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Speech and Language Processes in Children Who Stutter Compared to Those Who Do Not Within an Oral Narrative Task

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Abstract

Background and Purpose: Language ability in children who stutter has been linked to the occurrence of stuttering, however, the validity of research supporting this connection has been recently questioned. Previous research, within this area, has been limited by methodological confounds, such as lack of appropriately matched comparison groups, and the use of measures with insufficient sensitivity to potentially examine the subtle differences between children who stutter (CWS) and children who do not stutter (CWNS). Frequent hesitations or pauses are defining characteristics of the speech of people who stutter. However, little is known about the nature and frequency of the pauses found within the speech of CWS. Examination of pauses within speech is a novel method of analysing speech production with the potential to provide insight into the speech and language processing and an opportunity to explore differences between normal and disordered speech. This study aimed to compare the speech and language processes of CWS to CWNS.

Methods and Procedures: This study compared language and pause measures taken from narrative samples of age (Mean age = 6 years and 10 months) and gender matched CWS (n= 6), and CWNS (n= 6). The oral narratives were collected using a story generation task and were transcribed and analysed using the Systematic Analysis of Language Transcription (SALT) (Miller & Iglesias, 2012). For each sample the mean length of utterance in morphemes, the total number of utterances, the number of different word roots, the % intelligible words and the % words in mazes were calculated. Additionally the computer software programme PRAAT was used to segment the samples into sections of speech and pauses and the segmented samples were transformed into two lognormal pause distributions (Boersma, & Weenink, 2013). The pauses of CWS were analysed twice, once with stutters present and once with stutters removed. For the two groups the results from the language and pause analyses were compared through t-tests and the relationship between Percent Syllables stutters, and the pause and language measures, was examined through correlation.

Results: For all discourse and pause measures the difference between the CWS and CWNS was not significant. The only significant difference was found between the CWS and CWNS in the degree of overlap of the short and long pause distributions (Misclassification Rate) in the samples of CWS, when stutters were present. Percent Syllables Stuttered was found to be significantly positively correlated with Percent Mazes and Syllables Spoken per Second when stutters were present in the samples of CWS. Percent Syllables Stuttered was found to be significantly negatively correlated with Short Pause Mean with stutters present in the samples of CWS.

Conclusions: In this study, the connection between stuttering and language was not supported as the language measures gathered from CWS were all found to be similar to those gathered from CWNS. The findings in this research support explanations of stuttering in which stuttering is attributed to factors exclusive to language ability, such as stuttering being a difficulty in speech motor control.

Keywords: Stuttering, Speech, Language, Narrative, Pausing.

Speech and Language Processes in Children Who Stutter Compared to Those Who Do Not Within an Oral Narrative Task

1. Introduction

Developmental stuttering is a fluency disorder that typically emerges in the first two to four years of life (Yairi, 2004) and has an incidence of approximately 5% and a prevalence of approximately 1% (Bloodstein & Bernstein Ratner, 2008). A major contributor to the difference between incidence and prevalence of stuttering is the occurrence of spontaneous recovery in approximately 80% of children who start to stutter (Bloodstein & Bernstein Ratner, 2008; Ward, 2006). Of those who do not spontaneously recover, some respond well to current treatments and are able to achieve some degree of controlled fluency (Ward, 2006). However, it is common for treatment effectiveness to wane and for the individual to lose their controlled fluency (Ward, 2006). For those who do not respond to treatment or who experience relapse, stuttering can have a significant negative impact on their lives; such as decreased social interaction and speech avoidance, social anxiety, difficulty obtaining, maintaining and progressing within chosen employment, and marginalisation (Craig, Blumgart & Tran, 2009; Keodoot, Bouwmans, Franken & Stolk, 2011; Blumgart, Tran & Craig, 2010; Yaruss & Quesal, 2006).

1.1. Stuttering Language Connection

Previous research has investigated the development of language skills in children who stutter (CWS) and researchers within the field have proposed a connection between language development and use, and stuttering (Bajaj, 2007; Ntourou, Conture & Lipsey, 2011; Watkins & Johnson, 2004). This link has been called the stuttering-language connection (Nippold, 2012) and it has been explored in theories explaining the emergence of stuttering (Ward, 2006). The premise that language development and stuttering are linked has come from observations of CWS. For example, there is an overlap between the typical onset of stuttering and the period of time in which children typically experience rapid growth in language skills (Yairi, 2004). Additionally, stuttering has been found to increase in frequency as children experience greater demands on their language system, such as attempting to produce utterances of increasing length (Brundage & Bernstein Ratner, 1989; Reilly et al., 2009) and complexity (Bernstein Ratner & Sih, 1987; Bloodstein, 2006). As the cause of stuttering and the underlying processes that contribute to stuttering are yet to be determined developing an understanding of a potential link between stuttering and language may have clinical implications. Understanding these factors could lead to the development of more effective and more appropriate treatment methods that aim to target the underlying processes that cause stuttering. However to date, a range of methodologies have been used to examine whether there is a connection between stuttering and language, resulting in mixed findings (Bajaj, 2007).

Bernstein Ratner and Silverman (2000) used standardised tests to examine the language abilities of CWS and children who do not stutter (CWNS). They found that though the CWS performed within normal limits as a group, they achieved a lower mean score on all assessment measures (Bernstein Ratner & Silverman, 2000). Additionally, Bernstein Ratner and Silverman (2000) collected spontaneous language samples during play and analysed these to gather mean length of utterance in word, morphemes and syllables (MLUw, MLUm & MLUs), Type-Token Ratio (TTR), a measure of functional vocabulary skills, and Lexical Rarity. As a group, the CWS achieved lower mean scores for all MLU measures. They scored statistically significantly lower than CWNS for Lexical Rarity, but achieved an identical TTR mean, (Bernstein Ratner & Silverman, 2000). Bernstein Ratner and Silverman (2000) interpreted their research results in light of the Demands and Capacities model of stuttering (Adams, 1990; Starkweather & Gottwald, 1990). This model suggests that stuttering is the result of a dynamic interaction between the demands placed on a child's speech and language system, and the capacities of that child's speech and language system to meet these demands (Siegel, 2000). This dynamic interaction means that speech output can be affected by subtle changes in the speech and language system. The demands component of the model refers to conditions in the child's environment that may pose a challenge to the child's ability to produce fluent speech; such as speaking under the pressure of time constraints, expressing complex messages, or fear of being criticised for making speech errors (Siegel, 2000). The capacity component of the model refers to the underlying abilities of the child (Siegel 2000). Capacities cannot be directly observed but can be inferred by examining the speech and language performance of a child (Siegel, 2000). Based on this model, Bernstein Ratner and Silverman (2000) concluded that CWS had lower language ability than CWNS. CWS were more likely to experience demands on their language systems that exceeded their capacity for fluent speech suggesting CWS may have a reduced capacity to produce fluent speech (Bernstein Ratner & Silverman, 2000; Adams, 1990; Starkweather & Gottwald, 1990).

Other studies have also used language sampling to examine the language abilities of CWS compared to CWNS (Bajaj, 2007; Trautman, Healey, Brown, Brown & Jermano, 1999; Weiss & Zebrowski, 1994). Bajaj (2007) collected oral narratives from CWS and CWNS and compared them on the measures of length of the narrative sample, variation of tense, and syntactic complexity. Another study collected narrative re-tell and generation samples and compared performance between CWS and CWNS, specifically investigating measures of narrative complexity and cohesion (Trautman et al., 1999). There were no significant between group differences in either study and the authors concluded that CWS have similar expressive language abilities to their non-stuttering peers (Bajaj, 2007; Trautman et al., 1999).

The stuttering-language-connection has more recently been questioned in a literature review by Nippold (2012). Nippold (2012) investigated the connection between stuttering and language ability. She aimed to determine whether CWS were more likely to have weak or disordered language compared to CWNS, and whether a language deficit is associated with stuttering onset or if stuttering restricted children's development of language skills. Within her review Nippold (2012) questioned the validity and reliability of a number of previous studies and stated that findings were often compromised by methodological confounds. These methodological confounds included small sample sizes and a lack of appropriately matched comparison groups when considering variables that are associated with language development, such as age and gender (Nippold, 2012; Watkins & Johnson, 2004). Through the review Nippold (2012) found that the connection between stuttering and language was not supported and instead suggested that stuttering reflected a difficulty of speech motor control, the processes governing the coordination and control of articulatory subsystems, such as movement of the lips, jaw, tongue and larynx (Löfqvist & Lindblom, 1994). As such Nippold (2012) concluded that alternatives to the stuttering-language-connection perspective should be considered to expand the stuttering knowledge base, such as investigating the speech motor control abilities of CWS.

Nippold's (2012) review was focused on research that asked whether CWS are more likely to have a language deficit, rather than considering whether CWS have a language difference compared to CWNS. To date little research has investigated the potentially subtle differences between CWS and CWNS who are within the range of typically language development and mixed findings have resulted from studies that have investigated this difference within narrative tasks. Investigating whether CWS have a language difference compared to non-stuttering peers may require measures that are more sensitive to these differences in language ability than those used in previous research. Language difference may take the form of subtle features present within the normal range of language ability and different methods of analysis, such as the investigation of the production of pauses within speech.

1.2 Pausing Within Speech

The World Health Organisation (2010, para. F98.5) defines stuttering as "speech that is characterised by frequent repetition or prolongation of sounds or syllables or words, or by frequent hesitations or pauses that disrupt the rhythmic flow of speech". Of particular relevance to this research is the statement that frequent hesitations or pauses is one of the defining characteristics of the speech of people who stutter. However, little is known about the nature of the hesitancies or pauses found within the speech of people who stutter.

Natural speech contains intervals of silence and noise. The noise component of speech typically receives most of the attention in research and in the clinical setting, however, a significant portion of speech time is made up of pauses and these pauses are an essential component of speech. The intervals of silence (or pauses within speech) occupy 40-50% of speaking time for adults (Goldman-Eisler, 1968). Pausing is used by the speaker to provide time for speech and language planning and execution (Goldman-Eisler, 1968). For example time is needed for word retrieval, utterance formulation, for the speaker to physically move the articulators to form speech sounds (Goldman-Eisler, 1968) and for the speaker to breath while talking (Davis, Zhang, Winkworth & Bandler, 1996). Pausing has been related to a range of communicative functions, such as marking discourse boundaries and signalling anxiety or emphasis (Esposito, Stejskal, Smékal & Bourbakis, 2007). Additionally, pauses assist the listener in segmenting the speech signal to facilitate the process of auditory comprehension (Esposito et al. 2007).

Goldman-Eisler (1968) investigated pausing and described three general causes of pausing within speech; time taken shifting between articulatory postures, hesitations relating to speech and language planning, and pausing related to breathing. Goldman-Eisler (1968) presented participants with cartoons and compared pausing durations on a description task versus an interpretation task to examine whether task complexity impacted on the duration of pausing within oral language samples. She found pause durations increased during the more complex interpretation task, and that pause duration decreased when tasks were repeated. Goldman-Eisler (1968) concluded that longer pauses were related to speech planning and conceptualisation.

There has been little previous research into the production and development of pausing in children (Nang, 2012). Kowal, O'Connell and Sabin (1975) investigated the frequency of pause durations in children during narrative tasks and compared pause durations across age groups. Kowal and colleagues (1975), found that the frequency and duration of pauses decreased with children's age. They attributed this to the articulatory structures of younger children being less practiced in the production of speech sounds, resulting in articulation movements taking longer than in older children and adults, who are more practiced at moving quickly between speech sounds (Kowal et al., 1975). Further research is needed into the pausing of CWS as research in this area has the potential to provide important information about language ability and impairment.

In the past, methodological issues related to pause analysis procedures have been a barrier to the use of pausing in the analysis of language samples (Hird & Kirsner 2010; Little, Oehmen, Dunn, Hird & Kirsner, 2013). To overcome the limitations of early pause analysis procedures, a new approach called 'The Fluency Profiling System' was developed (Hird & Kirsner 2010). The Fluency Profiling System was developed to aid the segmentation of speech samples and the analysis of pausing within spontaneous speech samples (Hird & Kirsner 2010; Little et al., 2013). Previous research has shown that pause duration distributions of non-disordered speech reveals bi-modal log-normal distributions (Kirsner, Dunn & Hird, 2003).

The two peaks of these bi-modal log-normal distributions correlate to pause duration distributions: short and long pauses (Hird & Kirsner 2010).

The existence of the two distributions can be used to investigate the subset of skills required for speech production (Hird & Kirsner 2010). The short pause distribution is hypothesised to reflect pauses related to speech motor control and execution (Hird & Kirsner 2010). Hence, those processes relate to the articulatory level of speech production, of Levelt's (1993) model. Long pause distribution is hypothesised to reflect pauses related to breathing, as well speech and language planning processes that are described by Levelt (1993) as the conceptualisation and formulation processes. Data analysis using the Fluency Profiling System has the potential to provide us with important insights into the level of breakdown within the speech production system of CWS. A difference between the pausing profiles of CWS compared to children who do not may indicate the underlying component that is contributing to disfluent speech (Hird & Kirsner 2010).

It is recommended that pauses are measured in naturalistic speech samples as contrived speech sampling, such as repeating dictated segments of speech, eliminates the ability to measure cognitive process within speech (Little et al, 2013). Narratives are valid as a language sampling genre (Botting, 2002) as they occur naturally in children's communicative environments and can represent the way in which children use language in their everyday communicative contexts (Baja, 2007; Botting, 2002). Oral narrative has been used in previous research as a form of language sample for the analysis of children's language (Bajaj, 2007) as it can provide information about the child's language across a range of domains; such as comprehension, grammar, tense, vocabulary and sentence complexity (Engel, 1995). Narrative ability in children has also been shown to be highly correlated with other language measures and therefore performance on narrative tasks can be said to be indicative of overall language ability (Bajaj, 2007; Paul & Smith, 1993).

1.3 Study Aims

The mixed evidence for the stuttering-language connection suggests that further investigation is needed in order to clarify the nature of this potential connection. This study aimed to examine speech and language processes in CWS compared to CWNS within an oral narrative task to determine whether there is a difference between the speech and language processes of the groups. If a difference was found, this study aimed to describe the difference between the two groups. The study took into account the limitations of previous research as suggested by Nippold (2012) and compared the narrative samples of age and gender matched groups. In addition, this study aimed to investigate language difference, rather than impairment, and used the novel measure of pause analysis to extend previous findings. Investigation of language measures that has been gathered as a part of previous research such as SALT measures, as well as analysing pauses will provide a more comprehensive view of the speech and language processing system to be examined. It was hypothesised that a difference will be found between the speech and language processes of CWS compared to CWNS and that these differences would be reflected in the speech and language measures and the results of the pause analysis.

2. Methods and Materials

2.1 Design

A between groups design was used to compare the pause and language measures of CWS to those of CWNS. The study used de-identified narrative samples collected as part of a larger study that have not been previously analysed or reported (Nang, 2012). The analyses involved measures aimed to provide information on the language abilities and speech and language processes of CWS compared to CWNS. Within group comparisons were also conducted to compare the pausing of CWS, with and without stutters removed from the samples, to explore associations between the clinical stuttering measure of percent syllables stuttered to speech and language output.

2.2 Participants

This study analysed the oral narrative samples of 12 children, 6 of whom had been diagnosed with a stutter (CWS) and 6 whom had not (CWNS). Of the 6 CWNS, each one was chosen as a gender and age match to a CWS. For the participants in both groups the inclusion criteria were: an absence of a diagnosis of a previous neurological, psychological or intellectual impairment; no history of hearing difficulties; and English as first language. None of the children had parent-reported concerns or difficulties with speech and language development at the time they participated in the study. The participants in the stuttering group had a diagnosis of stuttering by a qualified speech pathologist. For participants with a stutter, the amount of previous therapy was not controlled. Participants in the control group were required to have no previous diagnosis of stuttering.

Nang (2012) recruited children who stuttered through advertisements placed in community newspapers and through contacting Perth metropolitan speech pathology services. Children who did not stutter were recruited via word-of-mouth.

The mean age of the stuttering groups was 80.17 months (SD = 15.87) and the mean age of the control group was 84.67 (SD = 15.46). The mean difference in age between matched participants was 4.5 months and this was not significantly different between the groups $t(10) = -0.498$, $p>.05$. Stuttering participants' narrative samples were analysed for stuttering severity by percent syllables stuttered (%SS) and the mean was 4.05%SS (SD = 3.19). The mean time since onset of stuttering was 30.17 months (SD = 20.45). Table 1 shows the age and gender of the individual children in the two groups, as well as the percent syllables stuttered (%SS) and time since onset of stuttering for the stuttering participants in the study.

Table 1

Participant Data

Group	Age (Months)	Gender	%SS in Narrative Sample	Time Since Onset (Months)
Stuttering	63	M	2.8	33
	76	M	2.5	58
	90	M	6.6	48
	107	M	9.3	23
	70	F	1.2	16
	75	M	1.9	3
Controls	64	M	-	-
	86	M	-	-
	95	M	-	-
	108	M	-	-
	75	F	-	-
	80	M	-	-

Note. %SS=Percentage of Syllables Stuttered

2.3 Materials

The language samples collected by Nang (2012) were recorded using a Panasonic NV-GS300 mini DV camera with an external microphone. Adobe Premiere Pro 2.0 was used to capture the audio/video recordings onto a desktop computer. Audio files were imported into PRAAT (Boersma & Weenink, 2013) for analysis in accordance with the Fluency Profiling System (Little et al. 2013). Systematic Analysis of Language Transcripts (SALT) (Miller & Iglesias, 2012) was used for the transcription and analysis of the language samples. MATLAB (Version 7.0) software (MathWorks, 2004) was used for the analysis of the pausing data and logarithmic transformation of the data into two log-normal distributions.

2.4 Procedure

2.4.1 Speech Samples

The narrative samples were collected in participants' homes, in a quiet room, as free from distractions as possible. The narrative samples were collected using a story generation task based on the wordless picture book "Frog, Where Are You?" by Mayer (1969). The examiner did not tell the story to the child but rather looked through the pages of the book with the child. The child then told the story from the pictures. The examiner provided brief prompts as needed to keep participants on task, such as "Keep going" and "Tell me what's happening in the story". The examiner avoided asking direct questions about events in the story and allowed participants to control the turning of pages so they told the story at their own pace. The narrative samples were video and voice recorded and the audio component of the recordings were converted into WAV audio files so that they could be imported into SALT and PRAAT.

2.4.2 SALT Procedure

The language samples were transcribed into SALT following SALT transcription conventions, using the communication unit (C-unit) as the basis for utterance segmentation (Miller, 2008). A C-unit is a unit of speech that cannot be further divided without removing an essential component of meaning, and is defined as "an independent clause and its modifiers" (Miller, 2008, p. 20). The transcripts were then analysed and a SALT Standard Measures Report was produced for all samples.

2.4.2.1 SALT measures

- Mean Length of Utterance in Morphemes (MLUm): a commonly used measure of syntactic complexity that has been found to be significantly positively correlated with age (Miller, 2008).
- Number of Different Word Roots (NDWR): a measure of lexical diversity that is calculated by summing the number of different words found in a language sample (Miller, 2008). In order for the NDWR to be compared across language sample, the samples must be of equal length, as NDWR may be influenced by the overall length of

the sample (Miller, 2008). As the samples that were analysed in this study were of differing lengths this measure was calculated based on the child's first 22 utterances of each sample, as this was the total length of the shortest sample.

- Total Number of Utterances: a measure that can be linked to language ability.
- Percentage of Intelligible Words: a measure of articulatory proficiency or clarity of speech production.
- Percentage of Maze Words to Total Words: provides a measure of disfluency within a speech sample as it measures the number of words found in filled pauses, false starts, revisions and repetitions compared to the number of total words (Miller, 2008). Percentage of maze words to total words is not correlated with age but can be indicative of language difficulties (Miller & Iglesias, 2012).

As the groups are the same age, any difference between the groups in those measures highly correlated with age could indicate speech and/or language processing difference between the two groups (Miller & Iglesias, 2012).

2.4.2.2 SALT Reliability

To ensure validity and reliability of the SALT language transcription, a transcript was randomly chosen for review by two speech pathologists experienced in SALT transcription. This review allowed for the accuracy of the transcription and adherence to SALT transcription conventions to be established.

2.4.3 PRAAT Procedure

For the pause segmentation the WAV audio files were imported into PRAAT for annotation to text-grids and segmentation into periods of speech and pause. The procedures used in the studies by Kirsner et al (2002) and Nang (2012) for the segmentation and transformation of pauses were also used in this study and will be summarised here. The minimum pause time cut-off used was 20 milliseconds. Pauses shorter than 20 milliseconds were included as parts of speech. All segments containing words, single phonemes, unintelligible speech, filled pauses, laughter, sound effects associated with speech or verbal play, or any other sounds involving vocal tract activity were coded as speech, as they were thought to be associated with a communicative functions and did not reflect a true pause. If sections of examiner's speech were present within the samples, these sections were coded and later removed from the sample in addition to the next line of the pause data of the child. In order to examine how sections of stuttered speech differed to sections of the perceptually fluent speech of the CWS, samples of CWS were analysed with and without stutters removed from the samples. Stutter removal was achieved by reviewing the output of the PRAAT analysis and deleting sections coded as containing a stutter. The segment of speech immediately following the sections coded as containing a stutter were also removed, as these sections may have also been impacted by the stuttered segment of speech.

Following the segmentation of samples into periods of speech, pause and stutter, the text-grids were analysed in accordance with the Fluency Profiling System (Little, 2013) using MATLAB software. The samples of the CWS were analysed twice, with the stutters included and then with the stutters removed. The speech that remains once stutters have been removed from a speech sample is termed the individual's 'residual fluency'. Examining the residual fluency of CWS allows us to investigate whether the speech of CWS is different from CWNS even when stutters are removed, and whether the breakdown in the speech and/or language systems of CWS which causes stuttering, is also present when CWS are not stuttering. Once the Fluency Profiling System was complete, the data formed two log-normal distributions that was able to be analysed using statistical tests and comparisons between groups.

2.4.3.1 Pause measures

- Short Pause Mean
- Short Pause Mean Probability (Percentage)
- Long Pause Mean
- Long Pause Mean Probability (Percentage)
- Proportion Pause Time (Percentage)
- Misclassification Rate (Percentage): a measure of the degree of overlap of the short and long pause distributions (Little et al., 2013).
- Distribution Threshold: measures the point at which the short and long pause distributions intersect, which is the point at which all shorter pauses are classified as ‘short pauses’ and all longer pauses are classified as ‘long pauses’ (Little et al., 2013).

2.4.3.2 PRAAT Reliability

To ensure accuracy of the pause segmentation the segmentor underwent a process of training and practiced segmenting a range of adult and paediatric language samples prior to analysing the samples of speech for this study. The practice segmentations were compared to segmentations of the same samples completed by another researcher and any discrepancies were discussed. Segmenting the samples into portions of speech and pausing was found to involve an element of subjective judgement regarding where speech ends and pausing begins, and vice-versa, therefore a standard procedure for segmenting speech and pausing was required for the reliable segmentation of the samples. No standard procedure for the segmentation of speech/pauses was found to be previously documented so a standard procedure was developed and can be found in Appendix B. This standard procedure was used for the segmentation of all the participants’ samples in this research.

To confirm acceptable reliability, two segmentors segmented one sample independently and compared the segmentations to determine the level of agreement for segmentation. In analysing 50 segments agreement rate on segmentation into speech and pausing was 92% and within those 50 segments 79% of the stutters were agreed upon for a sample of speech from a child who stuttered.

2.4.4 Other Measures

- Percent Syllables Stuttered (%SS) – used as an instrumental rating of stuttering severity. Speech samples were rated by identifying stuttered disfluencies using the syllable as the unit of measurement. Samples were analysed on-line using an electronic button-press stutter vs. syllable event counter. A stutter was defined as a disruption in the fluency of speech output, characterised by an involuntary part or whole word repetition or prolongation, or an involuntary block in speech output (Damico, Müller & Ball, 2010).
- Syllables spoken per second (SSpS) – a measure that has been found in previous research to have a moderate to strong correlations with stuttering severity measures (Logan, 2011). Syllables spoken per second is a measure of articulation rate with long pauses removed. It was gathered by identifying the number of syllables spoken divided by the time of the sample in seconds, using the transcript produced by the Fluency Profiling System where all long pauses have been removed. For CWS this procedure was conducted with and without stutters in the sample.

2.4.5 Statistical Analyses

The measures gathered from the SALT, the pause analysis and SSpS were compared between the two groups using independent samples t-tests, with stutters present and with stutters removed from the pause measures of the CWS. Paired samples t-tests were used to compare the pause measures and SSpS of the CWS with stutters present in the samples and with stutters removed. Analysis of correlation was also conducted to determine the relationship between %SS and the measures collected in SALT, pause measures and SSpS with stutters present.

3. Results

3.1 Descriptive Statistics

The descriptive statistics of the collected measures are detailed in Table 2.

Table 2

Control Group and Stuttering Group Means and Standard Deviations (SD).

Measures	Stuttering Group Mean (SD)		Control Group Mean (SD)
	Stutters Present	Stutters Removed	
No. of Utterances	39.67	-	39.00
	(11.17)	-	(14.75)
MLUm	6.01	-	6.84
	(1.19)	-	(1.36)
NDWR	54.50	-	55.50
	(10.41)	-	(8.55)
% Intelligible	98.17	-	98.67
	(2.99)	-	(1.63)
% of Mazes	11.33	-	10.33
	(6.83)	-	(4.50)
SSpS	3.07	3.20	3.56
	(0.50)	(0.71)	(0.38)
SPM	3.90	3.91	3.91
	(0.23)	(0.22)	(0.15)
SPM Probability (%)	47.67	54.33	57.83
	(15.12)	(17.27)	(8.52)
LPM	6.26	6.63	6.39
	(0.21)	(0.58)	(0.35)
LPM Probability (%)	52.33	45.67	42.17
	(15.12)	(17.27)	(8.52)
Proportion Pause Time (%)	55.38	56.08	47.57
	(9.80)	(13.30)	(6.01)
Misclassification Rate (%)	7.93	5.29	4.07
	(1.54)	(3.44)	(2.92)
Distribution Threshold	4.81	4.99	5.04
	(0.39)	(0.36)	(0.37)

Note. MLUm=Mean Length of Utterance in Morphemes, NDWR=Number of Different Word Roots, SSpS=Syllable Spoken per Second, SPM=Shot Pause Mean, LPM=Long Pause Mean.

Table 3 in Appendix C shows the pause distribution graphs with control and participants who stuttered placed in rows with their age and gender matched peers. This table shows the two log-normal pause distributions that were formed based on the algorithmic transformation of pausing of the participants and which was used to estimate the means and standard deviations of the measures.

3.2 T-Tests

An independent samples t-test indicated a significant difference between the misclassification rate of CWS with stutters present and that of the control group $t(10) = 2.86$, $p<.05$. The misclassification rate of CWS was found to be significantly greater than the misclassification rate of CWNS. No other significant differences were found between the control group and the stuttering group in the SALT measures, syllables spoken per second or Pause measures, with or without stutters present in the stuttering group ($p>.05$).

A paired samples t-test indicated no significant differences between the measures taken from the stuttering group with or without stutters present.

3.3 Correlations

Analysis of correlation was completed and Percent Syllables Stuttered was found to be significantly positively correlated with Percent Mazes, $r(4) = .958$, $p<.01$ when stutters were present in the samples of CWS. Percent Syllables Stuttered was also found to be significantly positively correlated with Syllables Spoken per Second, $r(4) = .934$, $p < .01$, when stutters were present in the samples of CWS. Percent Syllables Stuttered was found to be significantly negatively correlated with Short Pause Mean with stutters present, $r(4) = -.851$, $p < .05$. No other significant correlations with Percent Syllables Stutters were found. Figures 1 – 3 below show the graphs of the significant correlations.

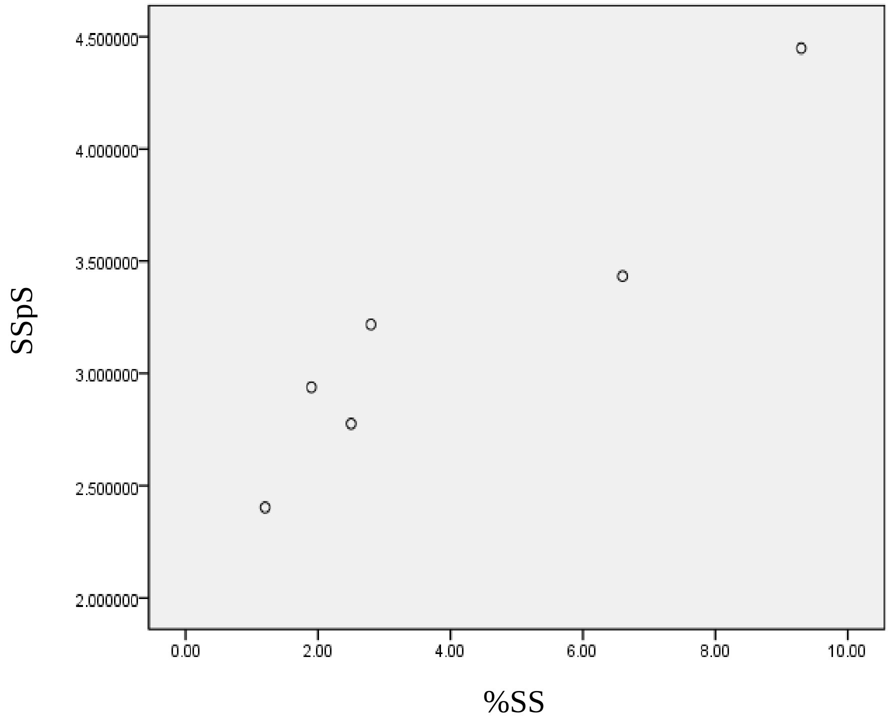

Figure 1. Significant positive correlation found between Percent Syllable Stuttered (%SS) and Syllables Spoken per Second (SSpS).

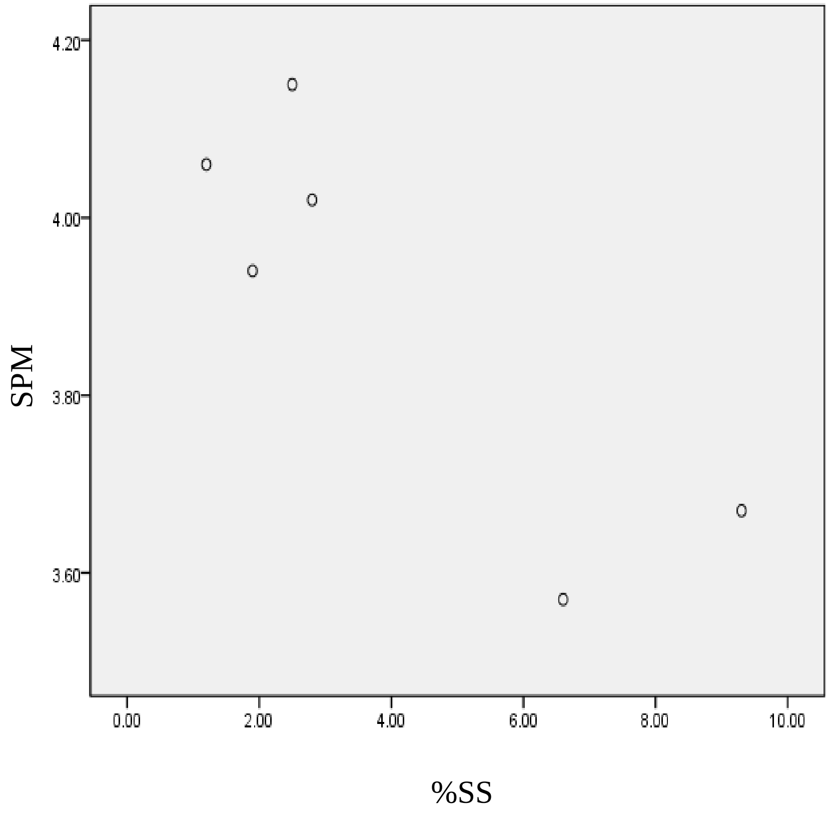

Figure 2. Significant negative correlation found between Percent Syllable Stuttered (%SS) and Short Pause Mean (SPM).

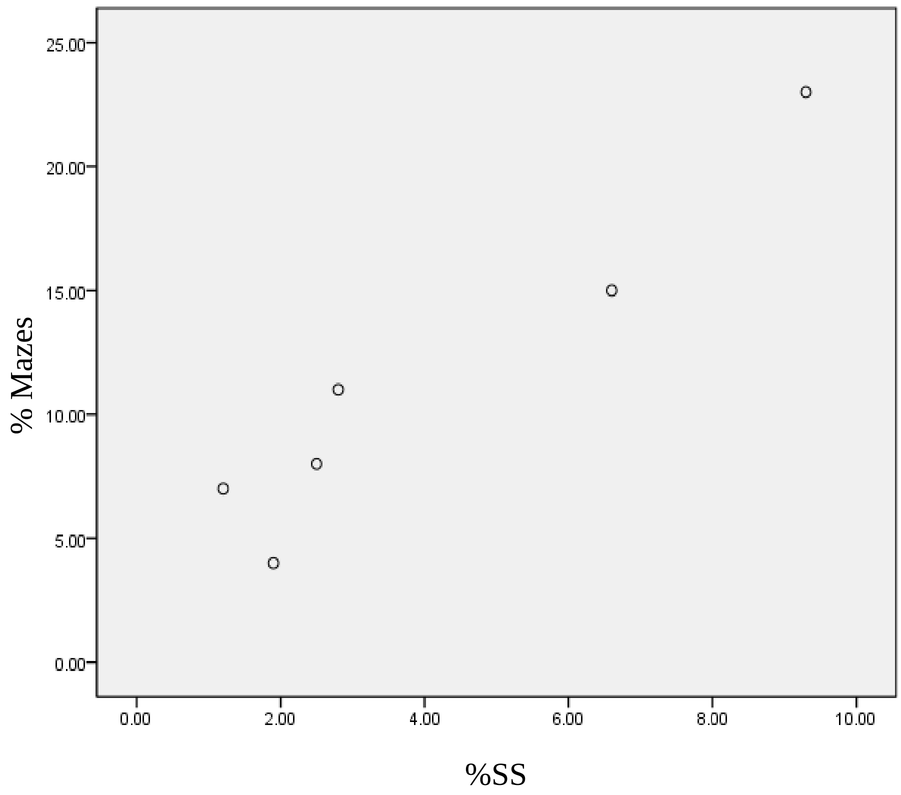

Figure 3. Significant negative correlation found between Percent Syllable Stuttered (%SS) and % Mazes.

4. Discussion

The aim of this study was to examine the differences between the speech and language processes of CWS compared to CWNS using analysis of oral narratives. In the SALT measures gathered in this study no significant difference was found between the CWNS and CWS, with and without stutters removed. The MLUm, NDWR, Number of Total Utterances, Percent Intelligible and Percentage of Maze Words to Total Words measure gathered from CWS were all found to be similar to those gathered from CWNS. This finding does not support a connection between stuttering and language ability and indicates that stuttering may be attributed to factors exclusive to language ability. These findings add support to Nippold's (2012) conclusion that stuttering is not associated with language deficits and that stuttering has a minimal to negligent impact on language development.

In the pause measures gathered in this research a significant difference was found only in the misclassification rate between the two groups. No other significant difference was found in the other pause measures (SPM, SPM Probability, LPM, LPM Probability, Proportion of Pause Time or Distribution Threshold) with or without stuttering present in the samples of CWS. Misclassification rate is the degree of overlap of the short and long pause distributions (Little et al., 2013). The between groups comparison found that CWS had a significantly greater misclassification rate than CWNS, when stutters were present in the samples of CWS. However, this significant difference was no longer present when stutters were removed from the samples of the CWS. Therefore, this suggests that the increased misclassification rate is due to the presence of stuttering in the speech samples. This finding suggests that the pauses surrounding stuttered sections of speech provides interference in the distinct classification of pauses as either short or long. It can be concluded that differences in pauses between CWS and CWNS only occur in segments of stuttered speech, and that pauses surrounding the non-stuttered segments of CWS are similar to the pauses surrounding the speech of CWNS. The fact that no other significant differences were found between the pause measures of CWS and CWNS suggests that the pauses of CWS are generally similar to the pauses of CWNS which in turn may suggest that the speech and language processes of CWS are similar to the speech and language processes of CWNS. Alternatively, this result could indicate that the measures used in this study were not sensitive enough to pick up subtle difference in speech and language processing between CWS and CWNS.

In the correlations analysis, Percent Syllables Stuttered was found to be significantly positively correlated with Percent Mazes, which was calculated with stutters present in the samples of CWS. This correlation is predictable in light of what is known about stuttering and the way in which stutterers are transcribed in SALT. In SALT, all false starts and part or whole word repetitions are coded as a maze, therefore all stuttered parts of speech are coded as mazes. It logically follows on from this that the greater the Percentage of Syllables Stuttered, the greater the Percent Mazes, as all stutters are also mazes. This does not represent a significant outcome in relation to this research.

Percent Syllables Stuttered was also found to be significantly positively correlated with Syllables Spoken per Second, when stutters were present in the samples of CWS. Similar results have been found by other researchers (Minifie & Cooker, 1964; Andrews & Cutler, 1974; Prins & Lohr, 1972; Logan, Byrd, Mazzocchi, & Gillman, 2011). Although the exact nature of the relationship between Percent Syllables Stuttered and Syllables Spoken per Second is unknown, it may be explained by interpreting it through an ‘impairment of speech motor control’ theory of stuttering. If stuttering is a result of an impairment at the level of speech motor control in an individual, this impairment may also impact on the rate control of an individual who stutters. Speech rate is an aspect of the articulation process that is governed by speech motor control (Löfqvist & Lindblom, 1994). Therefore, the more severe the individual’s stutter (which is commonly measured in Percentage of Syllables Stuttered), the greater their impairment of speech motor control, and the greater their impairment in controlling speech rate. This may be further supported by previous research that has provided evidence that modification of speech rate is an effective method of reducing stuttering severity (Howell & Sackin, 2000), as modification of rate could conceivably be therapeutically impacting on the same speech motor control processes that are responsible for stuttering. Further examination of the relationship between Percent Syllables Stuttered and Syllables Spoken per Second is needed.

Percent Syllables Stuttered was found to be significantly negatively correlated with Short Pause Mean with stutters present. As the short pause mean is related to the articulatory components of speech, a significant correlation between Percent Syllables Stuttered and the Short Pause Mean with stutters present may indicate a relationship between stuttering and the articulatory components of speech processing. This provides further support for an 'impairment of speech motor control' theory of stuttering. No other significant correlations with Percent Syllables Stutters were found.

This study's lack of support for the stuttering-language connection could provide further support for alternative theories of why stuttering occur, such as the theory supported by Nippold (2012), that stuttering is a reflection of a difficulty of speech motor control. If stuttering is a difficulty of speech motor control, and hence a difficulty within the processes governing the coordination and control of articulatory subsystems (such as movement of the lips, jaw, tongue and larynx), it may impact on the way in which stuttering is treated (Löfqvist & Lindblom, 1994).

4.2 Limitations and Future Directions

There were several limitations in this study that may have impacted on the results. It is important to highlight that the accuracy of the findings in this study may have been impacted by the small sample size, and that these finding should be interpreted with caution. The number of participants chosen for use in this study was deigned as appropriate for a pilot study, but should be increased in further research to improve the rigour of the research and to confirm the results found in this study.

Another limitation in this study was the quality of the voice recording of the oral narratives. As recordings were gathered in participants' homes, the environment could not be controlled for background noise. This impacted on the ease and accuracy of segmenting the samples as background noise sometimes overlapped periods of speech and made it difficult to determine with accuracy the onset and completion of sounds. In future research, this limitation may be overcome by gathering samples in a sound proof environment.

Another limitation was the amount of time required for the segmentation of speech samples. This limitation would make the segmentation for a similar study with a large number of participants very time consuming. However, the use of a large number of participants would greatly add to the rigour of research in this area. The use of robust speech recognition technology may serve to overcome this limitation. In recent years speech recognition technology has advanced considerably (Ramírez & Górriz, 2011). As speech recognition software becomes more accurate, the ability to automatically segment speech into periods of speech and pauses may make a similar study comparing a larger number of participants more feasible.

Another limitation in this research was that no extensive language testing was conducted on the participants in this study. Although the participants' parents reported that they had no concerns about their children's speech or language this may not have been an accurate report of the children's speech and language ability. This limitation could be overcome in future research by carrying out some standard speech and language testing and requiring children to have scores within normal limits as part of the inclusion criteria.

Research has provided mixed evidence whether the speech and language processes of CWS differ to those of children who do not (Bajaj, 2007; Trautman, Healey, Brown, Brown & Jermano, 1999; Weiss & Zebrowski). Therefore, a need still exists to further investigate whether speech and language processing differences are present in CWS. Understanding the speech and language processes of children could significantly contribute to the understanding of the nature of stuttering (Watkins & Johnson, 2004). It could impact on the design of treatment tasks, inform theories of how and why stuttering occurs and help us to understand what influences the development, endurance and frequency of stuttering (Watkins & Johnson, 2004).

5. Conclusions

In this study, the connection between stuttering and language is not supported, as the language measures gathered from CWS were all found to be similar to those gathered from CWNS. This finding may indicate that stuttering may be attributed to factors exclusive to language ability, such as stuttering being a difficulty in speech motor control.

The pauses of CWS were found to be similar to the pauses of CWNS with the exception of the finding that CWS had a significantly greater misclassification rate than CWNS, when stutters were present in the samples, but not when stutters were removed from the samples of CWS. This suggests that the increased misclassification rate was due to the presence of stuttering in the speech samples and that differences in pauses between CWS and CWNS only occur in segments of stuttered speech. Additionally, this suggests that the speech and language processing of CWS in the perceptually fluent segments of their speech is similar to the speech and language processing of CWNS.

A significant correlation between Percent Syllables Stuttered and the Short Pause Mean with stutters present may indicate a relationship between stuttering and the articulatory components of speech processing. This provides further support for an ‘impairment of speech motor control’ theory of stuttering. The finding that no other significant correlations with Percent Syllables Stutters were found, such as with the Long Pause Mean, provides further evidence that stuttering may be attributed to factors exclusive to language ability, as similar Long Pause Means may indicate that the conceptualisation and formulation processes between the two groups were similar.

This study provides some evidence against a theory of stuttering based on language impairment and some evidence for a theory of stuttering based on speech motor control impairment. However, the completion of further research that takes into account the limitations described in this paper could significantly improve the validity of these findings and hence improve our understanding of speech and language processing in CWS.

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Appendix A

List of acronyms used in this paper.

CWS	Children Who Stutter
CWNS	Children Who Do Not Stutter
LPM	Long Pause Mean
MLUm	Mean Length of Utterance in Morphemes
NDWR	Number of Different Word Roots
%SS	Percentage Syllables Stuttered
SPM	Short Pause Mean
SSpS	Syllables Spoken per Second
TTR	Type Token Ratio

Appendix B

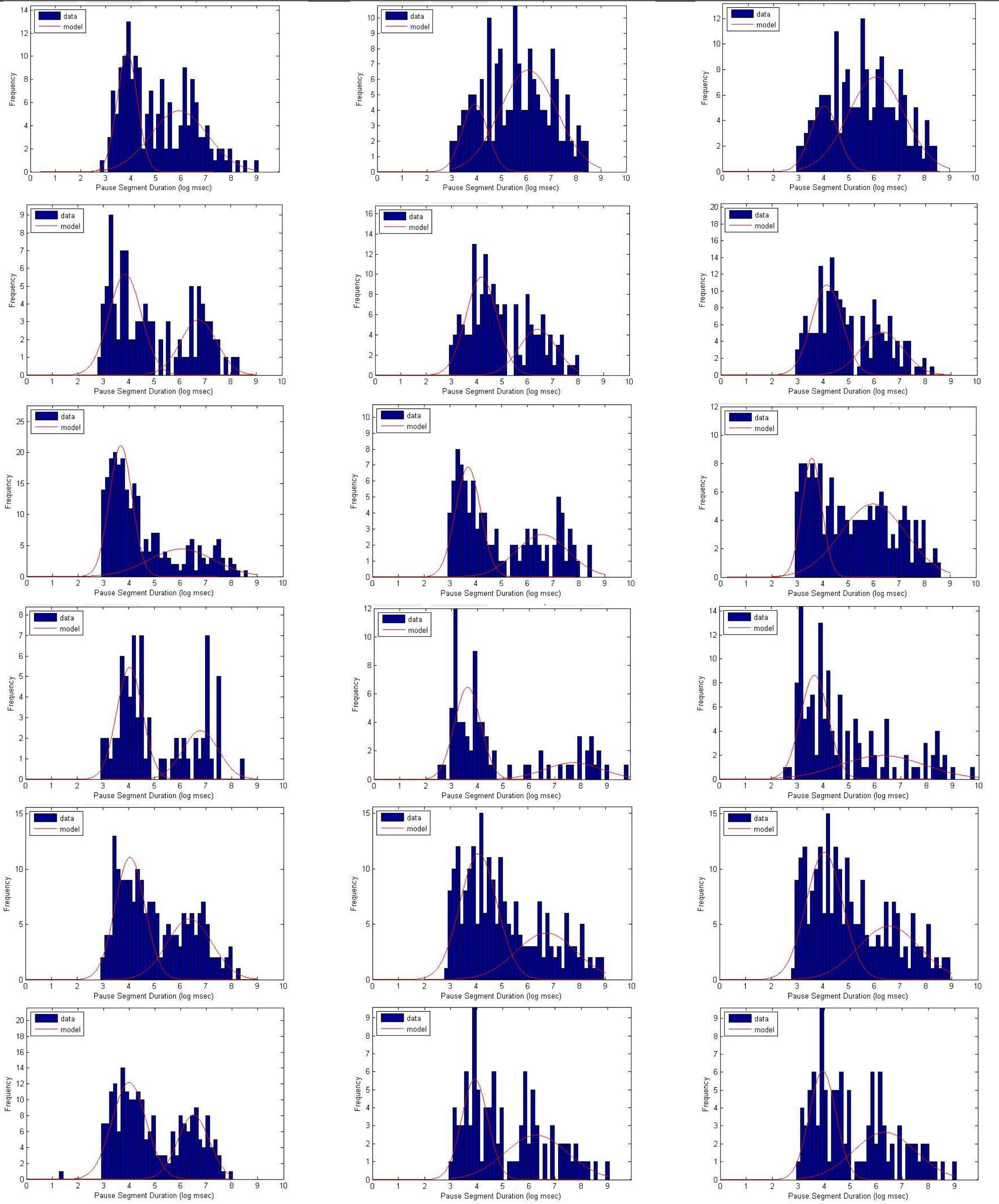
Summary of the standard pause segmentation procedure used in this research.

1. Visually examine the oscillogram and spectrogram of the sound sample.
2. Listen to sections of the sample, listening for sections of speech, pausing or stuttering.
3. Analyse the phonemes used in sections of the sample one utterance at a time, interpreting where short pauses are likely to be present due to time required to shift between articulators.
4. Look for dips in the intensity line or breaks in the pulses line to further confirm where pauses are present. Keep in mind that fricative sounds are not represented in these measures and will also be shown as a dip or break but must be coded as speech. Fricatives are more difficult than other phonemes to determine onset and completion, and pauses adjacent to fricatives should be segmented conservatively.
5. Place boundaries indicating segments of speech, pausing and stuttering.
6. Re-listen to segmented sections to confirm that they are correctly coded as sections of speech, pausing or stuttering.

Appendix C

Table 3. Pause distribution graphs with control and stuttering participants placed in rows with their age and gender matched peer.

Control	Stuttering, with Stutters Removed	Stuttering, with Stutters Present



Appendix D

Table 4. Pearson correlation coefficients for the language assessments administered in the current study.

	Age (Months)	%SS	Time Since Onset (Months)	No. of Utterances	MLUm	NDWR	% Intelligible	% Mazes	SSpS	SPM	SPM Probability %	LPM	LPM Probability %	Proportion Pause Time (%)	Misclassification Rate	Distribution Threshold
Age (Months)	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
%SS	.925**	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Time Since Onset (Months)	.063	.184	1	-	-	-	-	-	-	-	-	-	-	-	-	-
No. of Utterances	-.406	-.340	.275	1	-	-	-	-	-	-	-	-	-	-	-	-
MLUm	.323	.002	.081	-.392	1	-	-	-	-	-	-	-	-	-	-	-
NDWR	.474	.315	.238	.515	.269	1	-	-	-	-	-	-	-	-	-	-
% Intelligible	-.013	.102	.388	.265	.026	.087	1	-	-	-	-	-	-	-	-	-
% Mazes	.832*	.958**	.213	-.234	-.087	.270	.358	1	-	-	-	-	-	-	-	-
SSpS	.776	.934**	.100	-.469	-.212	-.006	-.027	.887*	1	-	-	-	-	-	-	-
SPM	-.784	-.851*	-.012	.121	.245	-.410	.307	-.730	-.827*	1	-	-	-	-	-	-
SPM Probability %	.309	-.025	-.186	-.219	.894*	.388	.187	-.041	-.289	.258	1	-	-	-	-	-
LPM	-.169	-.444	-.501	.076	.530	.194	.209	-.376	-.629	.540	.806	1		-	-	-
LPM Probability %	-.309	.025	.186	.219	-.894*	-.388	-.187	.041	.289	-.258	-1.000**	-.806	1	-	-	-
Proportion Pause Time (%)	.257	.461	-.488	-.201	-.610	-.275	.112	.557	.608	-.453	-.374	-.195	.374	1	-	-
Misclassification Rate	-.265	.021	-.341	.075	-.795	-.505	.295	.205	.230	-.014	-.568	-.173	.568	.840*	1	-
Distribution Threshold	-.337	-.584	-.179	.050	.644	.041	.342	-.498	-.748	.791	.778	.900*	-.778	-.470	-.300	1

Note. *p < .05. **p < .01. %SS=Percentage Syllables Stuttered, MLUm=Mean Length of Utterance in Morphemes, NDWR=Number of Different Word Roots, SSpS= Syllables Spoken per Second, SPM=Short Pause Mean, LPM = Long Pause Mean