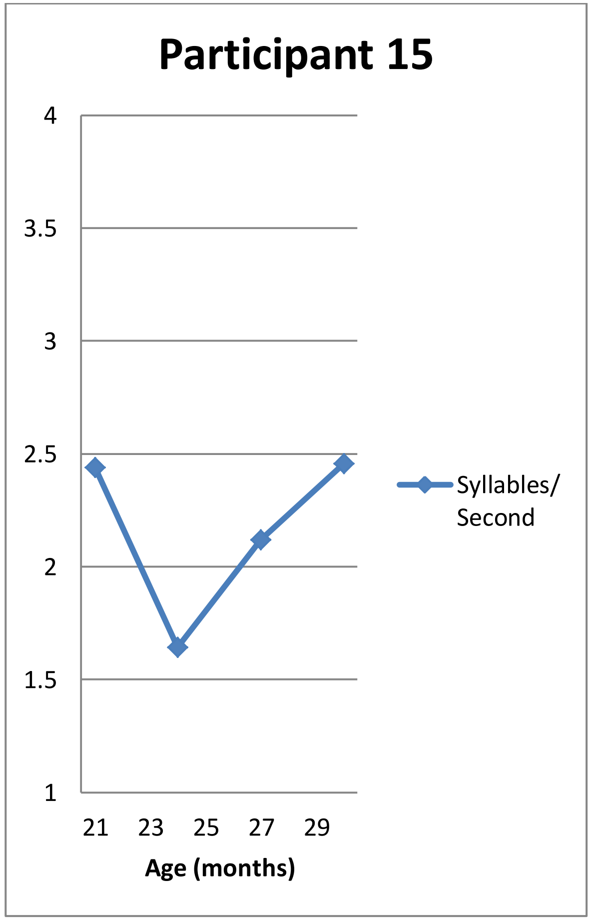

Participant 10
4
3.5
3
2.5
2
1.5
1
24
26
28
30
32
Age (months)
Syllables/
Second

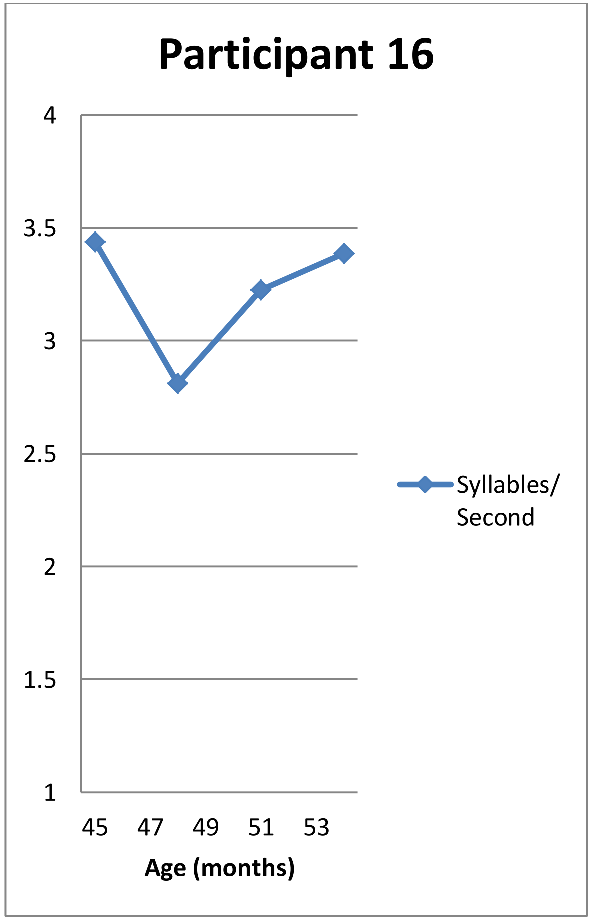

Participant 11
4
3.5
3
2.5
2
1.5
1
37
39
41
43
45
Age (months)
Syllables/
Second

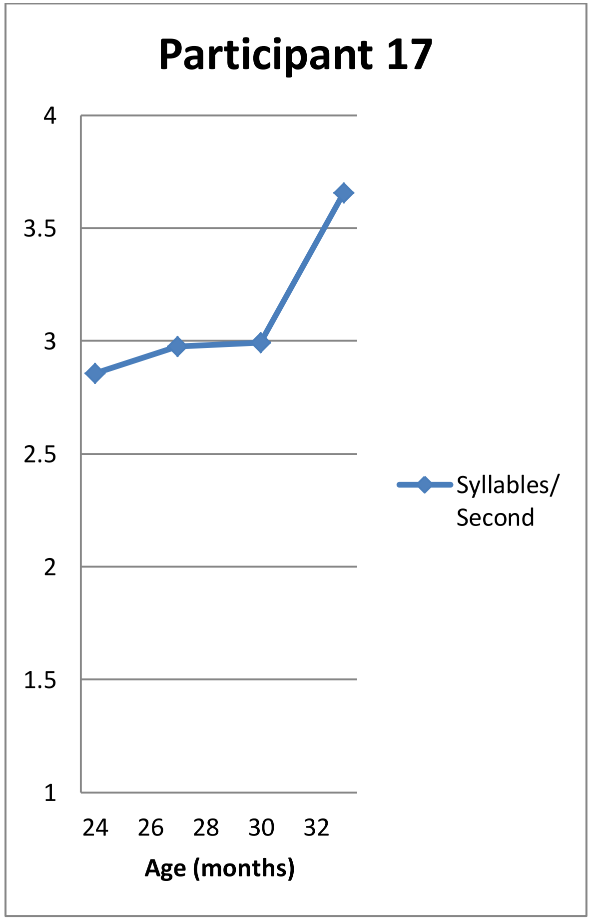

* Participant 12
4
3.5
3
2.5
2
1.5
1
40
42
44
46
48
Age (months)
Syllables/
Second

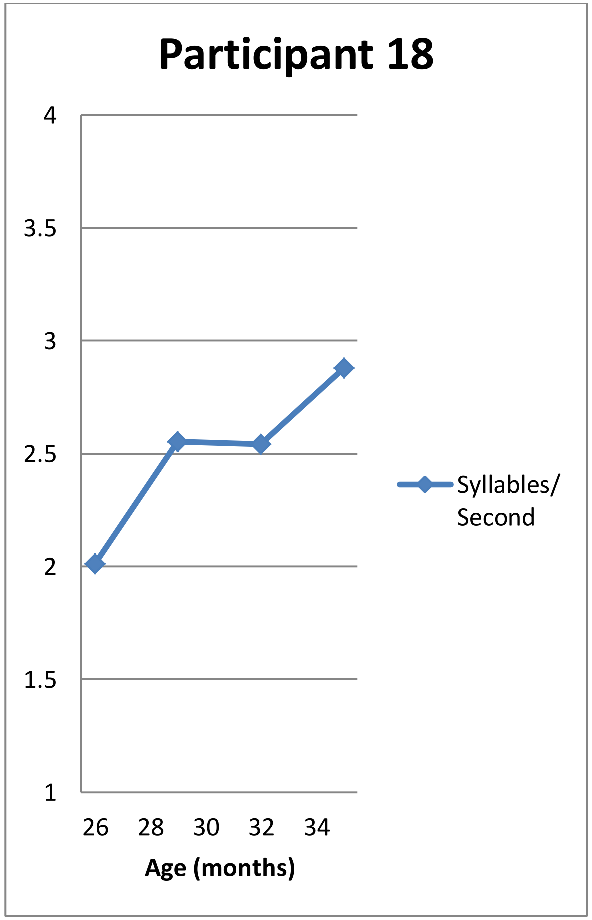

Participant 13
4
3.5
3
2.5
2
1.5
1
21 23 25 27 29
Age (months)
Syllables/ Second


Participant 14
4
3.5
3
2.5
2
1.5
1
23 25 27 29 31
Age (months)
Syllables/ Second


Participant 15
4
3.5
3
2.5
2
1.5
1
21 23 25 27 29
Age (months)
Syllables/ Second

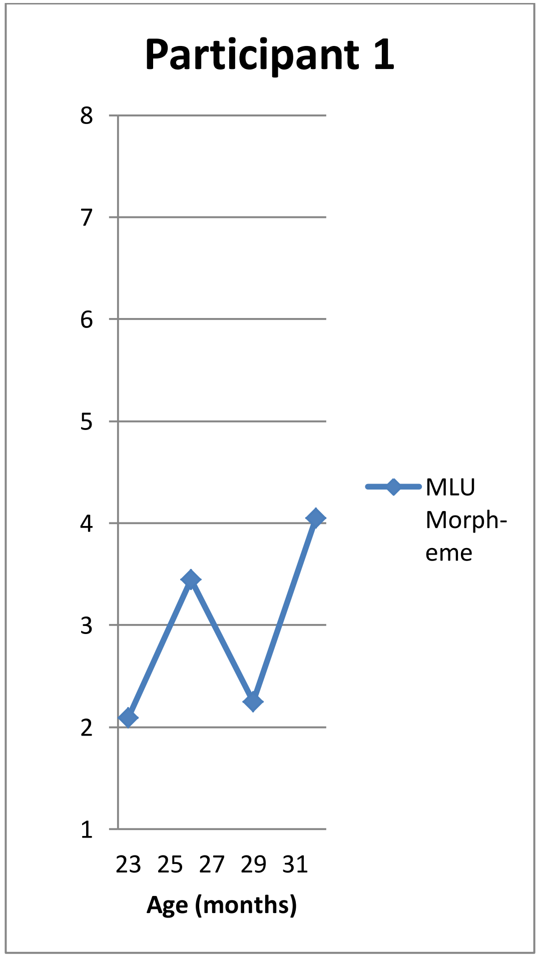

Participant 16
4
3.5
3
2.5
2
1.5
1
45 47 49 51 53
Age (months)
Syllables/ Second

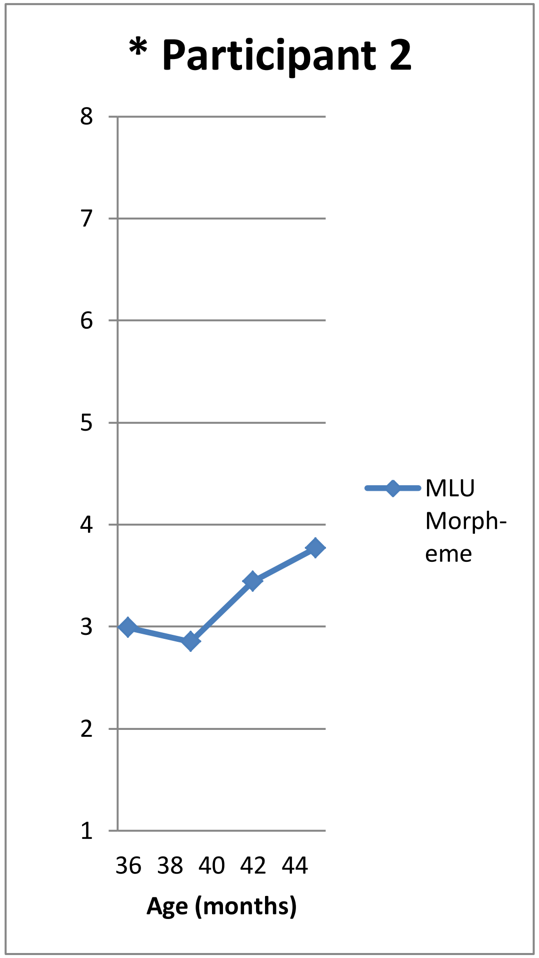

Participant 17
4
3.5
3
2.5
2
1.5
1
24 26 28 30 32
Age (months)
Syllables/ Second

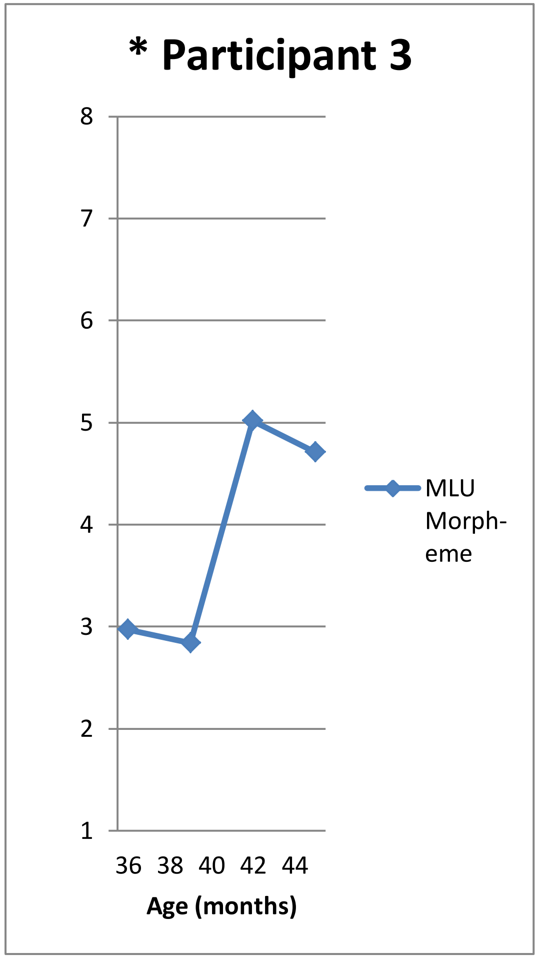

Participant 18
4
3.5
3
2.5
2
1.5
1
26 28 30 32 34
Age (months)
Syllables/ Second

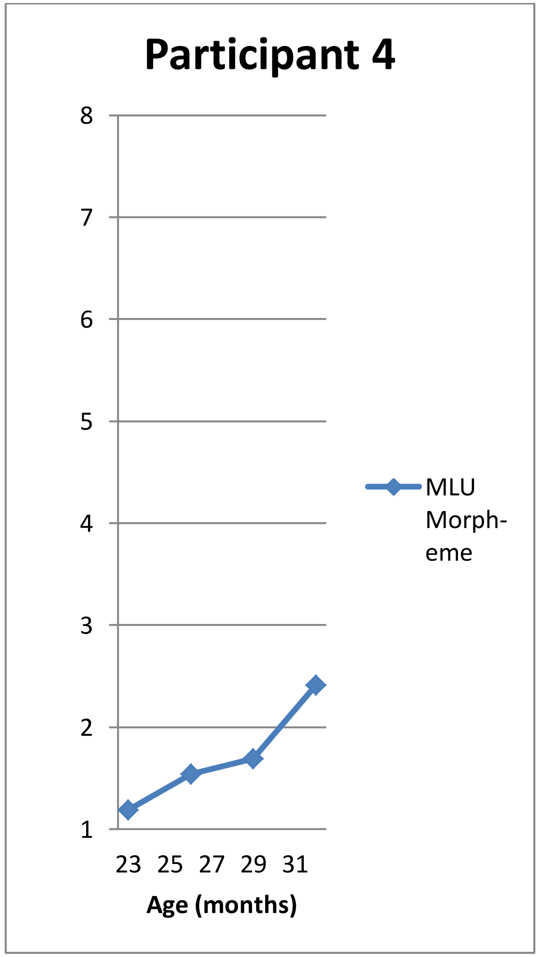
Appendix G: Study 1 Plots per Child across Four Sessions for MLU Morpheme

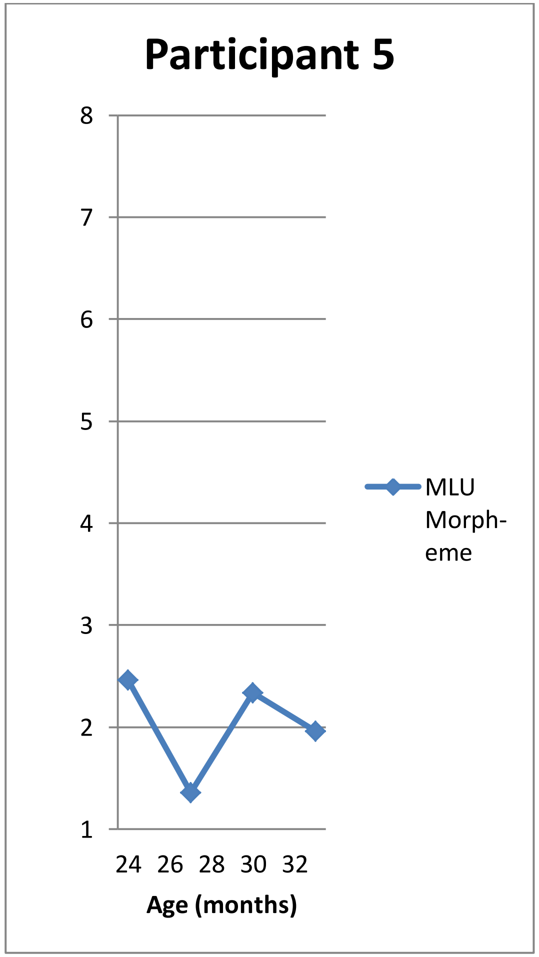
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

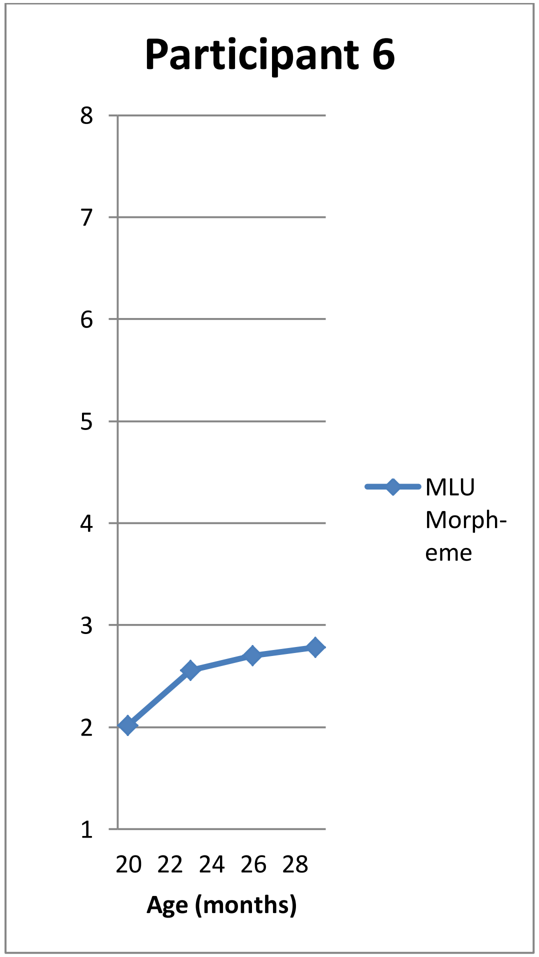

Participant 1
8
7
6
5
4
3
2
1
23 25 27 29 31
Age (months)
MLU Morph-eme

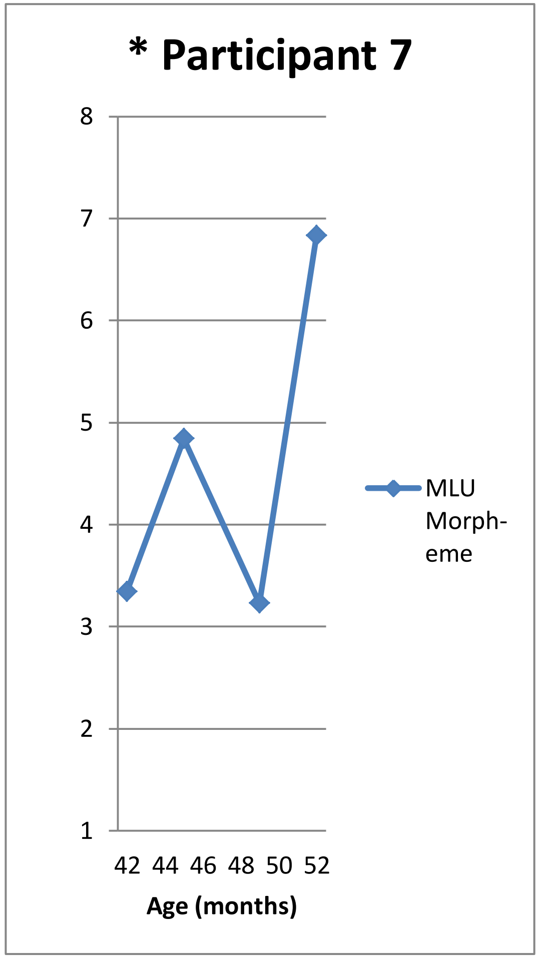

* Participant 2
8
7
6
5
4
3
2
1
36 38 40 42 44
Age (months)
MLU Morph-eme


* Participant 3
8
7
6
5
4
3
2
1
36 38 40 42 44
Age (months)
MLU Morph-eme

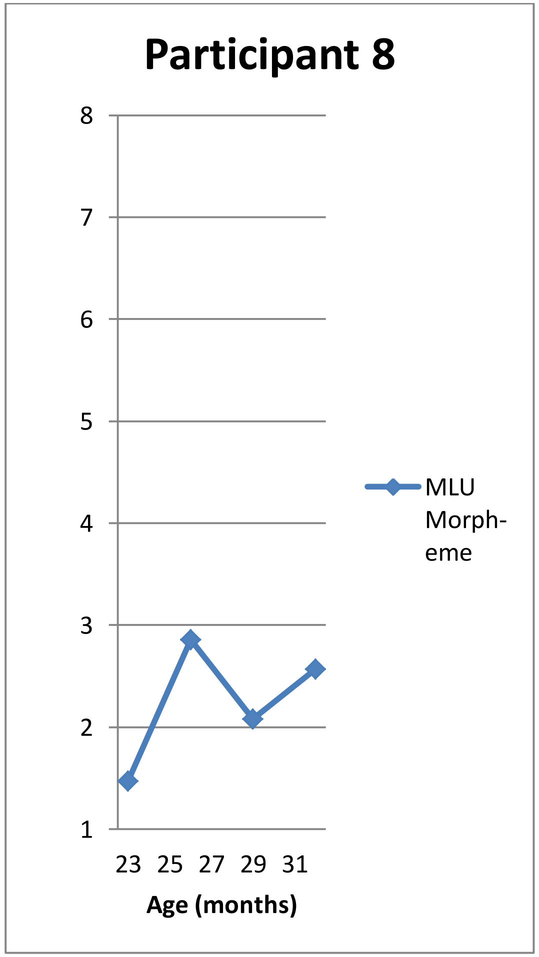

Participant 4
8
7
6
5
4
3
2
1
23 25 27 29 31
Age (months)
MLU Morph-eme


Participant 5
8
7
6
5
4
3
2
1
24 26 28 30 32
Age (months)
MLU Morph-eme

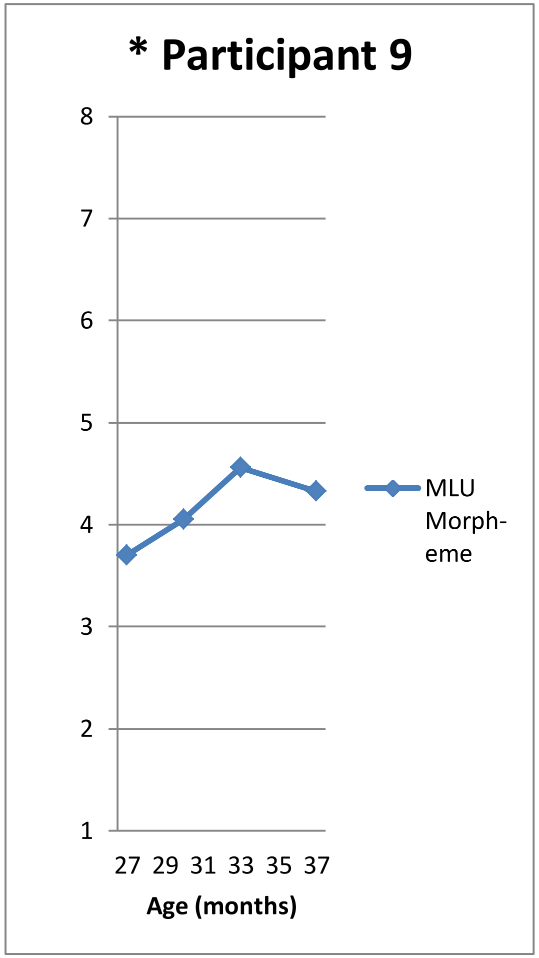

Participant 6
8
7
6
5
4
3
2
1
20 22 24 26 28
Age (months)
MLU Morph-eme



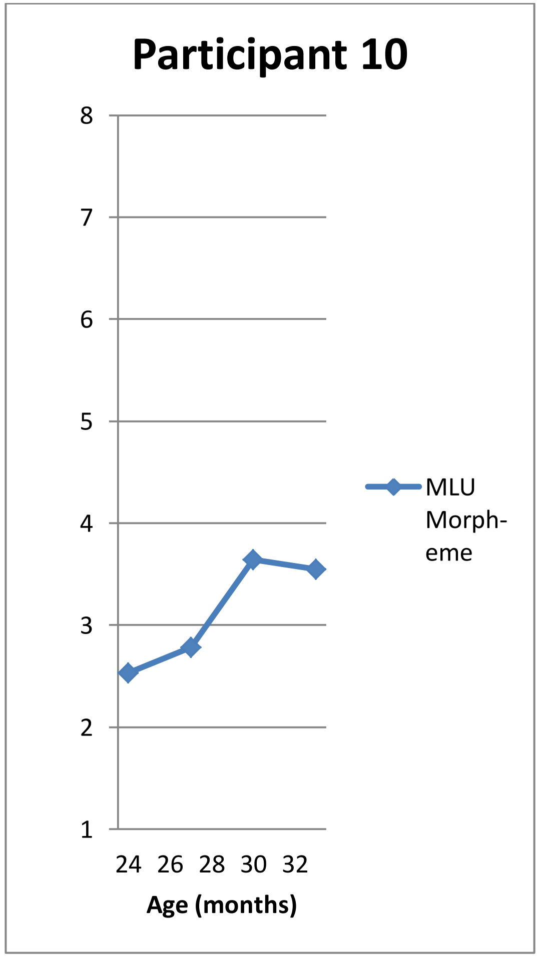
* Participant 7
8
7
6
5
4
3
2
1
42 44 46 48 50 52
Age (months)
MLU Morph-eme

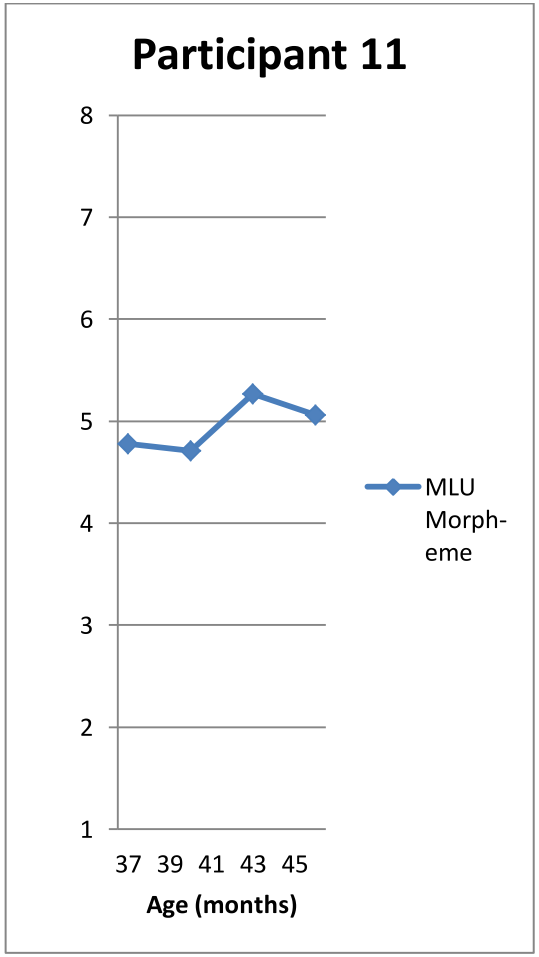


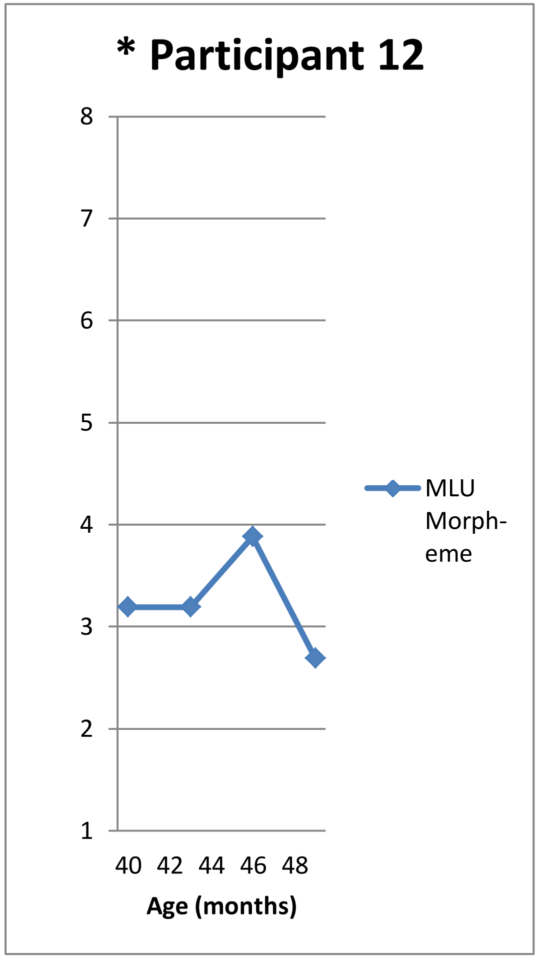
Participant 8
8
7
6
5
4
3
2
1
23 25 27 29 31
Age (months)
MLU Morph-eme

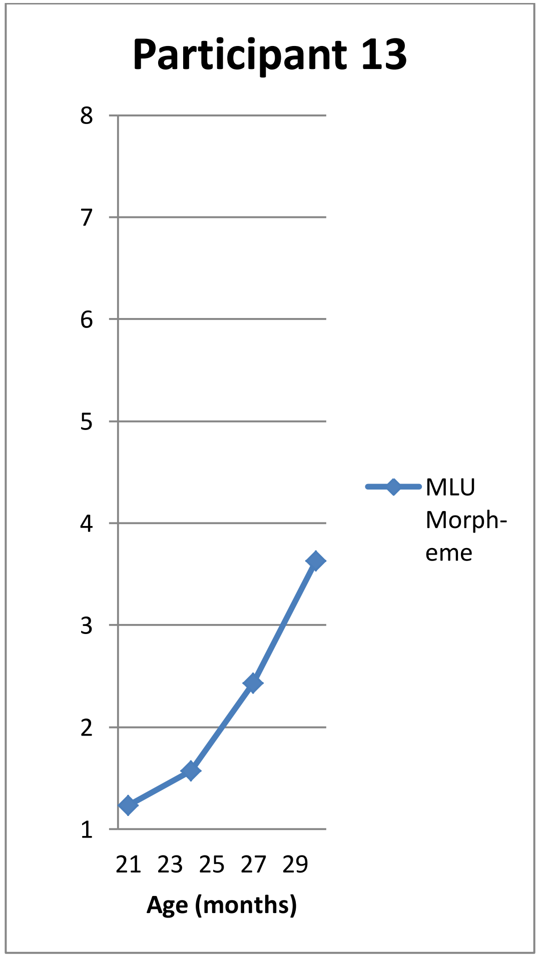


* Participant 9
8
7
6
5
4
3
2
1
27 29 31 33 35 37
Age (months)
MLU Morph-eme

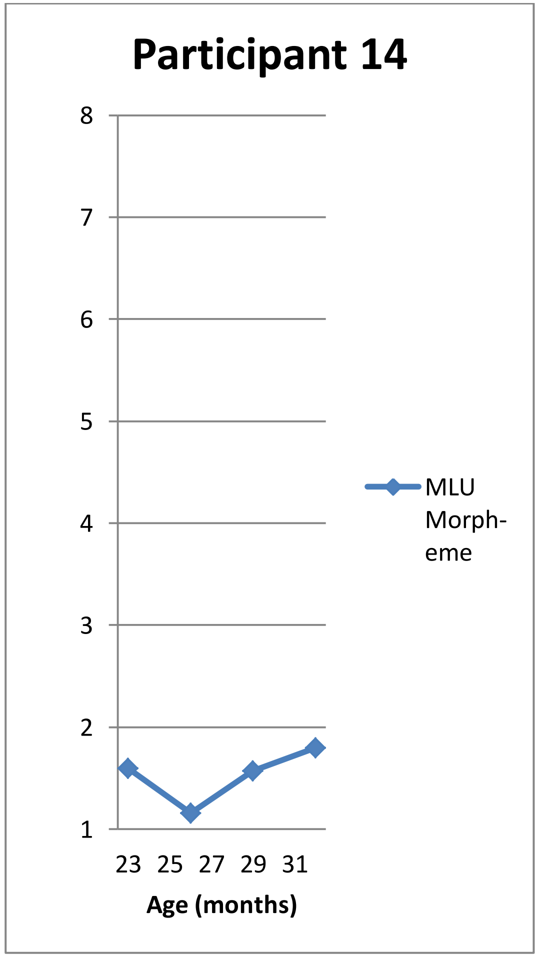

Participant 10
8
7
6
5
4
3
2
1
24 26 28 30 32
Age (months)
MLU Morph-eme


Participant 11
8
7
6
5
4
3
2
1
37 39 41 43 45
Age (months)
MLU Morph-eme

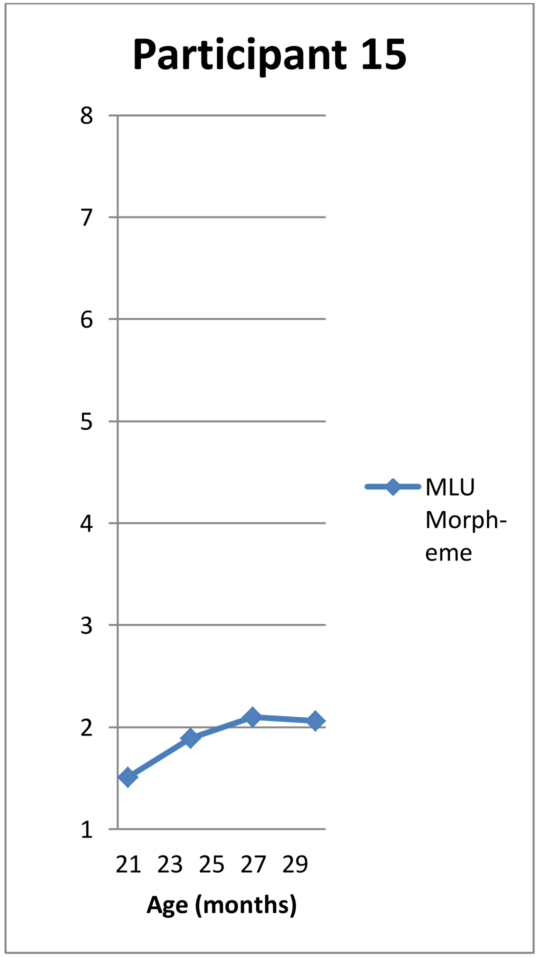

* Participant 12
8
7
6
5
4
3
2
1
40 42 44 46 48
Age (months)
MLU Morph-eme



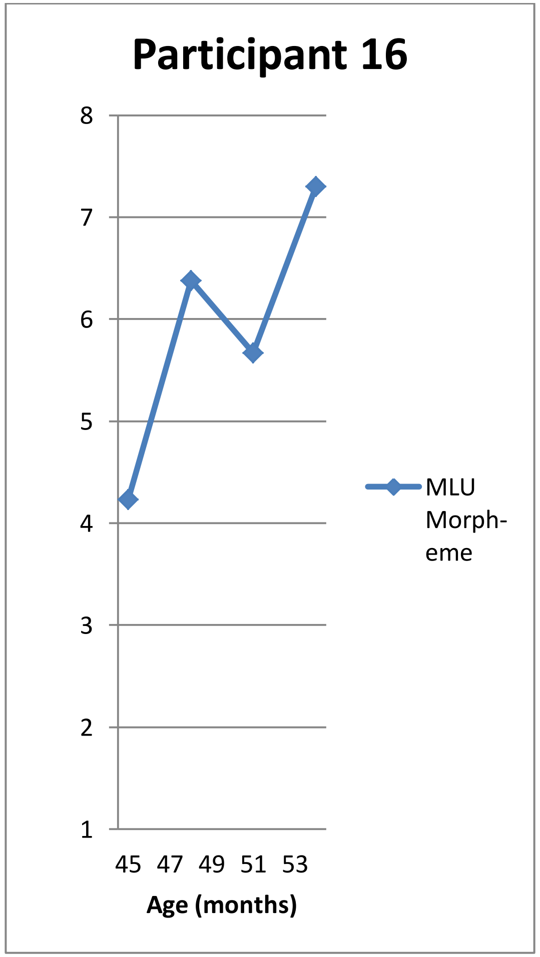
Participant 13
8
7
6
5
4
3
2
1
21 23 25 27 29
Age (months)
MLU Morph-eme

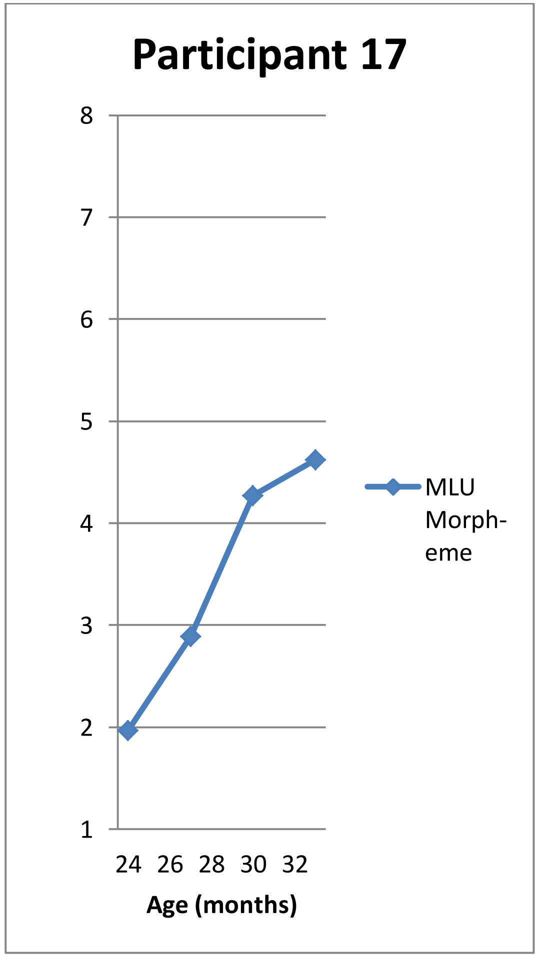


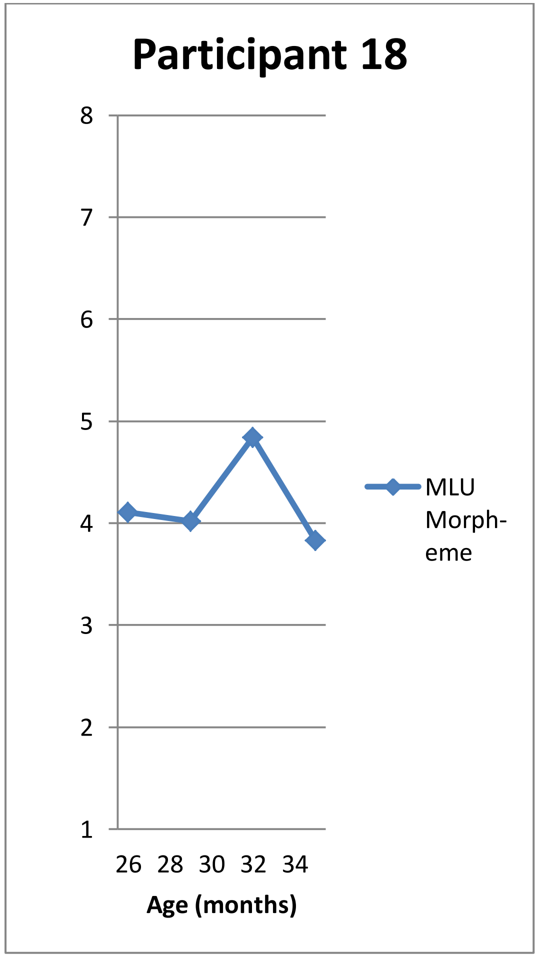
Participant 14
8
7
6
5
4
3
2
1
23 25 27 29 31
Age (months)
MLU Morph-eme



Participant 15
8
7
6
5
4
3
2
1
21 23 25 27 29
Age (months)
MLU Morph-eme

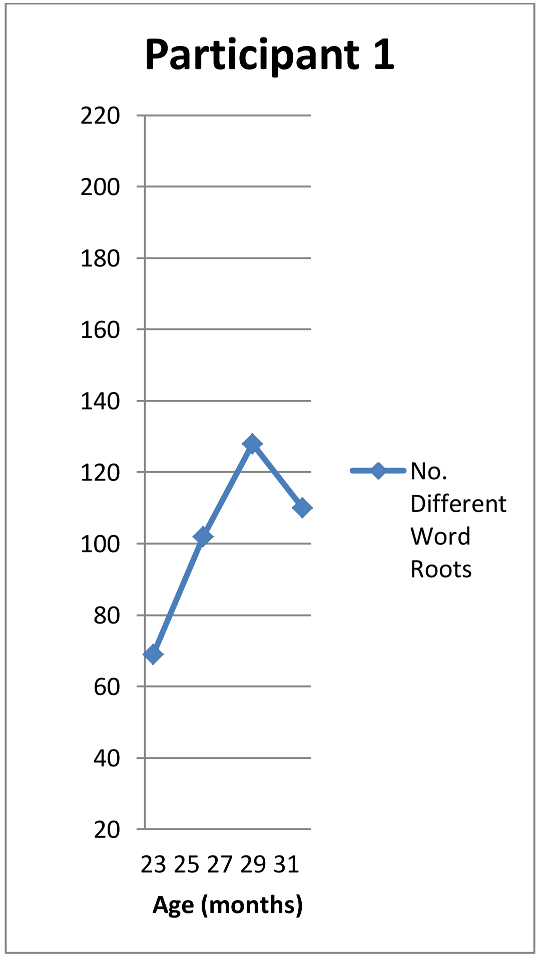

Participant 16
8
7
6
5
4
3
2
1
45 47 49 51 53
Age (months)
MLU Morph-eme

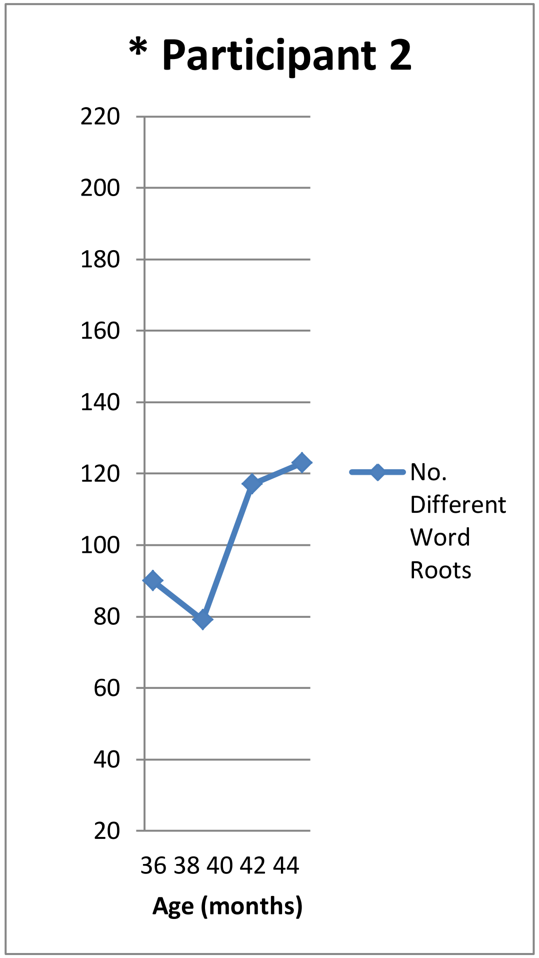

Participant 17
8
7
6
5
4
3
2
1
24 26 28 30 32
Age (months)
MLU Morph-eme

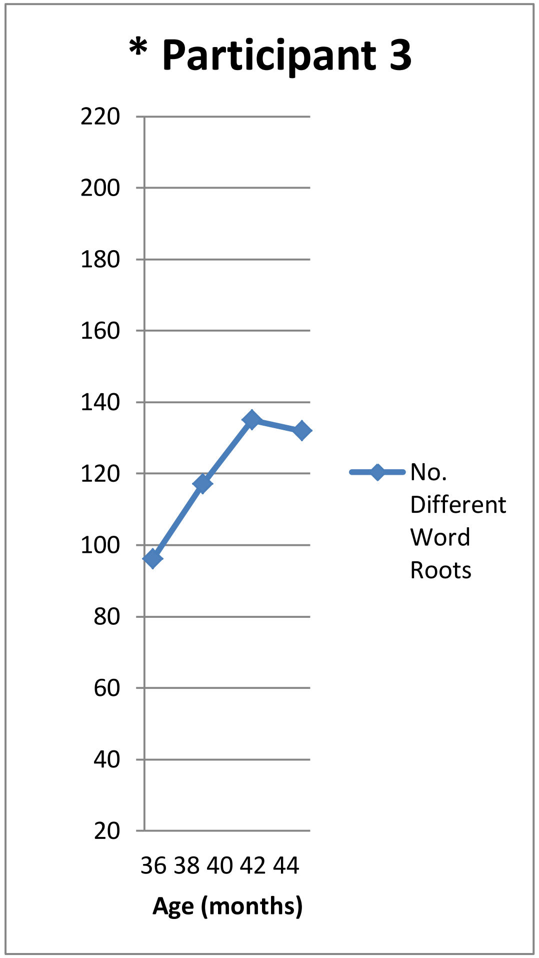

Participant 18
8
7
6
5
4
3
2
1
26 28 30 32 34
Age (months)
MLU Morph-eme

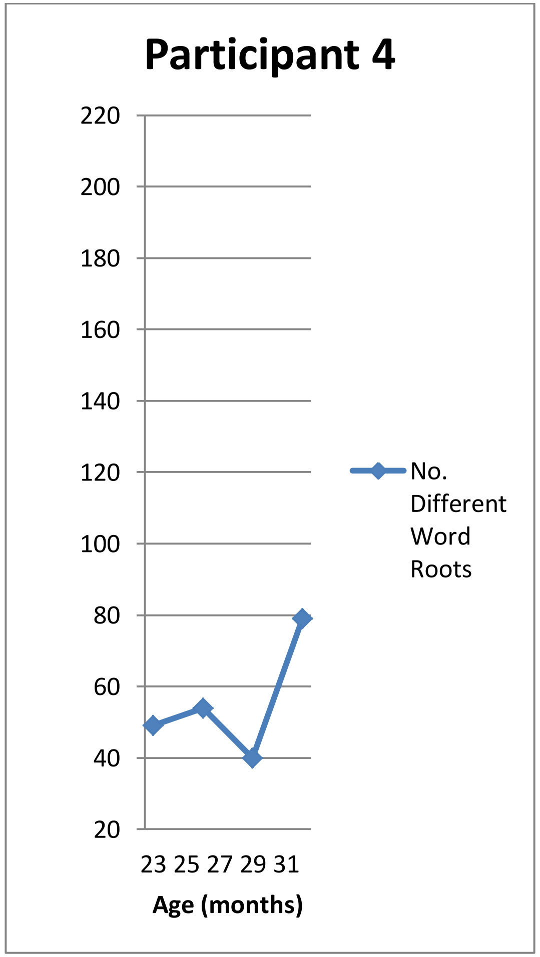
Appendix H: Study 1 Plots per Child across Four Sessions for Number of Different Word Roots

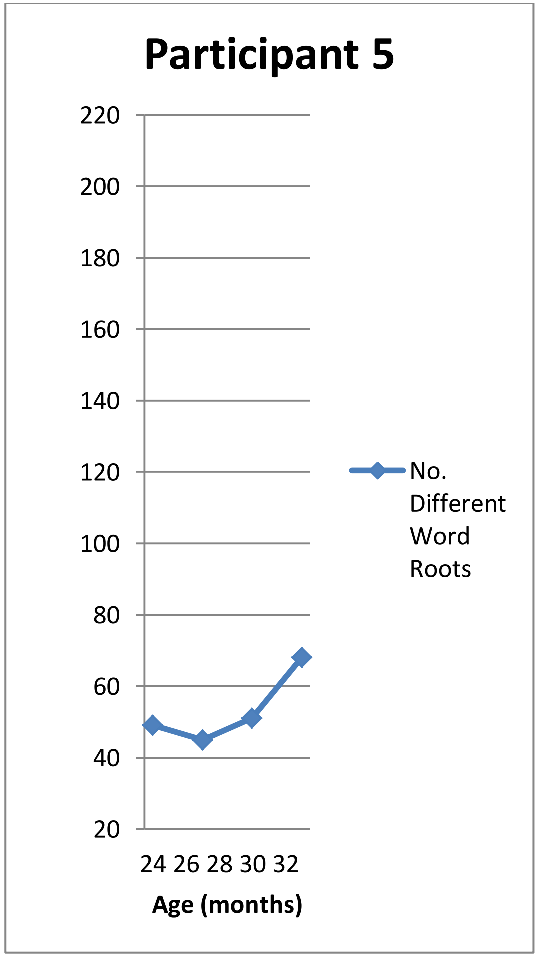
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

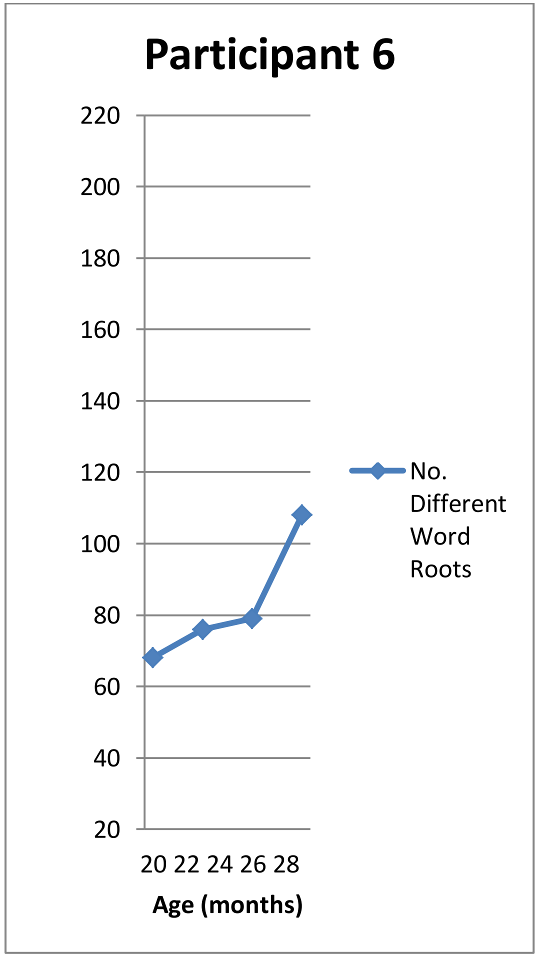

Participant 1
220
200
180
160
140
120
100
80
60
40
20
23 25 27 29 31
Age (months)
No. Different Word Roots

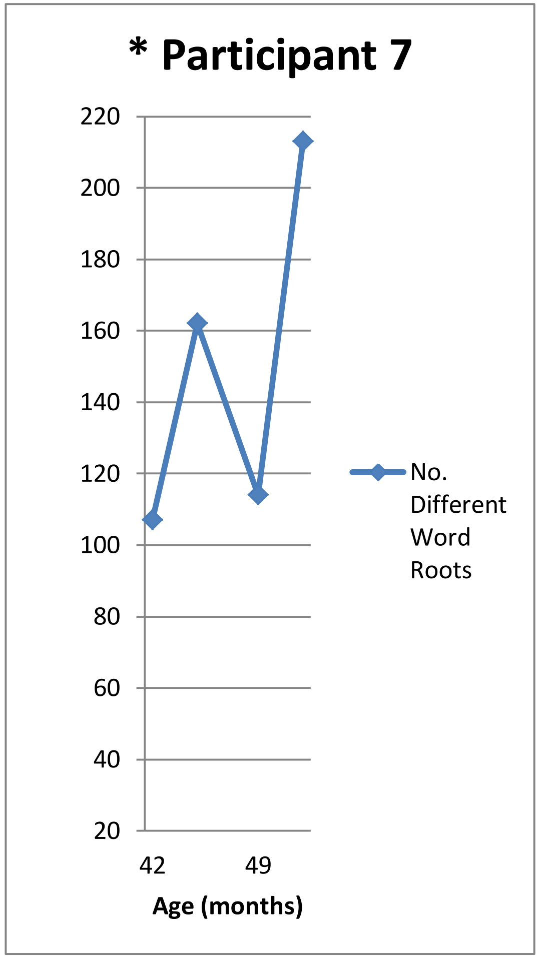

* Participant 2
220
200
180
160
140
120
100
80
60
40
20
36 38 40 42 44
Age (months)
No. Different Word Roots

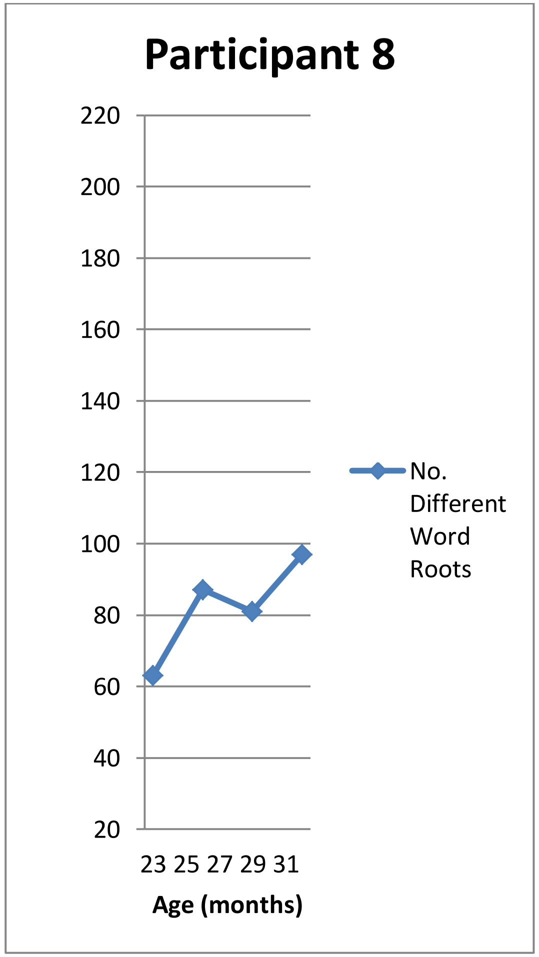

* Participant 3
220
200
180
160
140
120
100
80
60
40
20
36 38 40 42 44
Age (months)
No. Different Word Roots

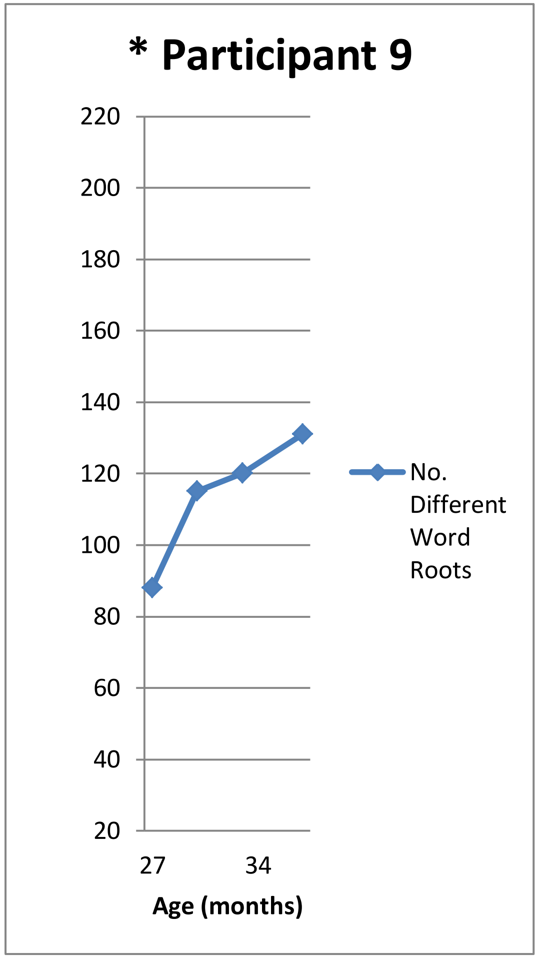

Participant 4
220
200
180
160
140
120
100
80
60
40
20
23 25 27 29 31
Age (months)
No. Different Word Roots

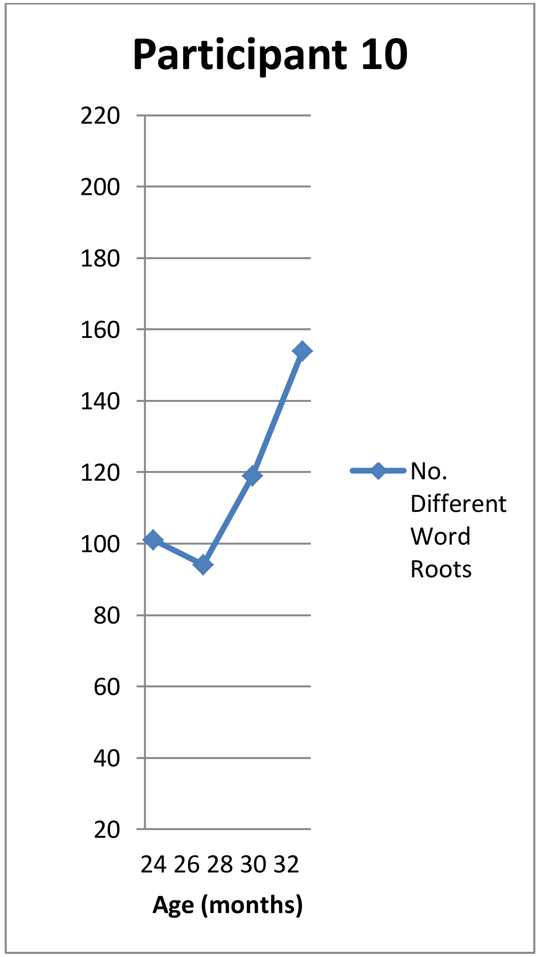

Participant 5
220
200
180
160
140
120
100
80
60
40
20
24 26 28 30 32
Age (months)
No. Different Word Roots

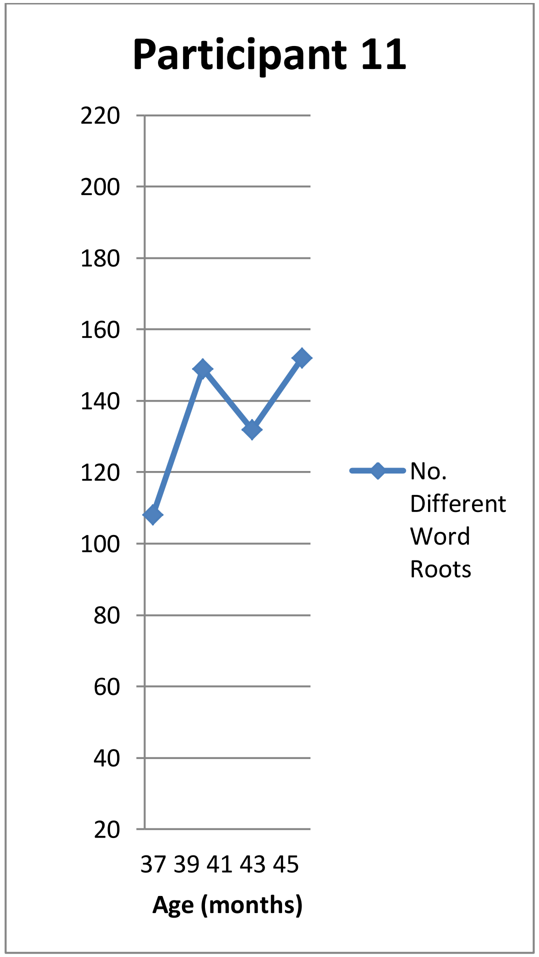

Participant 6
220
200
180
160
140
120
100
80
60
40
20
20 22 24 26 28
Age (months)
No. Different Word Roots

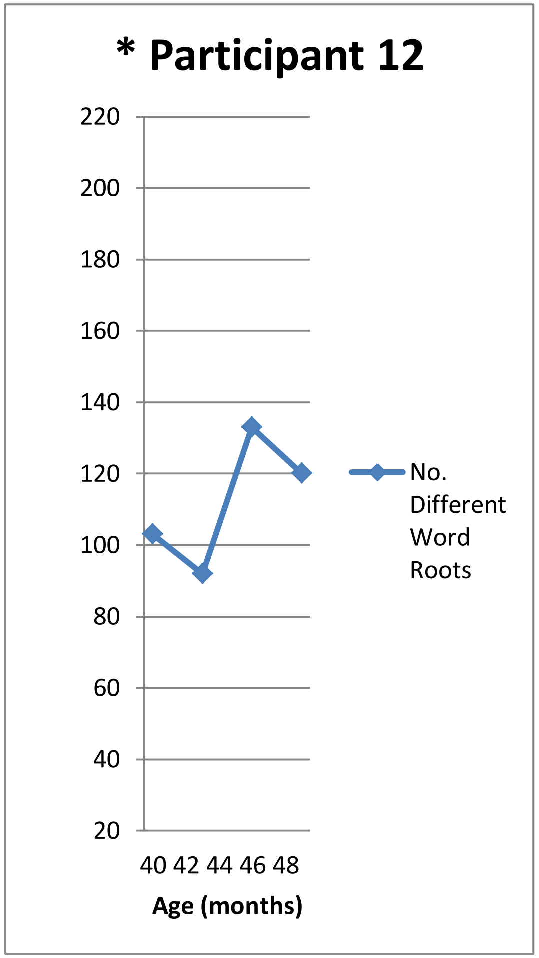

* Participant 7
220
200
180
160
140
120
100
80
60
40
20
42
49
Age (months)
No. Different Word Roots

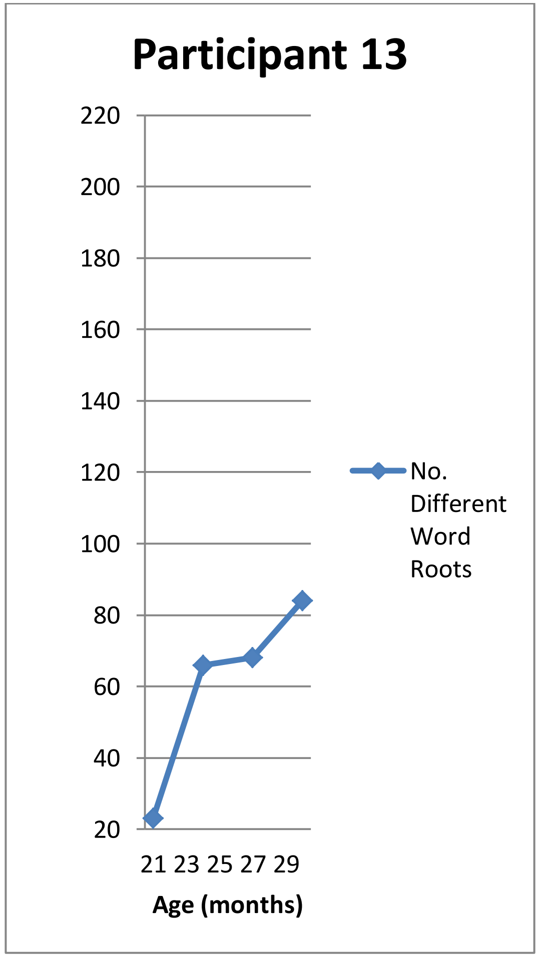

Participant 8
220
200
180
160
140
120
100
80
60
40
20
23 25 27 29 31
Age (months)
No. Different Word Roots

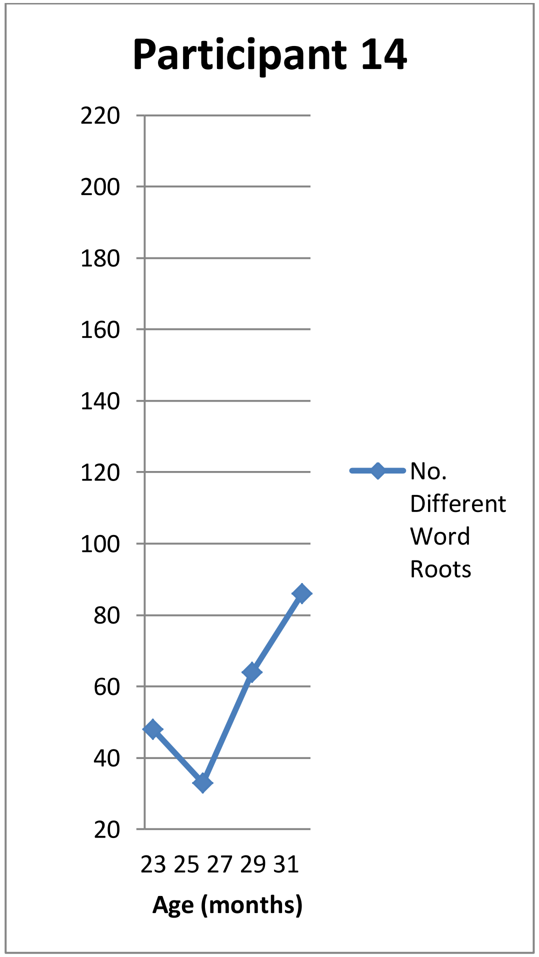

* Participant 9
220
200
180
160
140
120
100
80
60
40
20
27
34
Age (months)
No. Different Word Roots

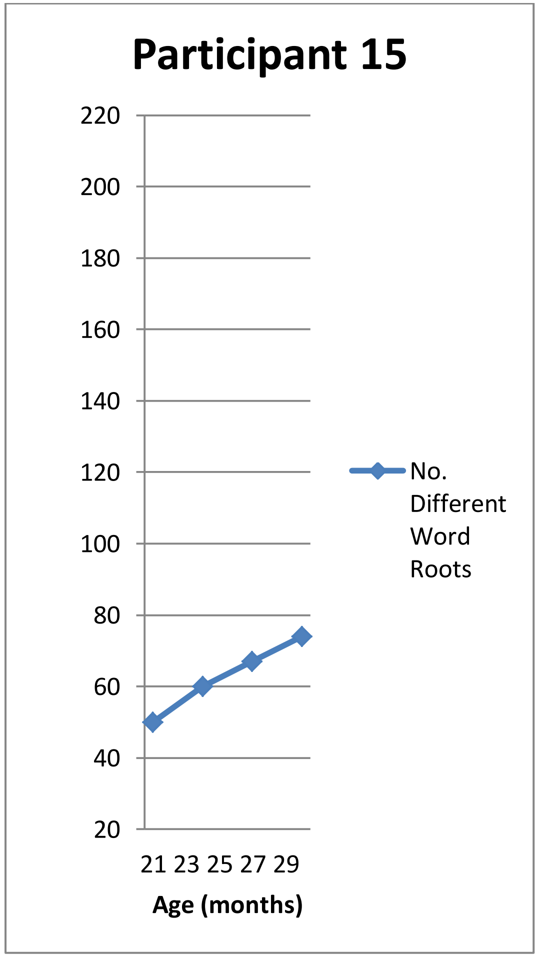

Participant 10
220
200
180
160
140
120
100
80
60
40
20
24 26 28 30 32
Age (months)
No. Different Word Roots

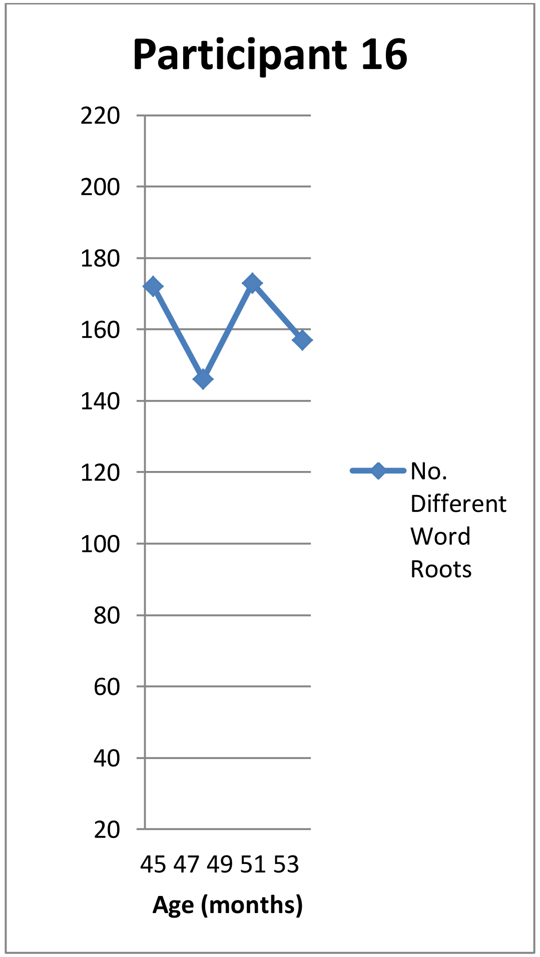

Participant 11
220
200
180
160
140
120
100
80
60
40
20
37 39 41 43 45
Age (months)
No. Different Word Roots

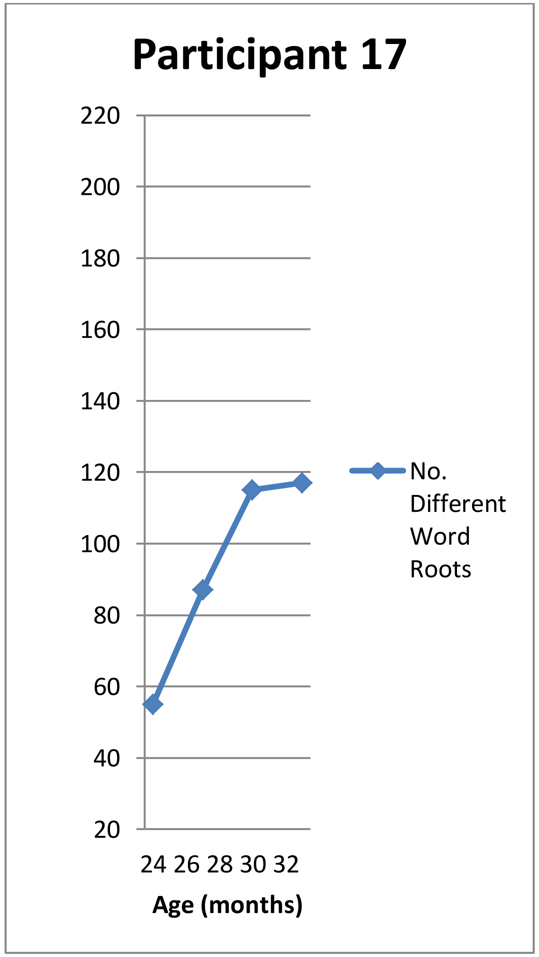

* Participant 12
220
200
180
160
140
120
100
80
60
40
20
40 42 44 46 48
Age (months)
No. Different Word Roots

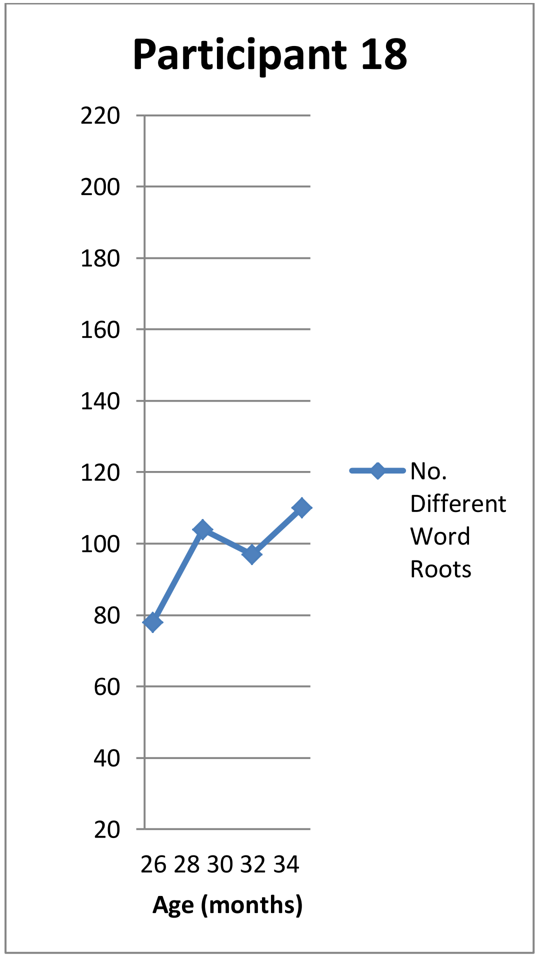

Participant 13
220
200
180
160
140
120
100
80
60
40
20
21 23 25 27 29
Age (months)
No. Different Word Roots


Participant 14
220
200
180
160
140
120
100
80
60
40
20
23 25 27 29 31
Age (months)
No. Different Word Roots


Participant 15
220
200
180
160
140
120
100
80
60
40
20
21 23 25 27 29
Age (months)
No. Different Word Roots

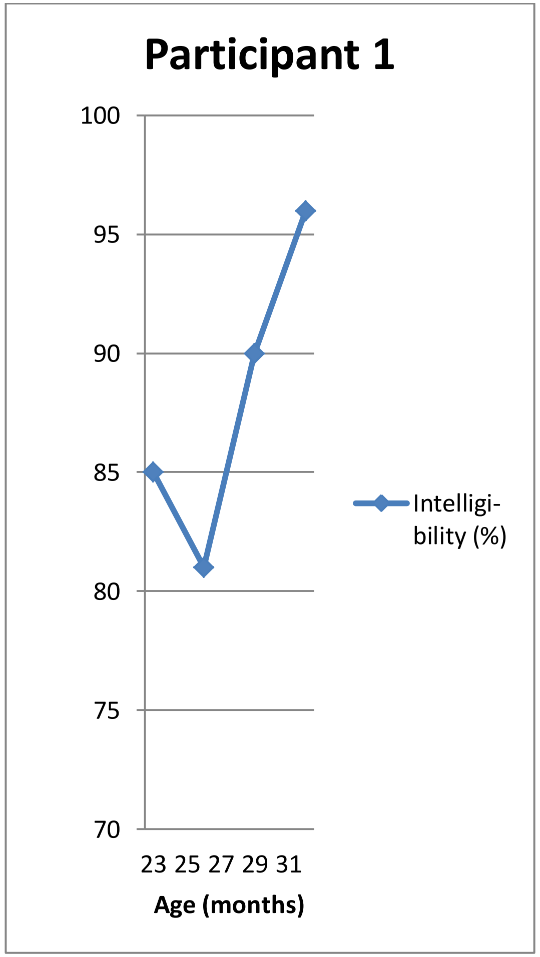

Participant 16
220
200
180
160
140
120
100
80
60
40
20
45 47 49 51 53
Age (months)
No. Different Word Roots

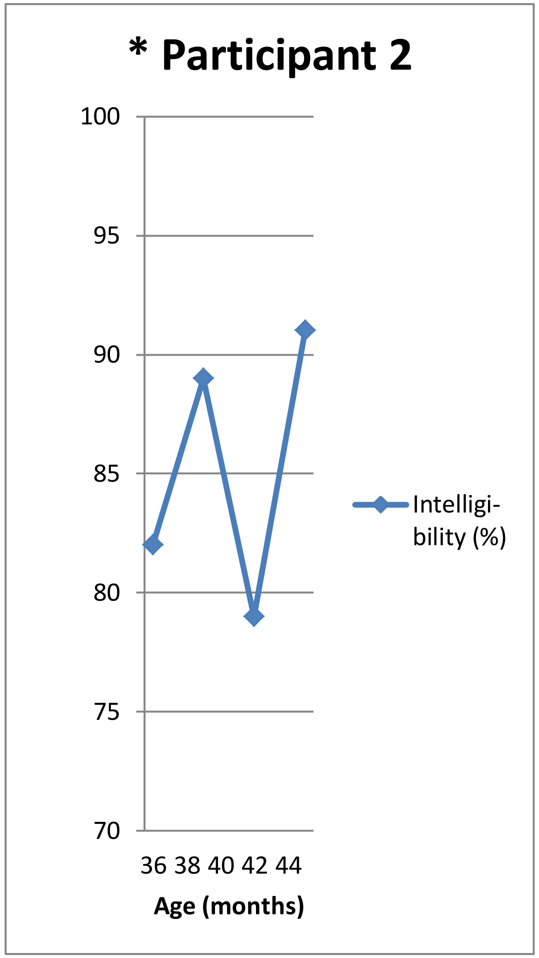

Participant 17
220
200
180
160
140
120
100
80
60
40
20
24 26 28 30 32
Age (months)
No. Different Word Roots

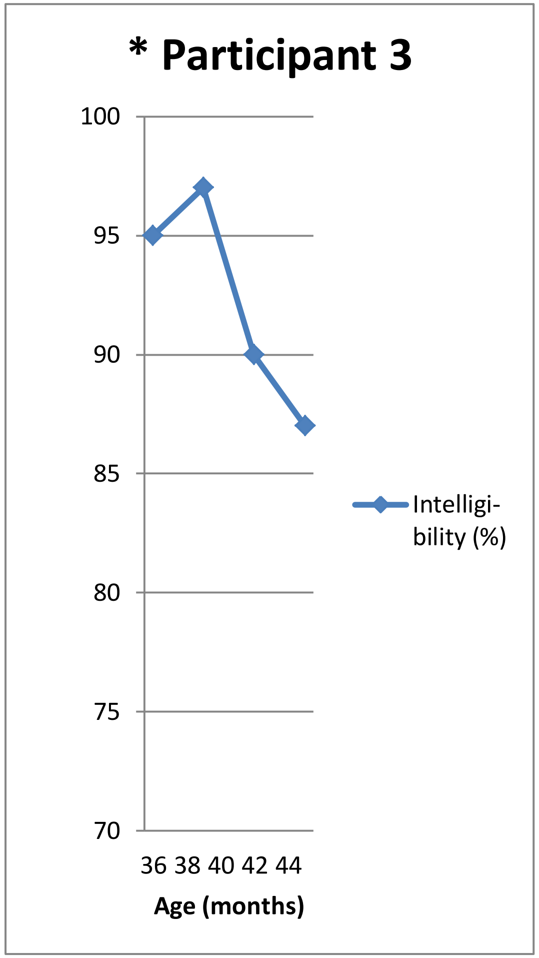

Participant 18
220
200
180
160
140
120
100
80
60
40
20
26 28 30 32 34
Age (months)
No. Different Word Roots

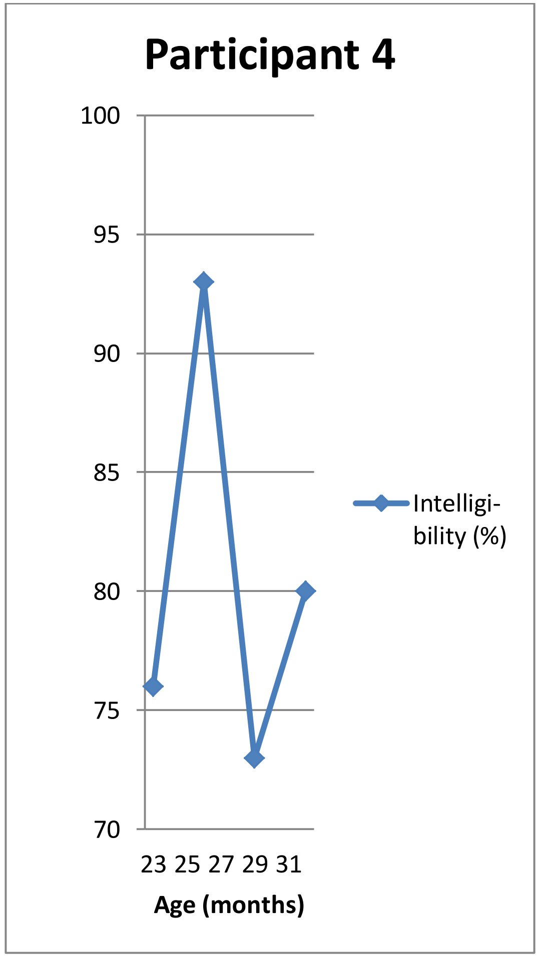
Appendix I: Study 1 Plots per Child across Four Sessions for Percent Intelligibility

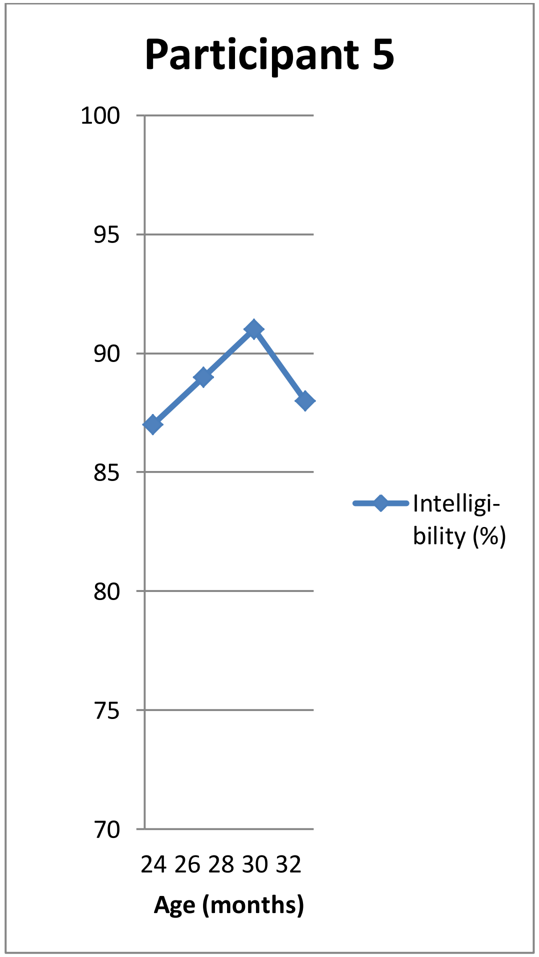
Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

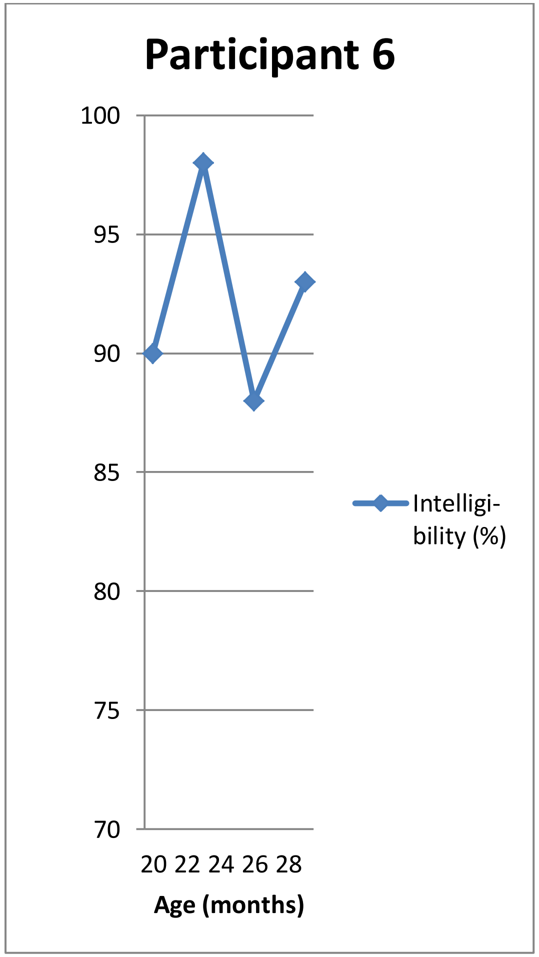

Participant 1
100
95
90
85
80
75
70
23 25 27 29 31
Age (months)
Intelligi-bility (%)

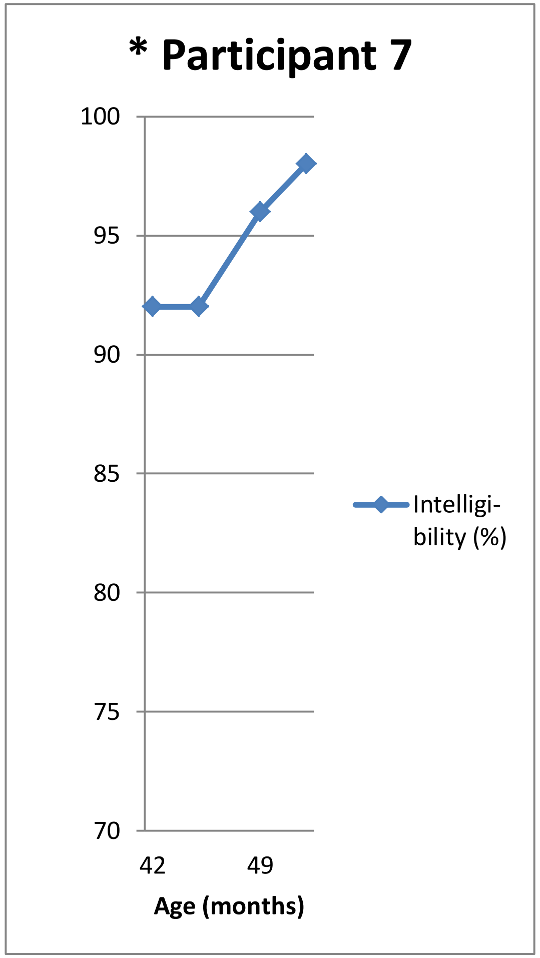

* Participant 2
100
95
90
85
80
75
70
36 38 40 42 44
Age (months)
Intelligi-bility (%)


* Participant 3
100
95
90
85
80
75
70
36 38 40 42 44
Age (months)
Intelligi-bility (%)

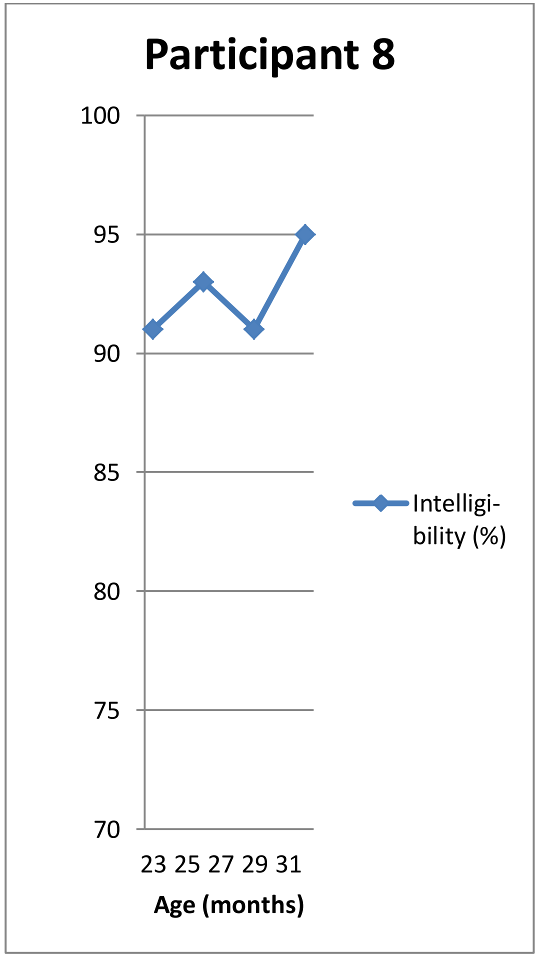

Participant 4
100
95
90
85
80
75
70
23 25 27 29 31
Age (months)
Intelligi-bility (%)


Participant 5
100
95
90
85
80
75
70
24 26 28 30 32
Age (months)
Intelligi-bility (%)

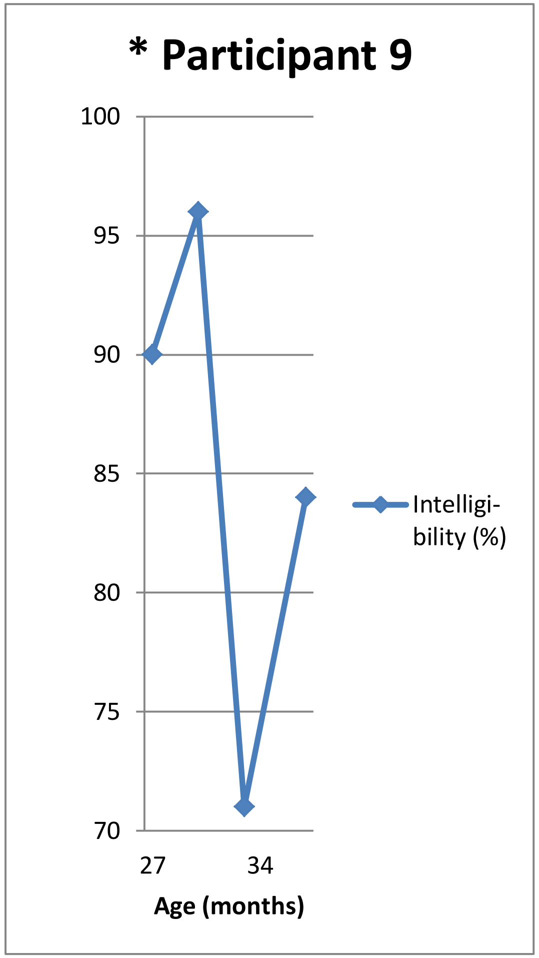

Participant 6
100
95
90
85
80
75
70
20 22 24 26 28
Age (months)
Intelligi-bility (%)



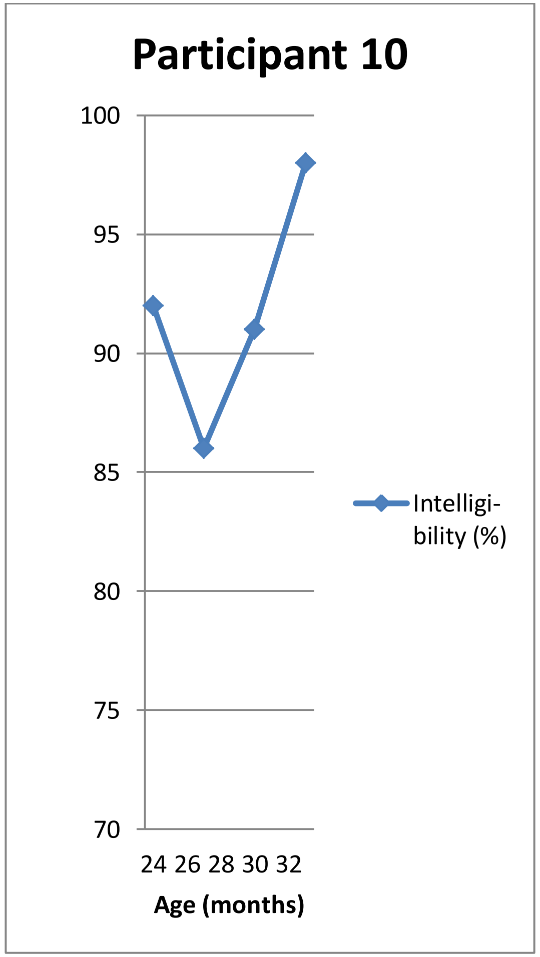
* Participant 7
100
95
90
85
80
75
70
42
49
Age (months)
Intelligi-
bility (%)

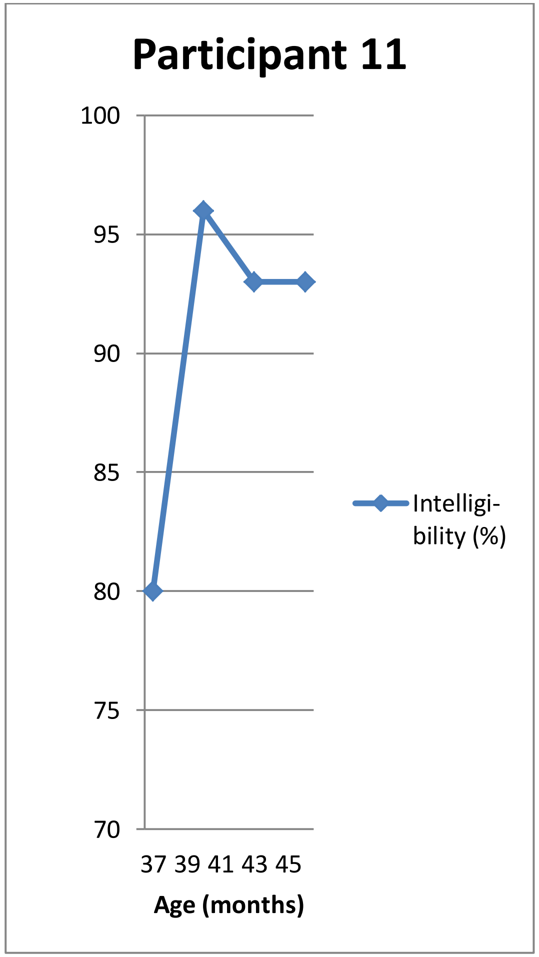


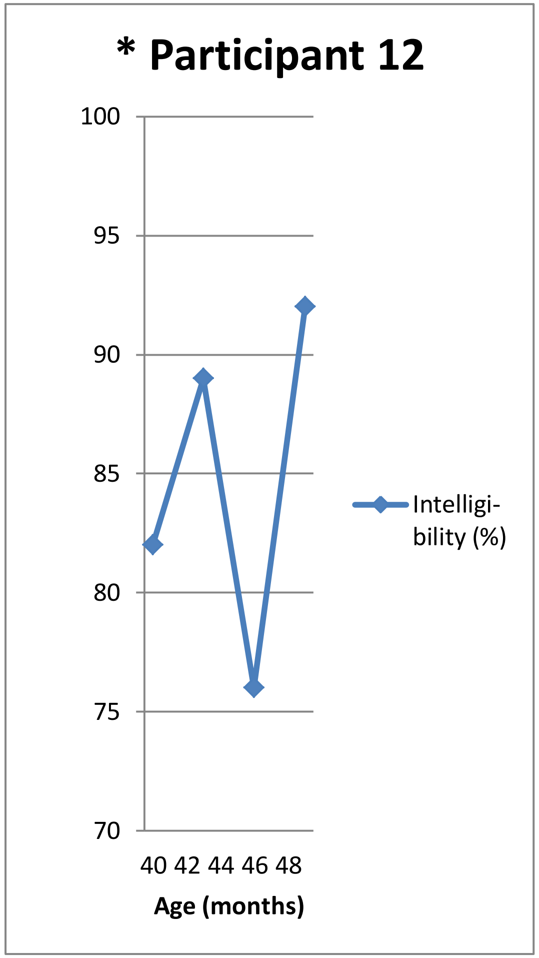
Participant 8
100
95
90
85
80
75
70
23 25 27 29 31
Age (months)
Intelligi-
bility (%)

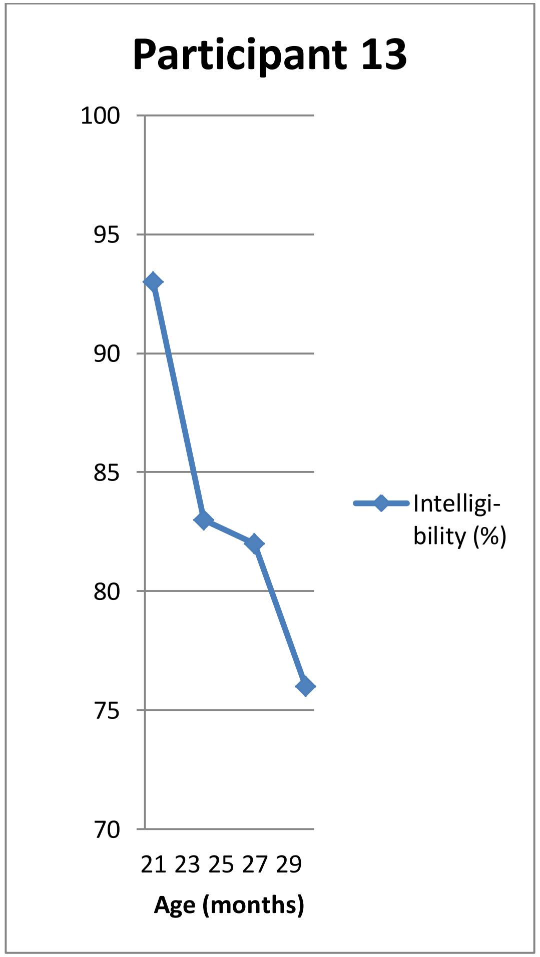


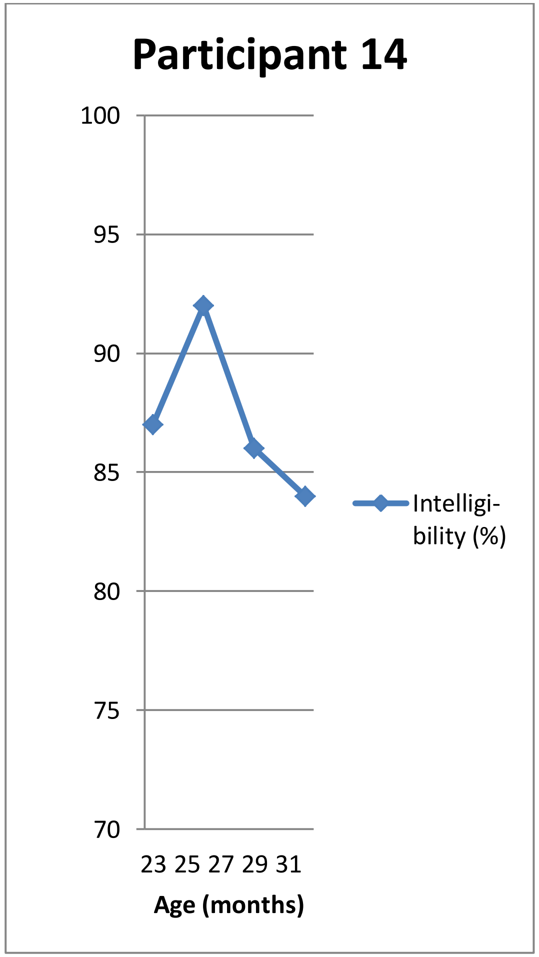
* Participant 9
100
95
90
85
80
75
70
27
34
Age (months)
Intelligi-
bility (%)

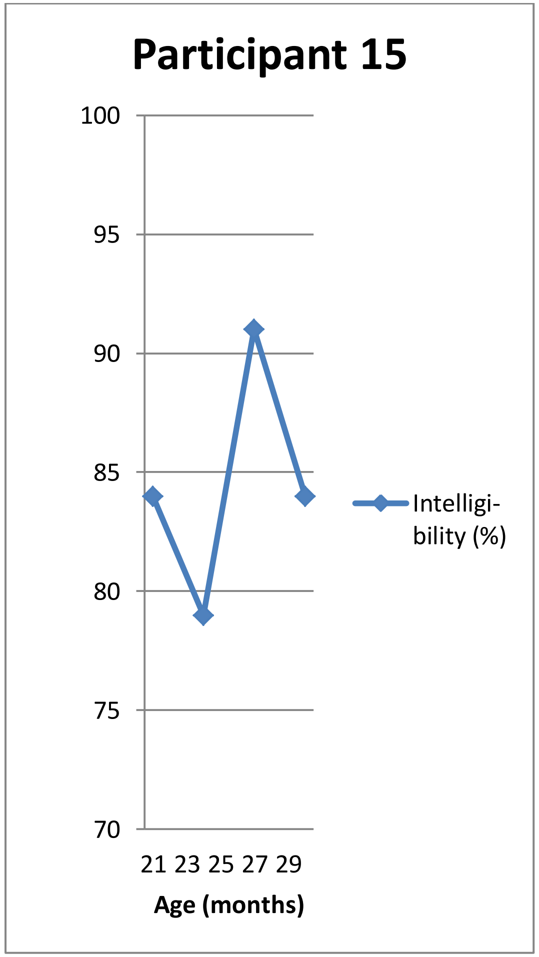

Participant 10
100
95
90
85
80
75
70
24 26 28 30 32
Age (months)
Intelligi-bility (%)

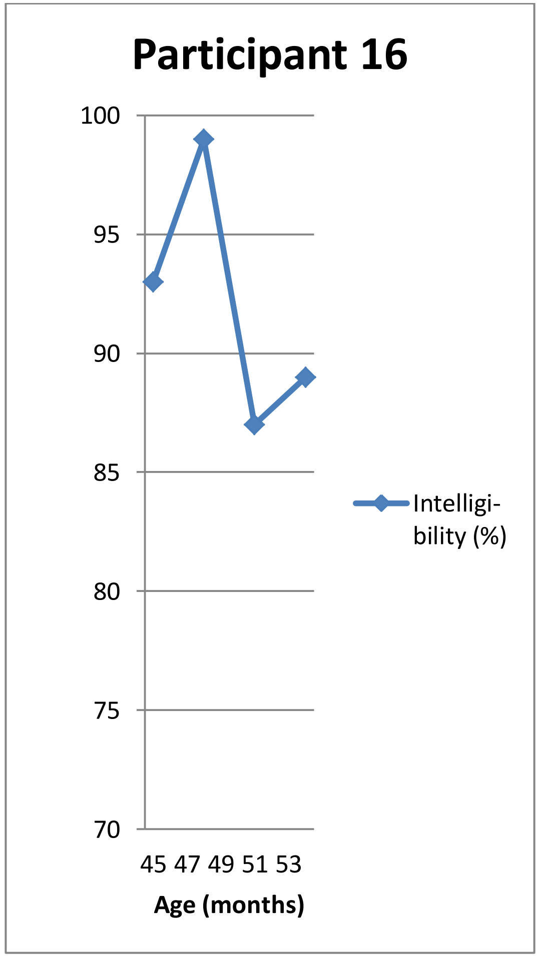

Participant 11
100
95
90
85
80
75
70
37 39 41 43 45
Age (months)
Intelligi-bility (%)

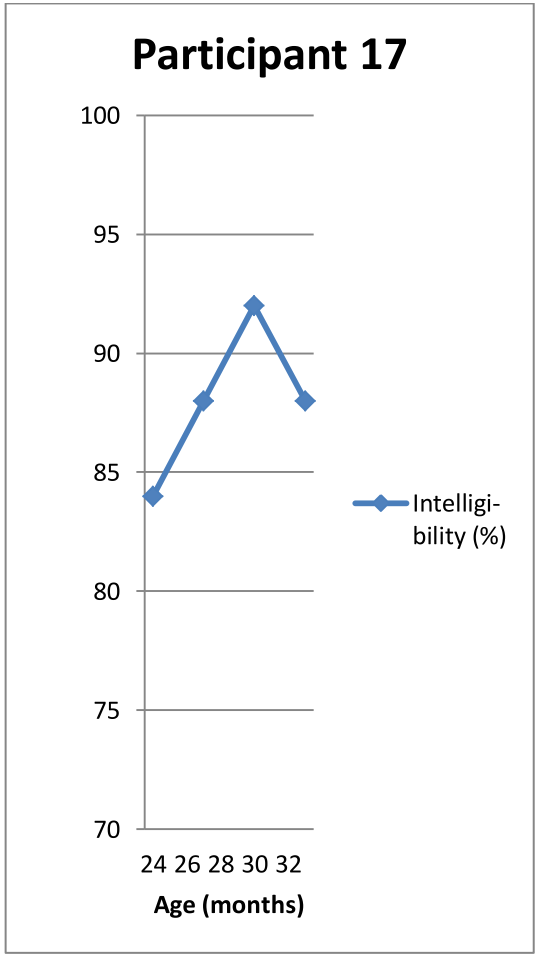

* Participant 12
100
95
90
85
80
75
70
40 42 44 46 48
Age (months)
Intelligi-bility (%)

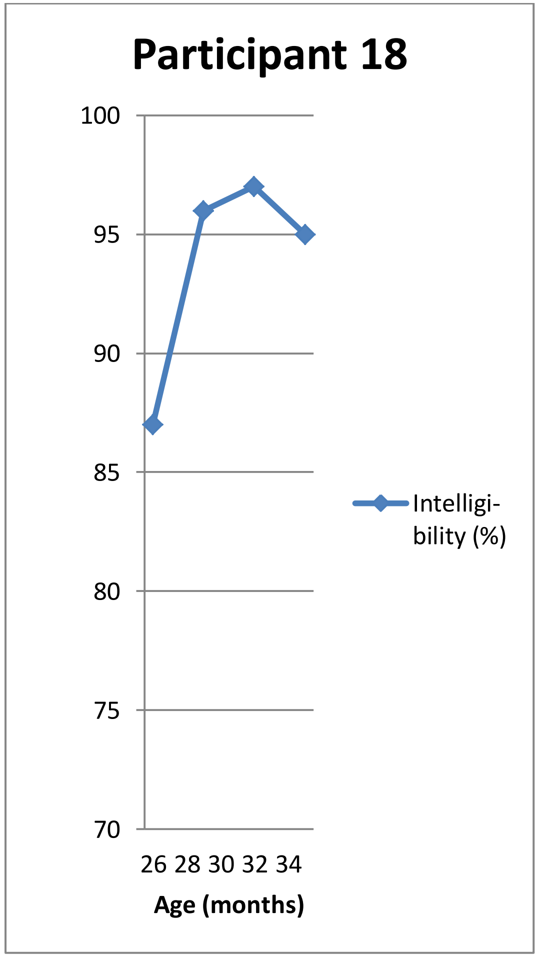

Participant 13
100
95
90
85
80
75
70
21 23 25 27 29
Age (months)
Intelligi-
bility (%)


Participant 14
100
95
90
85
80
75
70
23 25 27 29 31
Age (months)
Intelligi-
bility (%)


Participant 15
100
95
90
85
80
75
70
21 23 25 27 29
Age (months)
Intelligi-
bility (%)

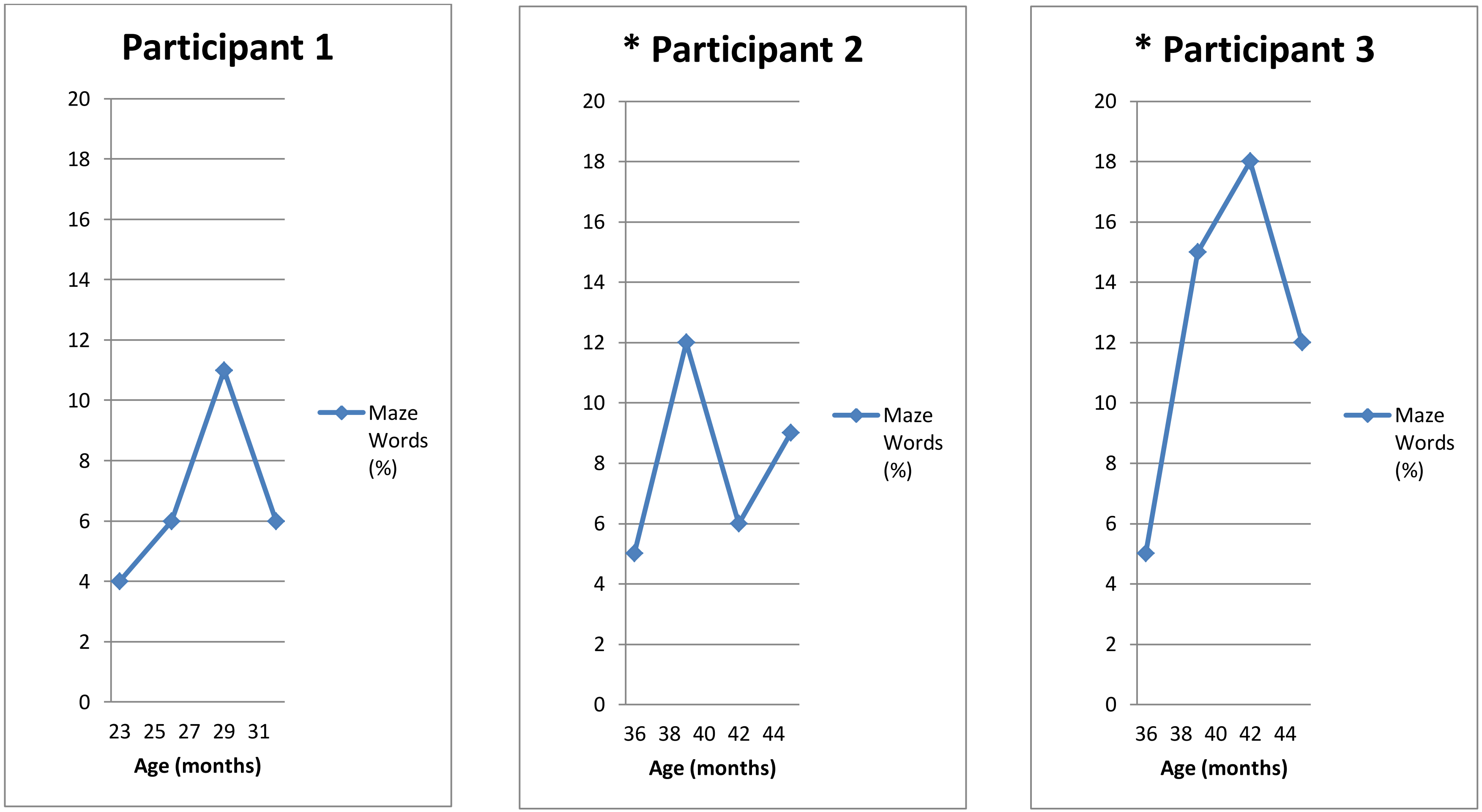

Participant 16
100
95
90
85
80
75
70
45 47 49 51 53
Age (months)
Intelligi-
bility (%)

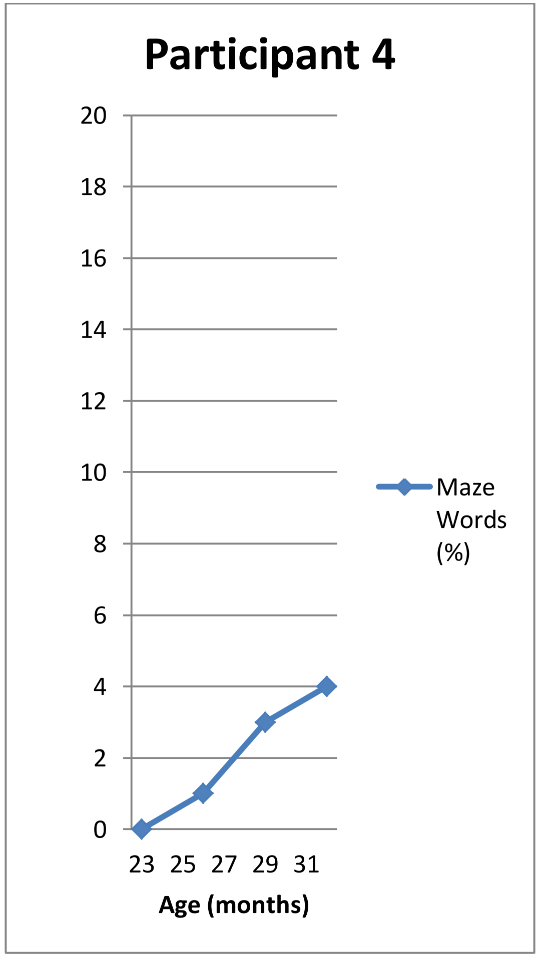

Participant 17
100
95
90
85
80
75
70
24 26 28 30 32
Age (months)
Intelligi-
bility (%)


Participant 18
100
95
90
85
80
75
70
26 28 30 32 34
Age (months)
Intelligi-
bility (%)

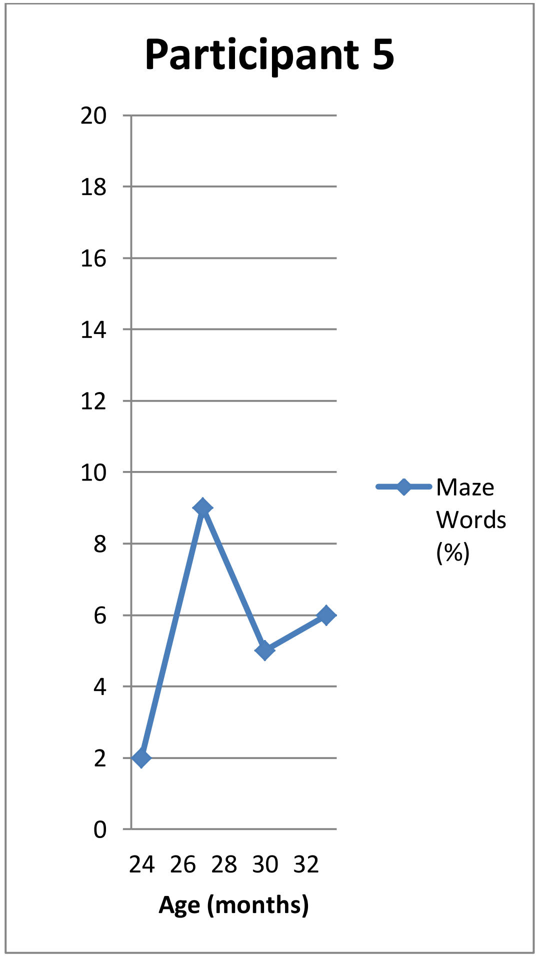
Appendix J: Study 1 Plots per Child across Four Sessions for Percent Mazes

Note: *child observed to start stuttering.
Participants 1 to 9 have a family history of stuttering.
Participants 10 to 18 do not have a family history of stuttering.

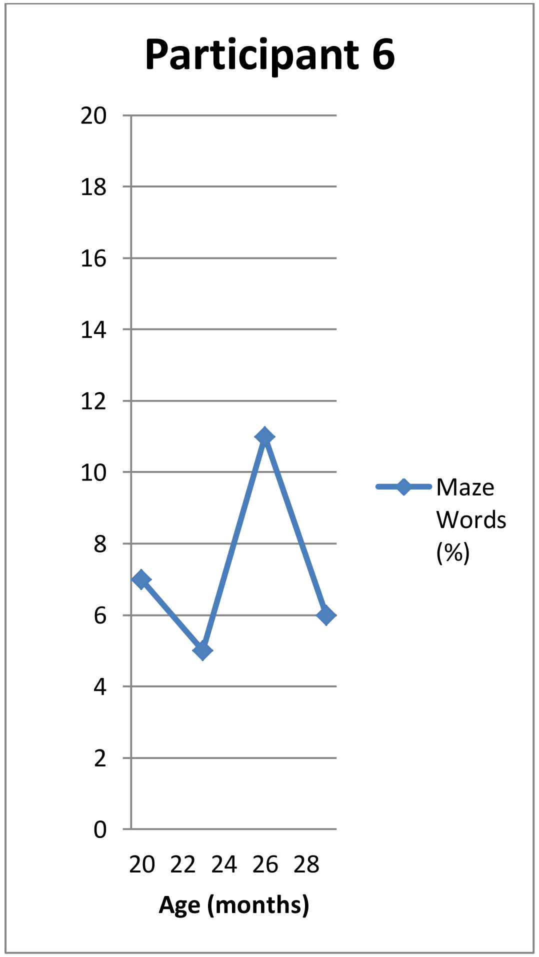

Participant 1
20
18
16
14
12
10
8
6
4
2
0
23 25 27 29 31
Age (months)
Maze Words (%)
* Participant 2
20
18
16
14
12
10
8
6
4
2
0
36 38 40 42 44
Age (months)
Maze Words (%)
* Participant 3
20
18
16
14
12
10
8
6
4
2
0
36 38 40 42 44
Age (months)
Maze Words (%)



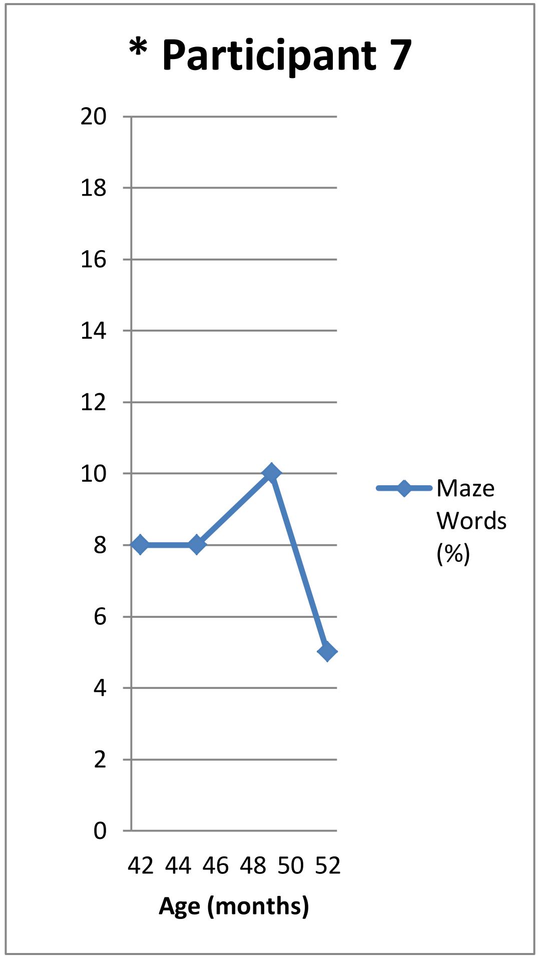
Participant 4
20
18
16
14
12
10
8
6
4
2
0
23 25 27 29 31
Age (months)
Maze Words (%)

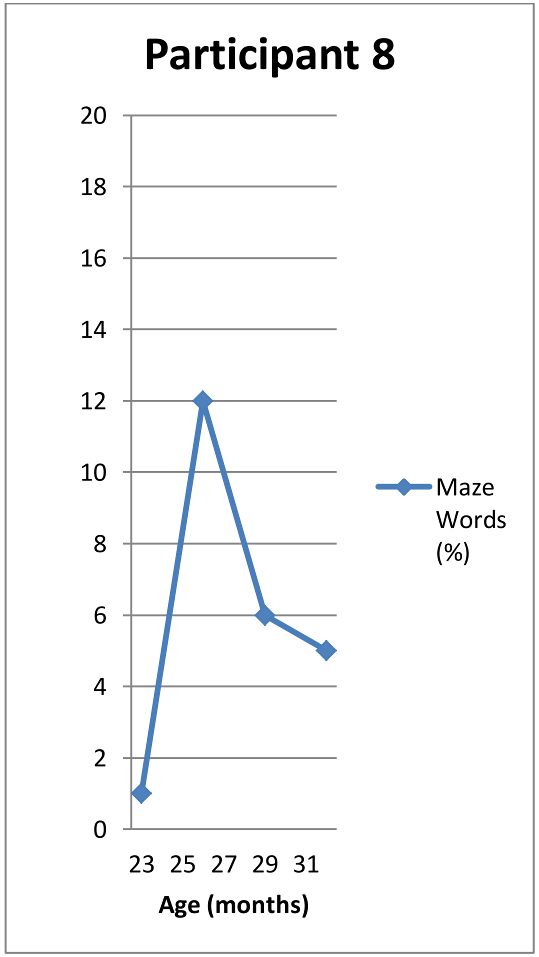


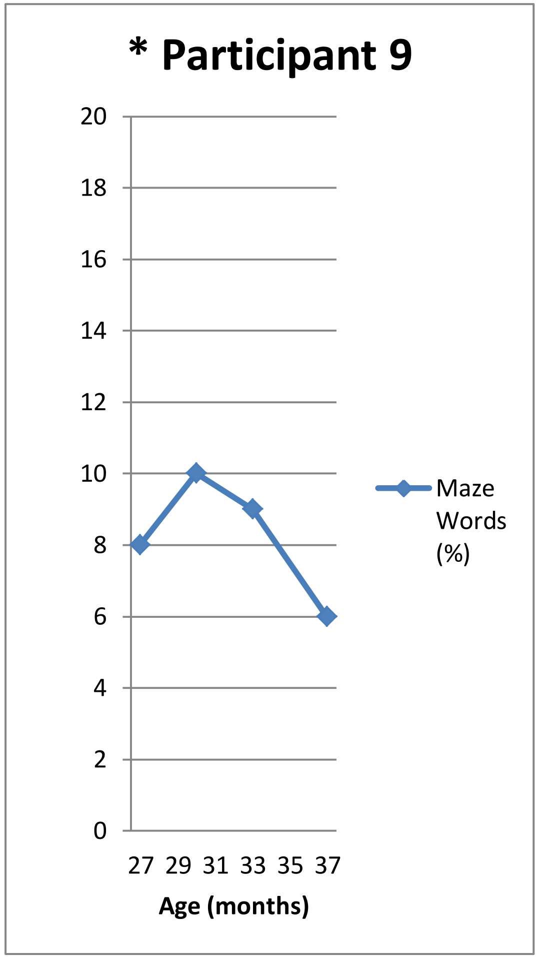
Participant 5
20
18
16
14
12
10
8
6
4
2
0
24 26 28 30 32
Age (months)
Maze Words (%)

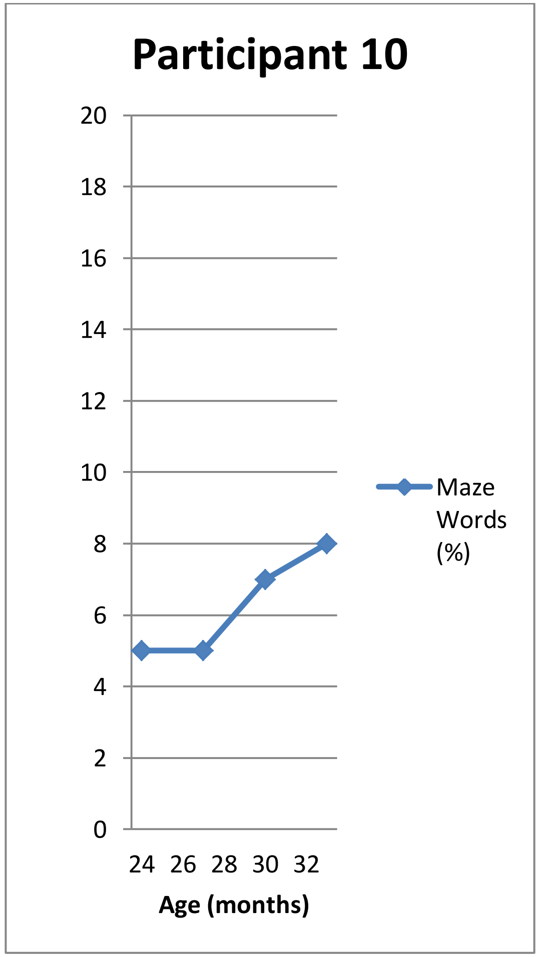


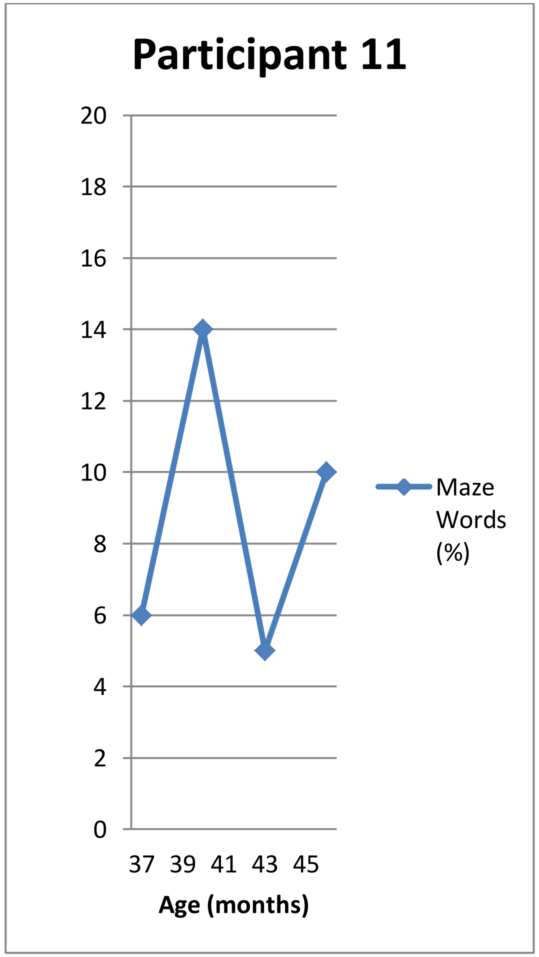
Participant 6
20
18
16
14
12
10
8
6
4
2
0
20 22 24 26 28
Age (months)
Maze Words (%)

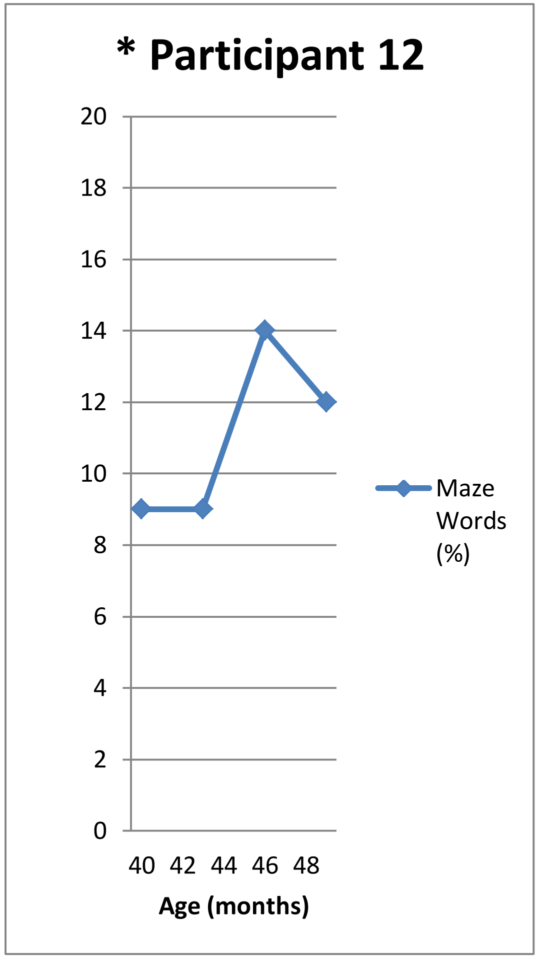

* Participant 7
20
18
16
14
12
10
8
6
4
2
0
42 44 46 48 50 52
Age (months)
Maze Words (%)

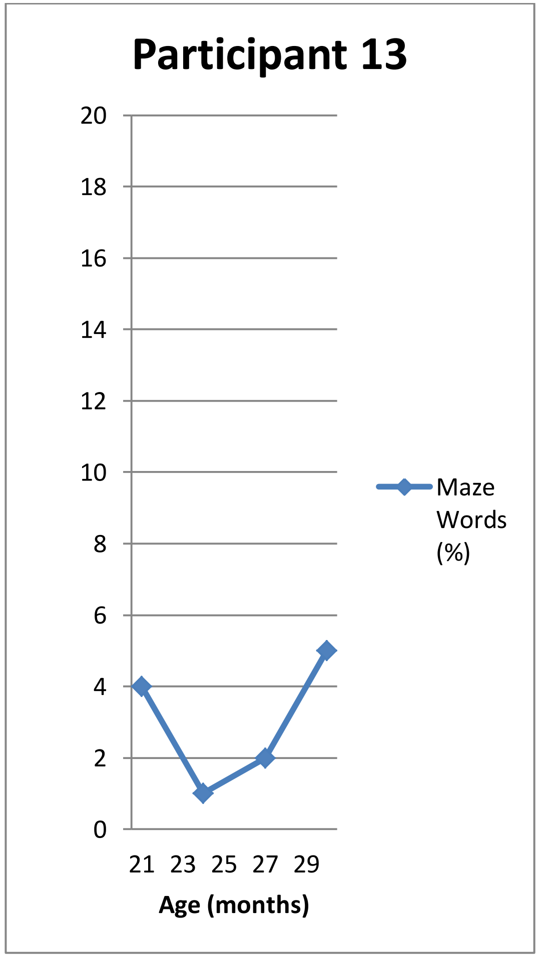

Participant 8
20
18
16
14
12
10
8
6
4
2
0
23 25 27 29 31
Age (months)
Maze Words (%)

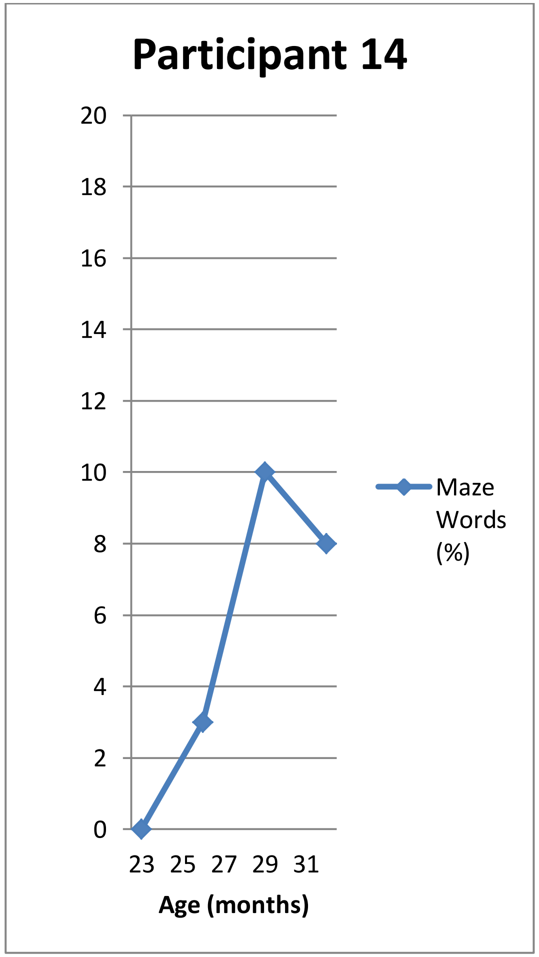

* Participant 9
20
18
16
14
12
10
8
6
4
2
0
27 29 31 33 35 37
Age (months)
Maze Words (%)

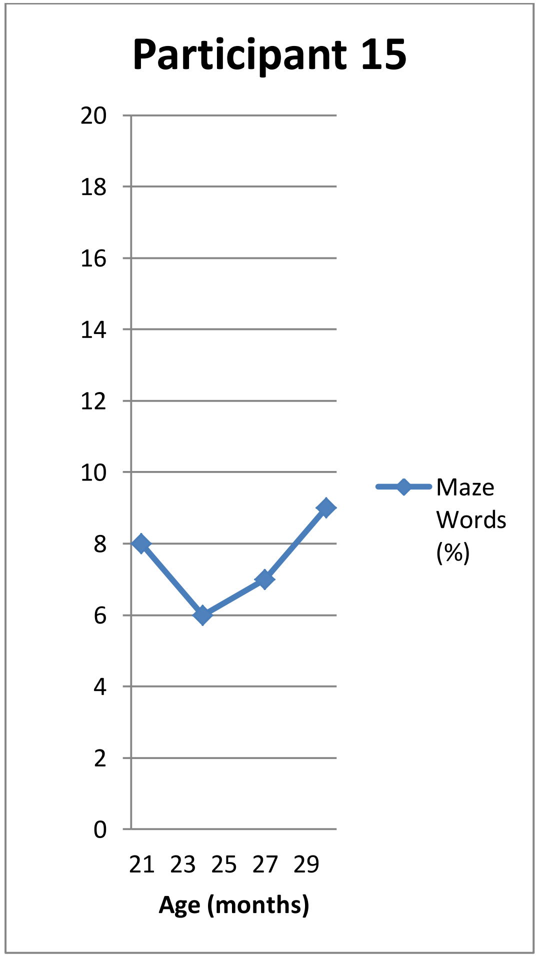

Participant 10
20
18
16
14
12
10
8
6
4
2
0
24 26 28 30 32
Age (months)
Maze Words (%)

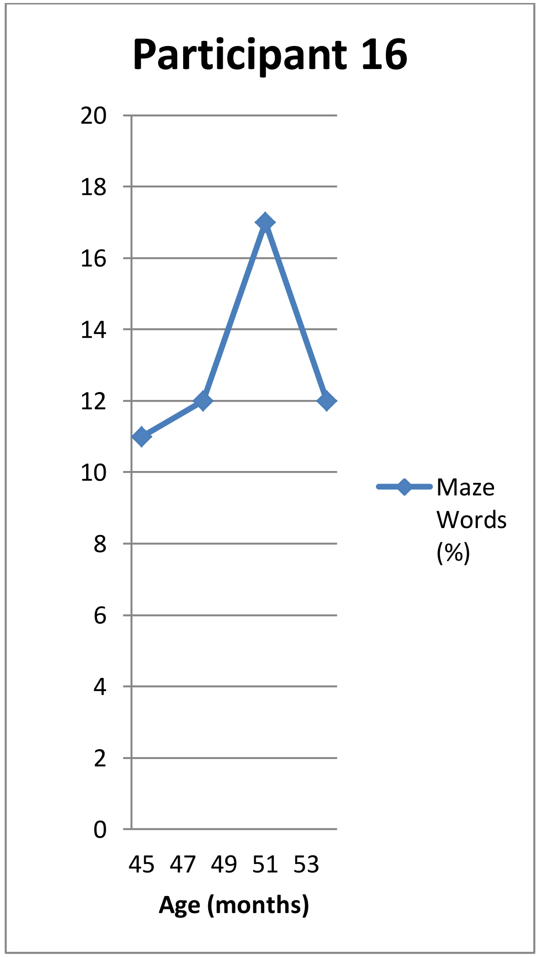

Participant 11
20
18
16
14
12
10
8
6
4
2
0
37 39 41 43 45
Age (months)
Maze Words (%)

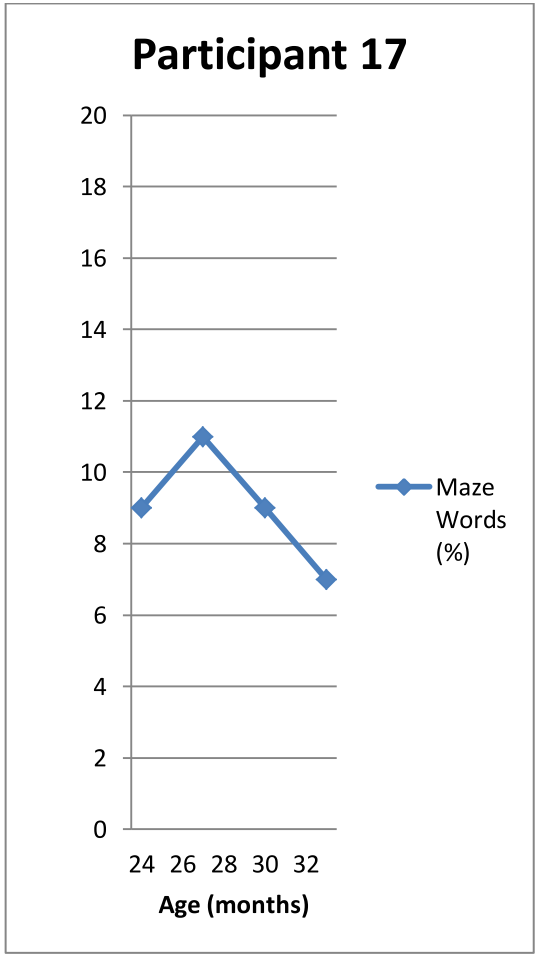

* Participant 12
20
18
16
14
12
10
8
6
4
2
0
40 42 44 46 48
Age (months)
Maze Words (%)

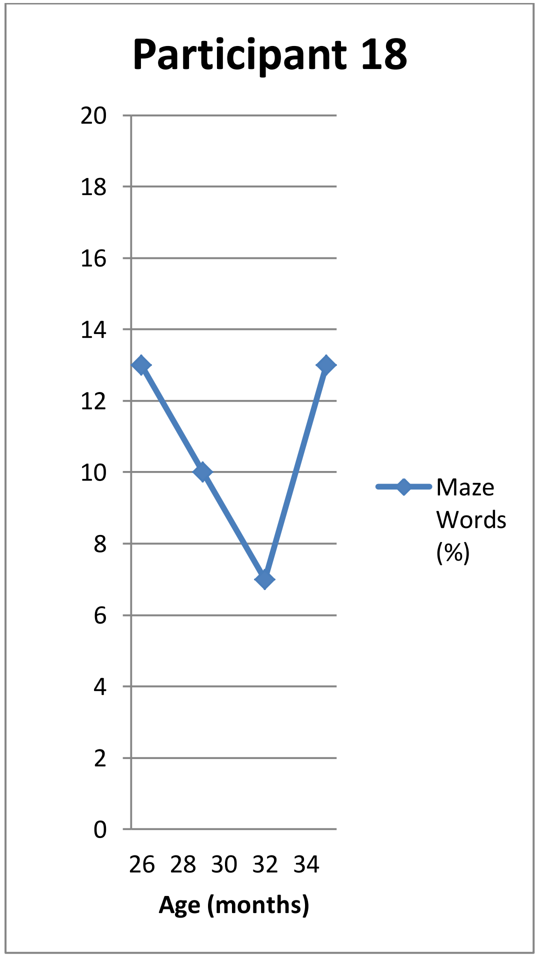

Participant 13
20
18
16
14
12
10
8
6
4
2
0
21 23 25 27 29
Age (months)
Maze Words (%)


Participant 14
20
18
16
14
12
10
8
6
4
2
0
23 25 27 29 31
Age (months)
Maze Words (%)

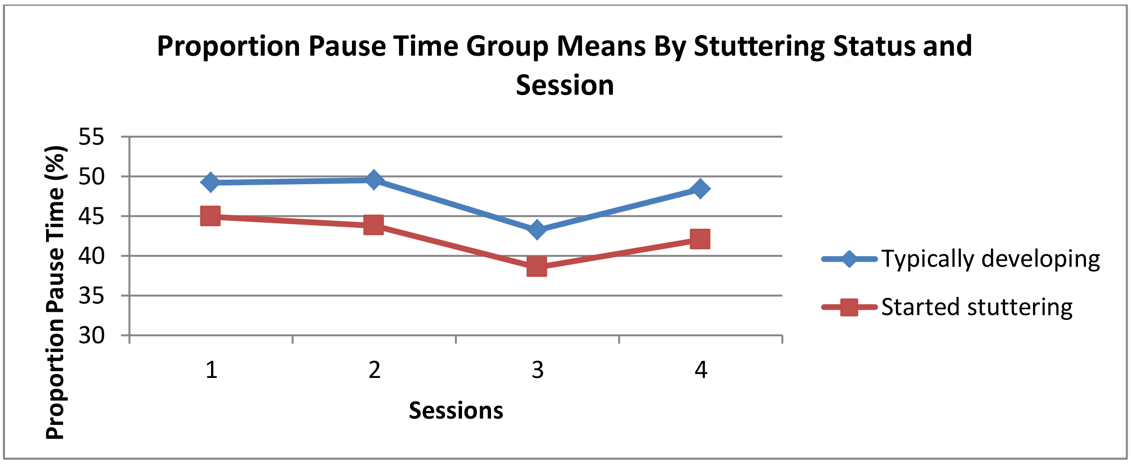

Participant 15
20
18
16
14
12
10
8
6
4
2
0
21 23 25 27 29
Age (months)
Maze Words (%)

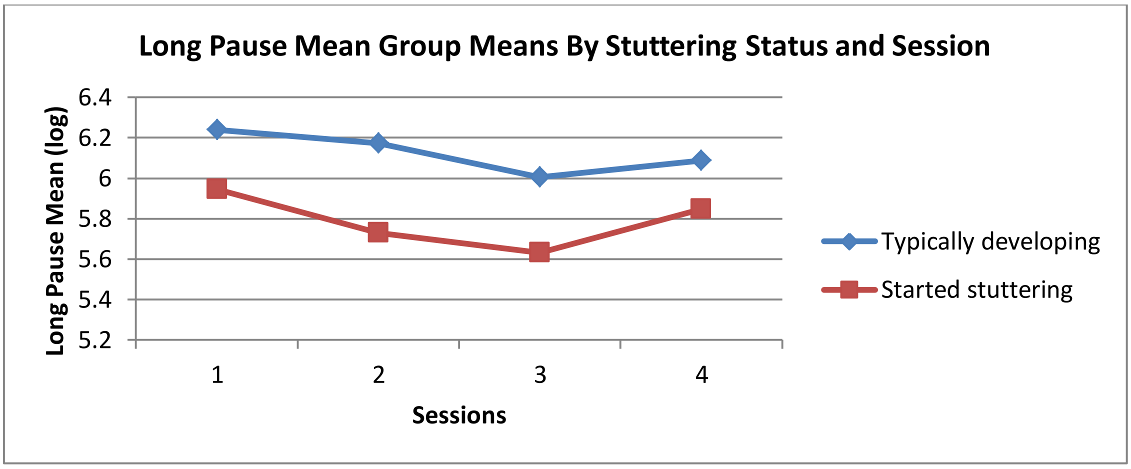

Participant 16
20
18
16
14
12
10
8
6
4
2
0
45 47 49 51 53
Age (months)
Maze Words (%)

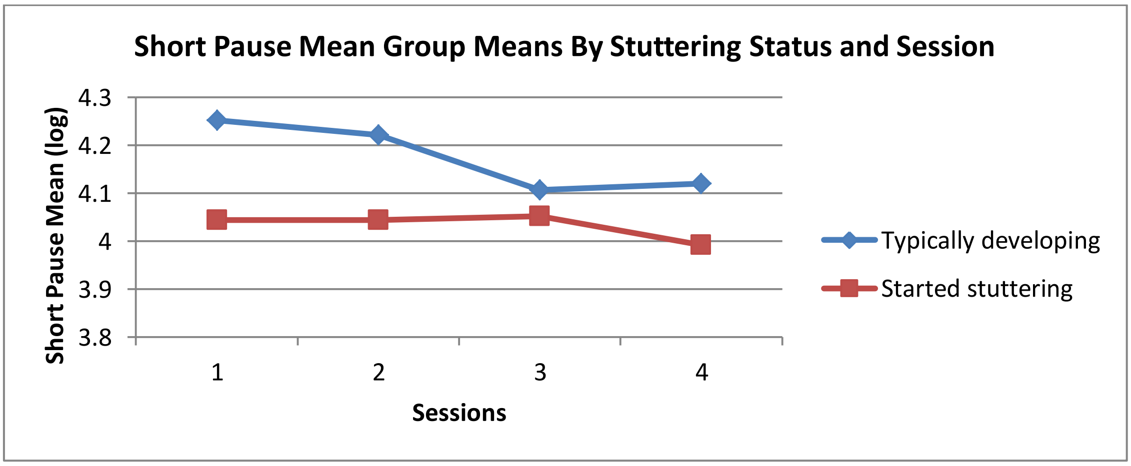

Participant 17
20
18
16
14
12
10
8
6
4
2
0
24 26 28 30 32
Age (months)
Maze Words (%)

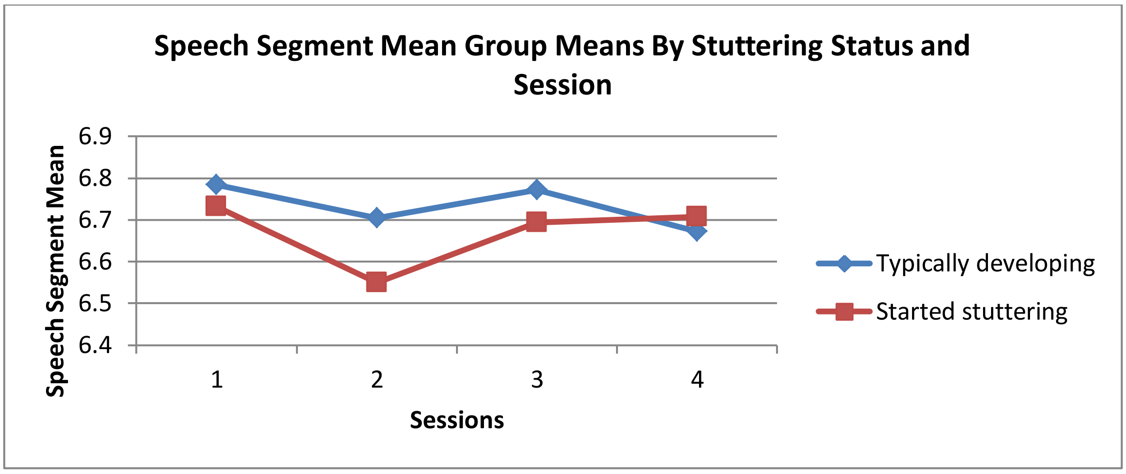

Participant 18
20
18
16
14
12
10
8
6
4
2
0
26 28 30 32 34
Age (months)
Maze Words (%)

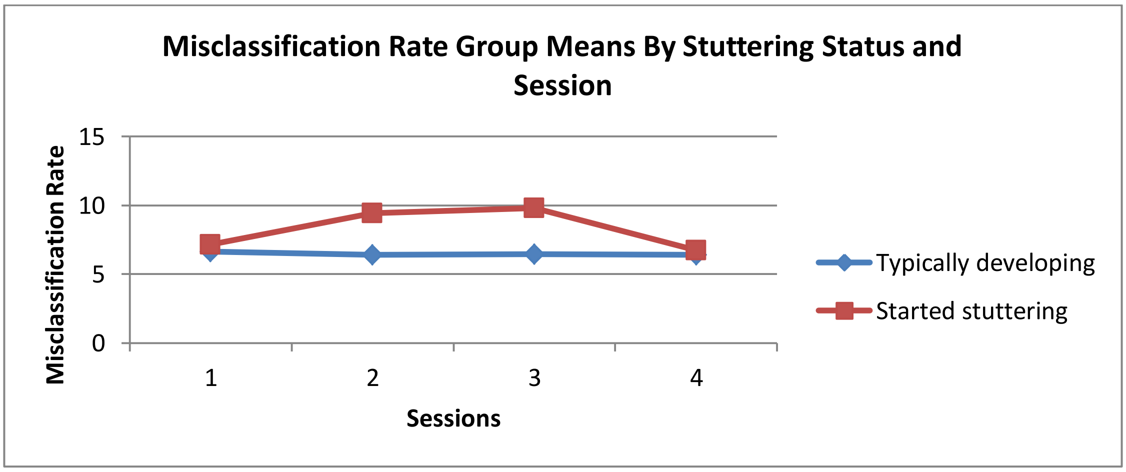
Appendix K: Study 1 Group Means for Speech and Language Measures by Stuttering Status and Session

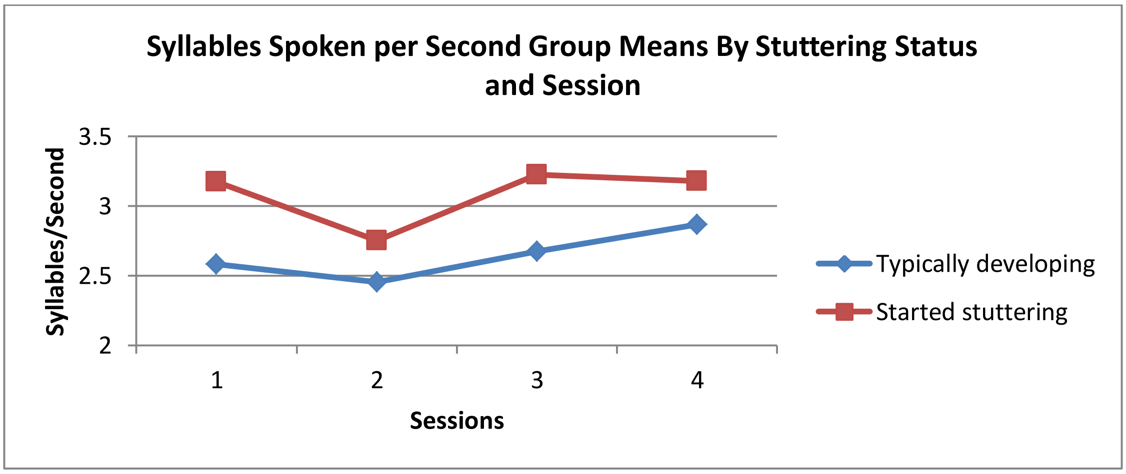


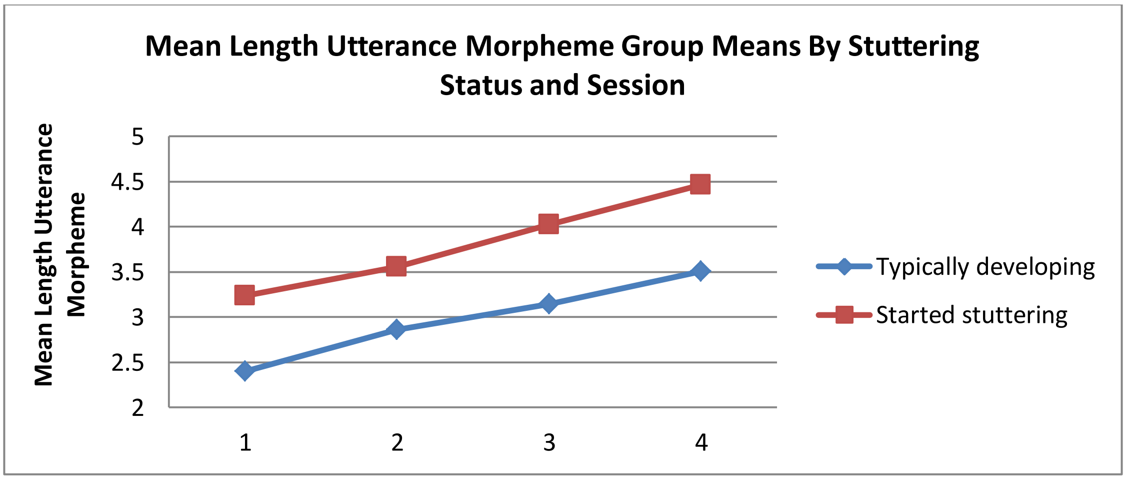


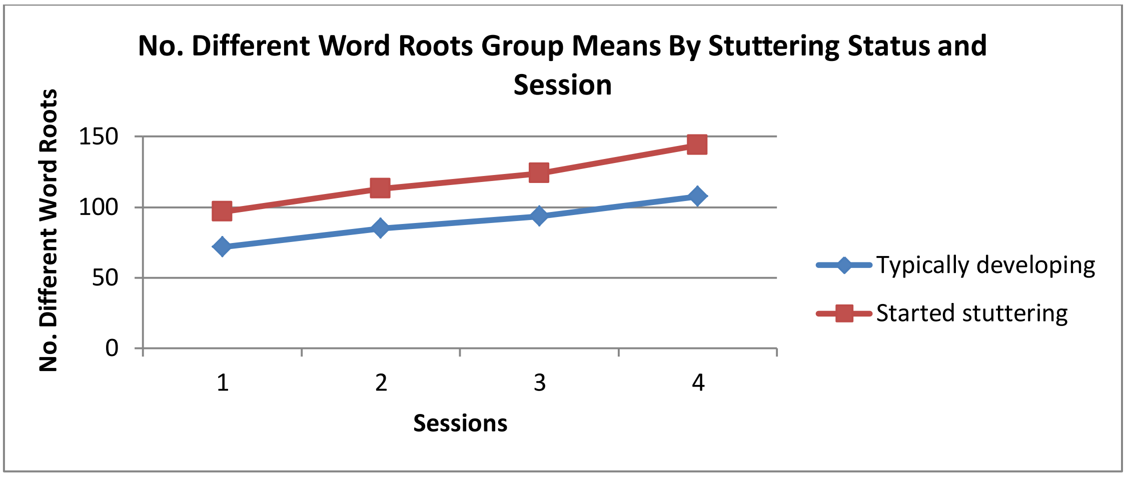


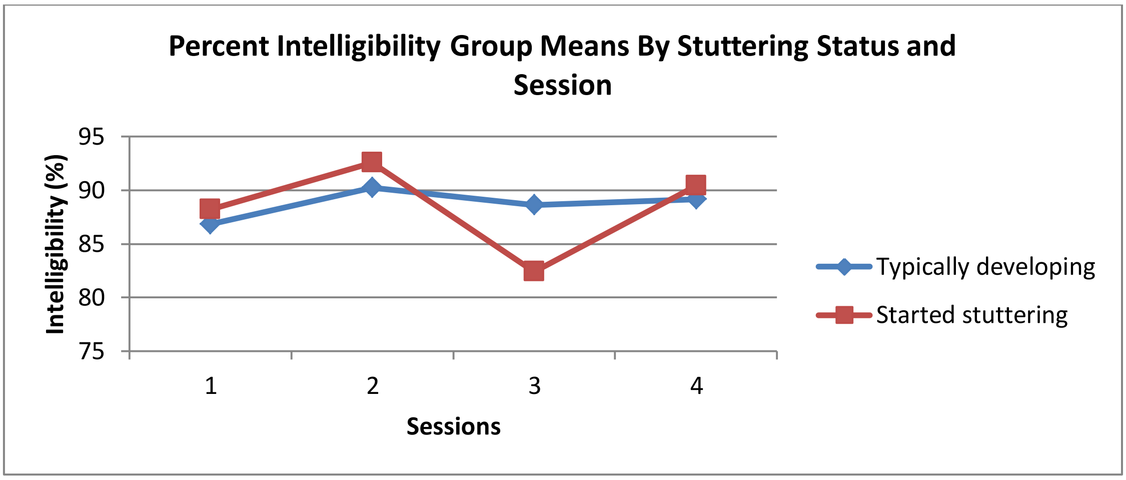

Speech Segment Mean Group Means By Stuttering Status and Session
Speech Segment Mean
6.9
6.8
6.7
6.6
6.5
6.4
1
2
3
4
Sessions
Typically developing
Started stuttering

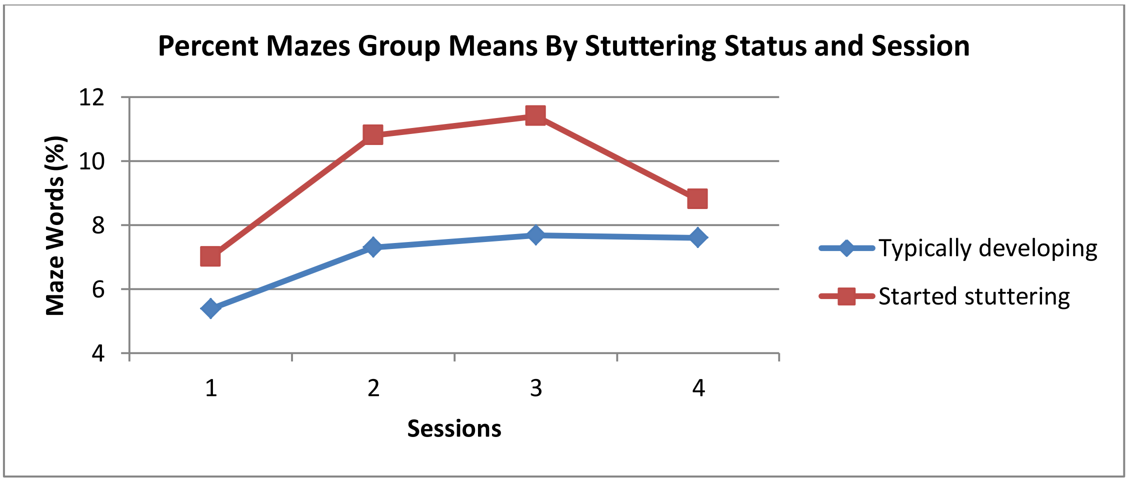

Misclassification Rate Group Means By Stuttering Status and Session
Misclassification Rate
15
10
5
0
1
2
3
4
Sessions
Typically developing
Started stuttering


Syllables Spoken per Second Group Means By Stuttering Status and Session
Syllables/Second
3.5
3
2.5
2
1
2
3
4
Sessions
Typically developing
Started stuttering


Mean Length Utterance Morpheme Group Means By Stuttering Status and Session
Mean Length Utterance Morpheme
5
4.5
4
3.5
3
2.5
2
1
2
3
4
Typically developing
Started stuttering


No. Different Word Roots Group Means By Stuttering Status and Session
No. Different Word Roots
150
100
50
0
1
2
3
4
Sessions
Typically developing
Started stuttering


Percent Intelligibility Group Means By Stuttering Status and Session
Intelligibility (%)
95
90
85
80
75
1
2
3
4
Sessions
Typically developing
Started stuttering


Percent Mazes Group Means By Stuttering Status and Session
Maze Words (%)
12
10
8
6
4
1
2
3
4
Sessions
Typically developing
Started stuttering

Appendix L: Study 2 Paediatric Case History Information Form

The information you provide on this form will provide us with some background information to ensure that we take all information into consideration when considering your child's difficulty in speaking fluently. All material and information will be kept strictly confidential. This form will be stored in secured departmental facilities, at The School of Animal Biology, University of Western Australia. Data will be accessed only by the listed researchers.

Date:
Person (s) Completing this form:
Relationship to child (parent, teacher):
General Information about the child:
Name: Date of Birth:
Current Age:
School and Grade:
Mother's Name: Father's Name:
Address:
Phone:
Email:

Please indicate mother's highest education level:

1. Highest Educational Level (please tick):
    - ☐ Primary School
    - ☐ High School (year 10)
    - ☐ High School (year 12)
    - ☐ TAFE or other further training institute
    - ☐ University
    - ☐ Other ______________________________

Please indicate father's highest education level:

1. Highest Educational Level (please tick):
   - ☐ Primary School
   - ☐ High School (year 10)
   - ☐ High School (year 12)
   - ☐ TAFE or other further training institute
   - ☐ University
   - ☐ Other ____________________________

Family History:

1. What are your child's living arrangements (e.g., living with both parents)?
2. Please list any siblings and their ages:
3. Is there a family history of stuttering or any other speech, language, learning, reading, attention or hearing problems? If yes, please indicate which family member and their relationship to the child as well as the nature of their difficulties:
4. Is English your child's primary language? If no, please indicate the primary language and any other languages that the child uses frequently:
5. Have any other specialists (physicians, psychologists) seen your child? If yes, please indicate the type of specialist, when your child was seen, for how long and the reason why:
6. As far as you know, did your child's speech and language develop in the same way as other children of similar age?
7. Please describe any differences in their developmental pattern when learning to use language or talk:
8. How has your child's general health been in the past? Good_____ Fair_____ Poor____
   If poor, please give details including age of illness/event.
9. How is your child's health presently? Good_____ Fair_____ Poor____
   If poor please give details.
10. Has your child ever been hospitalised? If yes, please state when, how old your child was, for how long he/she was hospitalised and state the reason:

11. Has your child had any feeding/eating problems? (E.g., any problems with sucking, tolerating specific food textures, swallowing etc…) If yes, please describe when and for how long the problems lasted:
12. Has your child had any ear infections? If yes, please indicate when what measures were taken to remediate that and if their ears are clear, how long has this been?
13. Has your child had their hearing tested? If yes, please state when and the outcome:
14. Do you have any current concerns about your child's hearing ability?
15. Do you have any other health related or developmental concerns regarding your child? Please indicate.

Stuttering Onset:

16. How old was your child when stuttering was first noticed?
17. Who first noticed it?
18. Please describe your child's speech and language when stuttering was first noticed:
19. Has your child's stuttering been diagnosed by a Speech Pathologist? If yes, please indicate when.

Development:

20. Please describe the your child's current stuttering behaviours (provide examples where possible):
21. Have there been any changes to the way in which your child stutters since it began? If yes, please describe:
22. List your child's typical reaction to his/her stuttering:
23. Treatment:

Please give details about treatment your child has received for his/her stuttering behaviours:

When Started (Date, and age of child at the time)	Where?	For how long been receiving this treatment?	What type of advice/therapy was given?

Appendix M: Study 2 Speech Sampling Protocol

From Jardine (2004).

Initial Greeting and Rapport (5-10 mins)

General introduction of self and the tasks. Introduction of the special reward. Inform child that they may make one selection from the sticker collection and that they may have that item once all the tasks are complete. Place the object behind the examiner, in plain sight of the child throughout the tasks.

Discourse Sampling

Today we're going tell some really long stories about lots of fun things. (Show child pictures of a train with a single carriage and a train with lots of carriages). We're going to tell stories that are long like this train (point to train with many carriages), not short stories like this tiny train (point to small train).

1. Let's tell some long stories (point to train with many carriages).

Do you know what my favourite game is? It's called Buckaroo. You can have four people play it. You all sit around a plastic donkey and you have each take turns at putting something on the donkey so he can carry it. You have to watch out though because the Donkey doesn't like to carry things so he might jump up and kick away everything he's carrying! If he does you're out of the game. So you have to be really careful and sneak up on the Donkey to give him something to carry. You can give him lots of things to carry like umbrellas, suitcases, lollies and lots of other fun stuff. The person who is sneakiest and doesn't make the Donkey jump up is the winner.

2. That was a long story about my favourite game wasn't it? What's your favourite game? I haven't played that game before; you'll have to tell me all about it! Remember to tell me a long story!

WOW! We're doing really well, I'm sure you're going to win (name of reward selected by child).

I just got a new toy last week. He’s my favourite toy in the whole world. He’s a robot and his name is Bobble! He’s a really big robot and he’s black and white with shiny red eyes. He can do lots of things. He can walk around the house and he chases my dog everywhere! He can dance and he can even do Karate chops! He even has a special bucket that he picks up and throws around. Sometimes he even tries to pick up my dog but he’s not strong enough. I can control him with a remote control and tell him what to do. Sometimes he’s a bit silly and he falls over and says “ouch!!” He’s my favourite toy because he can do all those different things and he’s really funny.

3. What’s your favourite toy in the whole wide world? WOW!! I’ve never seen one of those! You’ll have to tell me all about him/her/it Tell me a long story (point to train with many carriages) about ______

You know I was thinking that I would really like to be a superhero. If I was a superhero I would be Superman. I would be Superman because then I could wear a blue suit and a red cape and go flying around everywhere. If I was Superman I would be really strong so I could help the police catch lots of bad guys. I could fly around wherever I wanted and I could fly to the shops whenever I wanted to. I would like to be Superman because if I didn’t want to go to work I could just fly away!

4. If you could be a superhero who would you be? Yeah! What would you do all day if you were _____?

I’m going to tell you what I did yesterday, then you can tell me what you did. Remember we’re going to tell REALLY long stories Ok? Yesterday I did so many different things! First of all I got up and had a really big breakfast with lots of yummy things like eggs and bacon. Then I went out shopping and saw lots and lots of things that I would really like to buy. While I was at the shop I brought these stickers that I thought everyone at school might like. And then I watched lots of TV and had a really good lunch. After that I played with my PlayStation 2 and then I had dinner and went to bed.

5. That was a long story wasn’t it? Now tell me all the exciting things you did yesterday!

Appendix N: Study 3 Adult Case History Information Form

Form from Hennessey, Nang, & Beilby (2008).

Participant Number (office use only):

2. Date of Birth:
3. Suburb of Residence:
4. Highest Educational Level (please tick):
   - ☐ Primary School
   - ☐ High School (year 10)
   - ☐ High School (year 12)
   - ☐ TAFE or other further training institute
   - ☐ University
   - ☐ Other ______________________________

The following questions pertain to any previous treatments you have received for your stutter.

5. Are you currently receiving treatment for your stutter? If no, please refer to question 5). If yes, please answer the following questions about your current treatment:
   a. What type of treatment is it/the focus of the treatment?
   b. When did you start this treatment?
   c. How long have you been receiving this treatment?
   d. How often do you have treatment sessions (per week) and for what duration are these sessions?
6. If you are not currently receiving any treatment for you stutter please detail the most recent (last) treatment.
   a. What type of treatment was this/main focus of this treatment?
   b. When did you start this treatment?
   c. When did you stop this treatment?
   d. Your age at the time of commencement of this treatment.
   e. Was this service provided by a Speech Pathologist?

7. Please detail other previous speech therapy:

Start and Finish Date of Treatment	Your Age at the time	Description of Treatment	Service Provider (optional)

The following questions pertain to any control/fluency techniques you currently use/have used to control your stutter. This includes aspects of smooth speech (gentle onsets, continuous airflow), breathing techniques, slower speech rate etc…

8. Do you currently use any control techniques for your stutter? If no, please refer to question 11). If yes, please answer the following questions:
    a. What techniques do you currently use to control your speech?
    b. Where did you learn these techniques? If you were part of a speech training program (e.g. intensive smooth speech program), please detail where, when, the profession of the service provider and the duration of the program.
    c. How long have you been using these techniques to control your speech?

9. For how many hours do you use the above techniques in:
    a. A day
    b. A week

10. Do you practice these techniques? If yes, for how many hours do you spend practicing these techniques by yourself or with someone else? This includes time spent in group meetings and maintenance days (as part of self-help).
    a. Per day
    b. Per week

11. In what situations/for what purposes do you use these techniques (please tick)?

☐ Conversation with familiar people (family, friends)

☐ Conversation with unfamiliar people

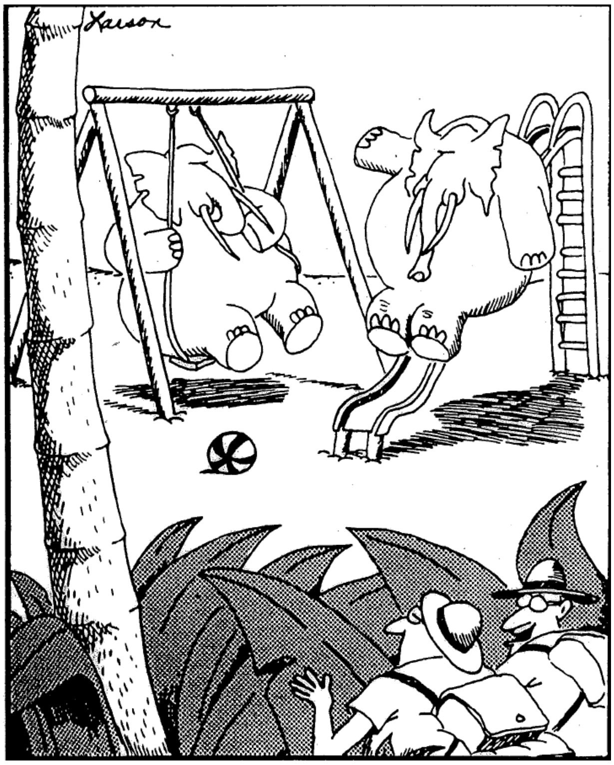
- ☐ At your work place
- ☐ Presentations/speaking in front of a group
- ☐ On the phone
- ☐ Interviews
- ☐ Reading aloud
- ☐ Ordering food/making an enquiry
- ☐ Other please list:

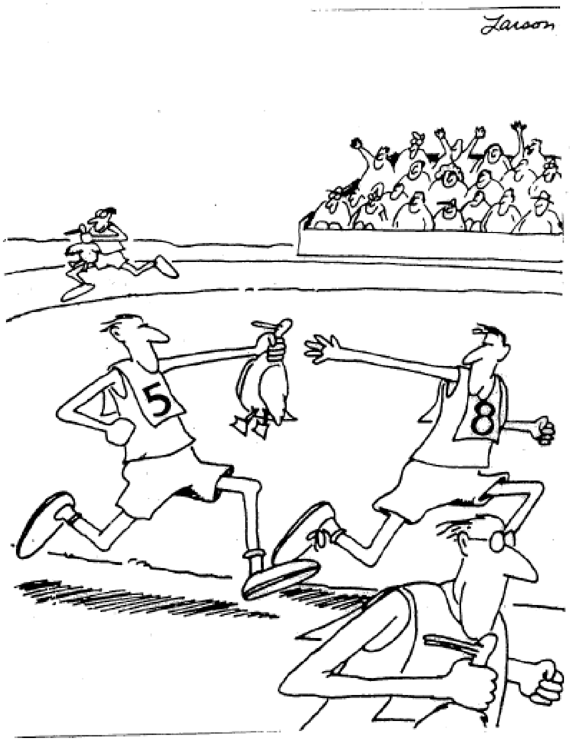
12. Does anyone else in your family have a stutter (immediate and extended)?

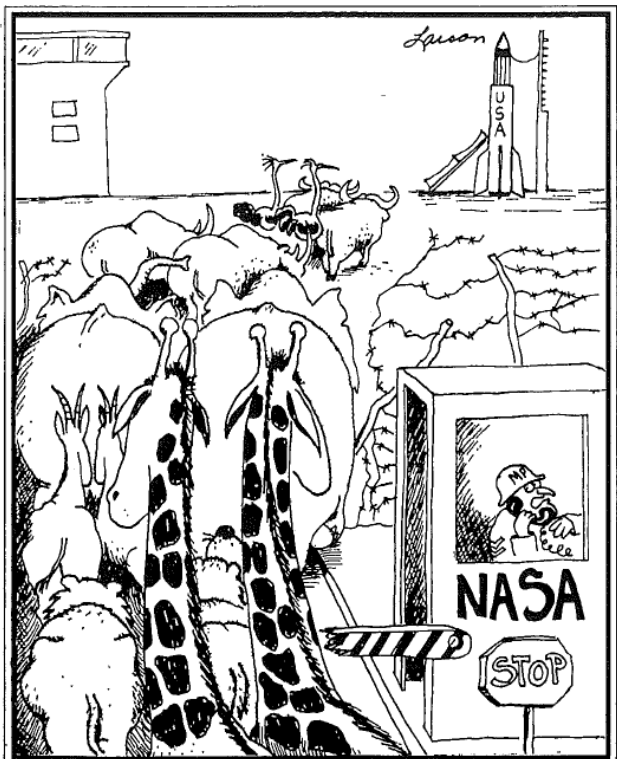
    If yes, please indicate who they are and their age.

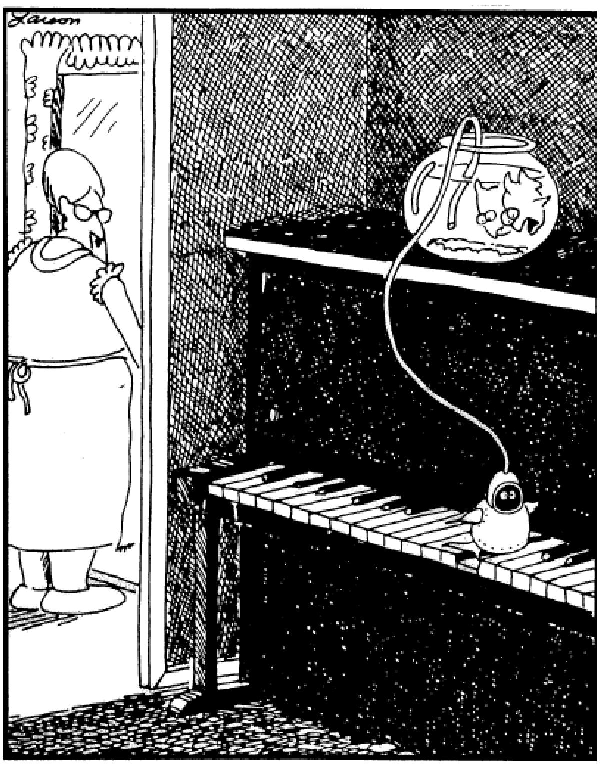
Appendix O: Study 3 Picture Stimuli for Speech Sampling Protocol

Picture stimuli from Larson (1989).






Larson
USA
MP
NASA
STOP


Larson

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