Acoustic Parameters of Speech and Attitudes Towards Speech in Childhood Stuttering:

Predicting Persistence and Recovery

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Abstract

The relations between the acoustic parameters of jitter and fundamental frequency and children's experience with stuttering were explored. Sixty-five children belonging to four talker groups will be studied. Children were categorized as stuttering (CWS) or non-stuttering (CWNS), and were grouped based on their diagnosis of stuttering/not stuttering at two time points in a longitudinal study: persistent stutterers (CWS→CWS), recovered stutterers (CWS→CWNS), borderline stutters (CWNS→CWS), and never stuttered (CWNS→CWNS). The children performed a social-communicative stress task during which they were audio-recorded to provide speech samples from which the acoustic parameters were measured. There were no significant relations between talker group and acoustic parameters, nor were children's attitudes towards their speech different across talker groups. Therefore, acoustic parameters nor children's attitudes towards their speech did not determining their prognosis with stuttering.

Stuttering is a type of speech disfluency in which words or phrases are repeated or sounds are prolonged. Yairi (1993) reported that stuttering affects about 1% of adults worldwide. The onset of stuttering typically begins in preschool children, with about 5% of children stuttering at some point in their lives. About three-fourths of these children recover, whereas the remaining children become the 1% of adults who stutter. There is a disproportionate gender difference, with stuttering affecting four times as many boys compared to girls. Some recent research concerned with stuttering has focused on identifying the different factors that may affect recovery, and identifying the differences between children who do (CWS) and children who do not stutter (CWNS). The results of research suggest that stuttering is related to emotion, temperament, and physiological measures of emotional arousal and regulation (such as skin conductance and respiratory sinus arrythmia) (e.g. Jones, Conture, & Walden, 2014; Jones, Conture, Walden, Buhr, Tumanova, & Porges, 2014; Walden, Frankel, Buhr, Johnson, Conture, & Karass, 2012).

Walden et al. (2012) suggest that two diatheses (vulnerabilities or predispositions) affect stuttering: an emotion diathesis and a speech-language diathesis. An example of an emotion diathesis would be difficulty with emotional regulation or a difference in emotional reactivity in children who stutter compared to non-stuttering peers. Walden et al. propose that stuttering-type disfluencies occur in situations that are novel or familiar situations that change because of the emotional reaction to the situation. For a speech-language diathesis, an instance in which a person's is on the spot, like an interview, speech planning, what they are planning on saying, and production, what they actually say, occurs simultaneously and would be a stressor on their expressive language abilities. Therefore, fluency problems in children who stutter may be related not only to the speech-language requirements in a speaking situation but also their emotions and how they feel.

Children's Attitudes Toward their Speech

The KiddyCAT is a questionnaire that asks children yes or no questions about their speech (Vanryckeghem, 2002). The KiddyCAT measures children's attitudes toward their speech, particularly perceived difficulty with speech (Clark et al., 2012). This measure indicates their awareness of speech difficulty and their attitude towards it. Research has shown that CWS and CWNS differ in their KiddyCAT scores (Clark et al. 2012). KiddyCAT is a self-reported measure, so it shows how children feel about their speech rather than how the adults in their life perceive it. Vanryckeghem, Brutten, and Hernandez (2005) indicate the children as young as three are aware of disfluencies in speech and, by age six, children who stutter have a negative speech attitude compared to fluent peers. De Nil and Brutten (1991) also indicate a difference in attitude towards speech for stuttering and non-stuttering children.

Acoustic Parameters of Speech

Pittam & Scherer (1993) have shown that researchers can perceive emotion in a voice from recorded samples. Bachorowski & Owren (1995) induced positive or negative emotions through feedback on a task in which participants were supposed to name words from a string of letters; they were placed in either a punishment or reinforcement condition that gave them pre-determined feedback regardless of their performance on the task and their voices were recorded in these tasks. In analysis of recorded samples, they found that acoustic parameters (i.e. jitter, fundamental frequency, shimmer) indicate there is a relation between emotion and acoustic parameters in fluent people. Rothkranz, Wiggers, van Wees, & van Vark (2004) found that listeners can hear the level of the stress response a person feels, because of psychological and physiological reactions to stress. These physiological changes include effects on the speech organs, specifically in respiration and muscle tension in the vocal cords for adults (Rothkranz et

al., 2004). Fuller & Horrii (1986) identify that the difference in respiration, the change in diameter of the airway, and the tightening of the vocal cords changes the pitch, called fundamental frequency (F_0), and causes perturbations in the pitch itself, called jitter, in infants. F_0 and jitter are not only useful for adult vocal analysis, but also can be used to measure children's voices. Protopopas & Lieberman (1997) found a correlation between mean F_0 and the amount of stress a person is under for fluent adults—the higher the mean F_0 the more stressful the situation. The stressful situation in this instance is fear—the vocal samples were taken from real life helicopter pilot in neutral conversations with the control tower and stressful situations like when the helicopter was going to crash. Additionally, Mendoza and Carballo (1999) found that adults in stressful situations, a situation in which their cognitive load was high because of difficult speaking tasks, experienced an increase in mean F_0 and a decrease in jitter.

Researchers have found differences in F_0 and jitter in children and adults who stutter (e.g. Hall & Yairi, 1992; Subramanian, Yairi, & Amir 2003; Yaruss & Conture, 1993; Zebrowski, Conture, & Cudahy, 1985). Stuttering individuals have smaller increases in mean F_0 when speaking than those who do not stutter who experience greater changes in F_0 in speaking tasks (Bosshardt, Sappok, Knipschild, & Hölscher, 1997). Adults who stutter show less pitch variability in more emotional circumstances than fluent peers—emotional circumstances in these studies being ones in which extreme states of nervousness are induced through questioning, blindfolding, firing a gun, and administering electrical shocks or by embarrassing the speaker as they were speaking (Travis, 1926; Bryngelson, 1932). Similarly, children who stutter have been found to have lower mean F_0 than their fluent peers (Healey, 1982; Natke, Grosser, and Kalveram, 2001).

The results of studies such as those conducted by Subramanian et al. (2003) and Yaruss et al. (1993) have suggested there are differences in acoustic parameters (i.e. jitter, shimmer, F_0) of preschool children who do and do not stutter. Hall et al. (1992) only identified differences between CWS and CWNS to be significant in regards to shimmer, which is a random change in the amplitude of speech over time and affects the roughness or harshness of the voice, but identified close to significant differences in jitter and fundamental frequency between these two talker groups, fundamental frequency for stutterers being lower than those who do stutter. Subramanian et al. (2003) took those outcomes a step further and identified a longitudinal difference in the formant frequencies, how much energy is concentrated around a certain frequency in a speech wave, in the children, studying differences second formant transitions in children who persisted in their stuttering and children who recovered from stuttering over the longitudinal study in fluent speech samples, collecting data every six months for several years.

This study focuses on the intersection of children's stress or emotional arousal, children's attitudes towards their speech, and the acoustic qualities of speech to identify relations between arousal, attitudes, and the speech itself over time. Data were collected during a social-communicative stress tasks to measure emotional arousal. This study looked at developmental stuttering through a longitudinal lens. The study focuses on what acoustic parameters might indicate for persistent stutterers (CWS→CWS), recovered stutterers (CWS→CWNS), borderline stutterers (CWNS→CWS), and children who have never stuttered (CWNS→CWNS), as well as children's attitude towards their stuttering.

The hypotheses are as follows:

1. There is a significant difference between the recovered stutterers (CWS→CWNS) and persistent stutterers (CWS→CWS) for mean F_0 and jitter during social stress task.

    a. Directional: Recovered stutterers (CWS→CWNS) would have higher mean F_0 than persistent stutterers (CWS→CWS) at T2.

    b. Directional: Persistent stutters' (CWS→CWS) jitter will be lower than recovered stutters (CWS→CWNS) at T2.

2. There is a significant difference between the borderline stutterers (CWNS→CWS group) and the never stuttered (CWNS→CWNS group) for mean F_0 and jitter during social stress task.

    a. Directional: Borderline stutterers (CWNS→CWS) lower mean F_0 than never stuttered (CWNS→CWNS) at T2.

    b. Directional: Jitter lower for borderline stutterers (CWNS→CWS) than never stuttered (CWNS→CWNS) at T2.

3. CWS with higher KiddyCAT scores will have lower F_0 and lower jitter for the group.

    a. Persistent stutterers (CWS→CWS) will have the highest scores.

    b. Recovered stutterers (CWS→CWNS) will have scores lower than the persisting group.

Method

Participants

        Participants were paid participants who are naïve to the hypotheses of this study. They were all participants in a longitudinal study focusing on developmental stuttering, emotion reactivity, and emotion regulation. Besides the participants who stutter, the participants had no known other speech-language, neurological, emotional, hearing, developmental, or intellectual problems. All are monolingual, native speakers of Standard American English. There were 65 participants. At Timepoint 1 the participants ages were 3;0 to 6;4 (years;months; mean, M=4;11,

standard deviation, SD=0;7). At Timepoint 2 the participants ages were 3;8 to 7;0 (years;months,

mean, M=4;8, standard deviation, SD=0;7).There were 41 females and 24 males. Participants

were referred to the Vanderbilt Bill Wilkerson Center for participation by their caregiver.

Caregivers were informed of the study through a free, widely read parent-oriented magazine,

local health care provider, or self/professional referral to the Vanderbilt Bill Wilkerson Hearing

and Speech Center. The original data set contained 148 participants. 26 were excluded because

they were too old. 43 were excluded because they had no workable audio files. 6 were excluded

because they did not complete the card stressor task. 8 were excluded because they did not

complete the KiddyCAT.

Groups. There were 13 participants in three groups, and 26 in one group. These groups

are based on classifications of stuttering or non-stuttering at two different time points over the

longitudinal study. Children are either categorized as stuttering (CWS) or non-stuttering

(CWNS) based on the number of stuttered speech-language disfluencies in a 300-word

conversation. Stuttered speech-language disfluencies, according to our lab's paradigm, are

single, whole, and partial word repetitions, phrase repetitions, interjections, revisions, and

audible and inaudible sound prolongations. Children with more than three stuttered speech-

language disfluencies per one hundred words are considered CWS. Depending on their

classification at the two timepoints, the children are placed into one group either as persistent

stutterers (CWS→CWS), recovered stutterers (CWS→CWNS), borderline stutterers

(CWNS→CWS), or never stuttered (CWNS→CWNS).

Persistent Stutters (CWS→CWS) Participants were 13 preschool-age children who

stuttered at timepoint 1 and at timepoint 2. At timepoint 1, participants were between the ages of

3;0 and 5;1 (years;months, mean, M=3;11, standard deviation, SD=0;6). At timepoint 2,

participants were between the ages of 3;8 and 5;9 (years;months, mean, M=4;8, standard

deviation, SD=0;7). The persistent stutters consisted of 10 boys and 3 girls.

Recovered Stutters (CWS→CWNS) Participants were 13 preschool-age children who

stuttered at timepoint 1 and at timepoint 2. At timepoint 1, participants were between the ages of

3;0 and 5;3 (years;months; mean, M=4;1, standard deviation, SD=0;8). At timepoint 2,

participants were between the ages of 3;8 and 5;11 (years;months; mean, M=4;8, standard

deviation, SD=0;7). The persistent stutters consisted of 11 boys and 2 girls.

Borderline Stutters (CWNS→CWS) Participants were 13 preschool-age children who did

not stutter at timepoint 1 and stuttered at timepoint 2. This distinction is more challenging than

other groups, because 9 participants eventually recovered, whereas 4 participants are unknown,

because they did not complete the study. However, these children experienced the onset of

stuttering in the lab, regardless of whether they recovered. Therefore, they are borderline

stutterers. Participants at timepoint 1 were between the ages of 3;0 and 6;4 (years;months; mean,

M=3;11, standard deviation, SD=0;11). At timepoint 2, participants were between the ages of 3;8

and 7;0 (years;months; mean, M=4;8, standard deviation, SD=0;10). The borderline stutterers

consisted of 5 boys and 8 girls.

Never Stuttered (CWNS→CWNS) Participants were 26 preschool-age children who did

not stutter at timepoint 1 or timepoint 2. At timepoint 1, participants were between the ages of

3;1 and 4;11 (years;months; mean, M=3;11, standard deviation, SD=6). Participants were

between the ages of 3;9 and 5;8 (years;months; mean, M=4;8, standard deviation, SD=6). The

never stuttered group consisted of 15 boys and 11 girls.

Design

This study involves a between-group and within-group design. The between groups factor

is group classification (4 groups described above). The within group variable is time point. The

independent variables are talker groups and timepoint. The dependent variables are KiddyCAT

scores, fundamental frequency, and jitter.

Procedure

The participants visited the lab for 4-5 two-part visits about 8 months apart. The two parts

of the visit take place a week apart. The first visit is a diagnostic visit and the second part is to

collect data about emotion and stuttering.

The first part of the visit is a diagnostic visit and serves to collect information about the

participant so that they may be deemed suitable for the study and to be sorted into the

appropriate talker group for that point in their development.

At their visit, the participant engages in play conversation with a speech-language

pathologist. The conversation is recorded and transcribed. The conversation is meant to reach

300 words. From this conversation, the number of stuttered language disfluencies and other

disfluencies are recorded. Based on stuttering during the 300-word conversation children are

assigned to talker groups.

After the play conversation, the child is hooked up to electrodes on their fingers, and is

administered a social stress task. What the participant says is recorded during the task. These are

both captured through AcqKnowledge Data Acquisition software. The social stress task is meant

to challenge children while performing a social-communicative task. The examiner instructs

participants to identify the pictures on cards while being told by the examiner to go faster. Every

card named is then placed forcefully on the table in front of the child, thus creating stress via the

loud noise made by hitting the card on the table. Skin conductance and respiratory sinus

arrhythmia are collected along with the vocal acoustic data during this task.

The child is then administered expressive and receptive language tests, the *Peabody*

Picture Vocabulary Test – Third Edition (PPVT-III), the *Expressive Vocabulary Test* (EVT), the

Test of Early Language Development-Third Edition (TELD-3) and the *Goldman-Fristoe Test of*

Articulation: Second Edition (G-FTA-2) to assess whether language is within normal limits.

They are given the KiddyCAT to asses their attitudes towards their speech. In addition children

are given a hearing test to make sure they fit the qualifications of the study, to insure that they

have normal hearing.

Word Selection Short A (ă) was studied for acoustic analysis. There are 30 words in the

card stressor task, and those with ă vowel sounds were selected. Three words were analyzed per

sound. They were chosen based on the quality of the recording, and whether the child named the

picture appropriately. The vowels sound ă was taken from: hammer, candle, cat, caterpillar,

hand, and apple.

Vocal analysis. Words were recorded using a stand-alone microphone that captured the

data into AcqKnowledge computer software. The audio was converted from an AcqKnowledge

file to a .wav file using Audacity software. In Audacity, samples were cut to only include the

words being studied, like grapes and cat, from the entire audio recording of the card stressor task.

Then, files were imported into PRAAT where vowel sounds in words were individually isolated.

Using a data script, F_0, jitter, and duration was calculated for all of the chosen sounds. Duration

and intensity are not used in acoustic analysis, but the PRAAT script collects this data. The

PRAAT Script is in Appendix A.

Coding. A reliability coder coded 20% of the data. The goal was 0.90 correlation or higher. For mean F_0 of the groups at timepoint one, the correlation coefficient, r, was equal to 0.936, and at timepoint 2 was equal to 0.999. For jitter at timepoint 1, the correlation coefficient was 0.979, and at timepoint 2 0.974. The means were not significantly different between the two raters.

Results

Data Analyses

Shapiro-Wilk tests of normality determined if the scores were normally distributed for age, KiddyCAT, F_0, and Jitter at timepoint 1 and timepoint 2. Results are in Table 1. F_0 at timepoint 1 (*p*=.528) and timepoint 2 (*p*=.422) and age at timepoint 2 (*p*=.086) were found to be normally distributed. All other variables were non-normally distributed.

Therefore, there were two options for analysis: continue with normal regressions without meeting the assumption that the data were normally distributed or complete a generalized estimating equation (GEE). GEE was considered, because it is used when data are skewed. These outcomes are in some cases leptokurtic and in others platykurtic. The concern with using GEE for these data is the small sample size, because GEE places a large model on a small sample and causes overfitting (Harrell, 2001). Normality is a limitation to consider, but overfitting can cause false results in a small sample. Harrell recommends that 10-20 subjects per variable are needed to be protected from overfitting, and this model has comparisons with N = 26 participants with 4 variables (age, KiddyCAT, F_0, and Jitter) resulting in a ratio of 6.5, which is not adequate for the 10-20 standard (Harrell, 2001). Fearing overfitting more than alpha error, typical significance tests rather than the GEE were run.

For Hypothesis One, independent samples t-tests were run between recovered and persistent stutterers talker groups for acoustic and attitude variables. For Hypothesis Two,

independent samples t-tests were run between borderline and never stuttered groups for acoustic

and attitude variables. Additionally, post-hoc regression analyses were run between the groups

with gender, age, acoustic, and attitude values to detect information not directly explored in the

hypotheses.

Descriptive Statistics

        Overall and group means are in Table 2.

Hypotheses Testing

        Recovered stutterers (M=338.68, SD=61.0023) and persistent stutters (M=309.32,

SD=85.09) did not significantly differ in mean F_0 at timepoint 1, t(24)=1.011, ns. Recovered

stutterers (M=323.54, SD=81.63) and persistent stutters (M=326.02, SD=79.56) did not

significantly differ in mean F_0 at timepoint 2, t(24)=.078, ns. Recovered (M=1.30, SD=.38) and

persistent (M=1.91, SD=1.41) also did not significantly differ for mean jitter at timepoint 1,

t(24)=1.514, ns. Recovered (M=1.45, SD=.71) or persistent (M=1.50, SD=.61) did not

significantly differ at timepoint 2, t(24)=.218, ns. Recovered stutterers (F_0= 323.54) did not have

higher mean F_0 than persistent stutterers (F_0= 326.02) at timepoint 2. The persistent stutterers'

group mean jitter at T2 (jitter = 1.50) was not lower than the recovered stutterer's group mean

jitter at T2 (jitter = 1.45). Therefore, all parts of hypothesis one are not supported.

        Borderline stutterers (M= 302.43, SD= 78.53) and the never stuttered group (M= 320.75,

SD= 73.60) did not significantly differ in mean F_0 at timepoint 1, t(37)=-.72, ns. Borderline

stutterers (M=309.07, SD=114.56) and the never stuttered group (M=300.94, SD=67.57) did not

significantly differ in mean F_0 at timepoint 2, t(37)=.28, ns. Borderline (M=1.07, SD=.47) and

never stuttered (M=1.38, SD=.60) also did not significantly differ for jitter at timepoint 1, t(37)=-

1.65, ns. Borderline (M=1.68, SD=1.00) and never stuttered (M=1.41, SD=.75) did not

significantly differ at timepoint 2, $t(37)=.96$, ns. Borderline stutterers ($F_0= 309.07$) did not have lower mean F_0 than the never stuttered group ($F_0= 300.94$) at timepoint 2. The borderline stutterers' jitter at T2 (jitter $= 1.68$) is not lower than the never stuttered group's jitter at T2 (jitter $= 1.41$). Therefore, all parts of hypothesis two are not supported.

At timepoint 1, talker group did predict KiddyCAT score ($F(1,60)=.03$, ns, with an $R^2 = 0.0004$). Furthermore, at timepoint 2, talker group did not predict KiddyCAT score ($F(1,62)=.37$, ns, with R^2 of .006). At timepoint 1, talker group and KiddyCAT score did not predict mean F_0 ($F(2,59)=.54$, ns, with $R^2 = .018$) or mean jitter ($F(2,59)=1.16$, ns, with $R^2 = .038$). At timepoint 2, talker group and KiddyCAT score did not predict mean F_0 ($F(2,59)=.43$, ns, with $R^2 = .014$) or mean jitter ($F(2,59)=.049$, ns, with $R^2 = .002$). The persistent stutters did have the highest average score, compared to the other three talker groups, at T1 (KiddyCAT score $= 4.42$) and T2 (KiddyCAT score $= 3.5$). The recovered stutterers' scores on the KiddyCAT at timepoint 1(KiddyCAT score $= 3.23$) and timepoint 2 (KiddyCAT score $= 2.15$) were lower than the persistent stutterers. Therefore, only hypothesis 3(a) is supported by the results.

Post-Hoc Analyses

Post-hoc linear regressions and correlations were run to see if there was an effect over time between talker group, gender, and age, and the dependent variables, KiddyCAT score, F_0, and jitter. None of the regressions or correlations were significant. The data do not support a difference between the talker groups over time in regards to KiddyCAT, F_0, or Jitter.

Discussion

This study predicted a significant difference in acoustic parameters (F_0 and Jitter) and children's attitude towards their speech over time, dependent on talker group. This study furthered previous research done on the intersection of emotion and stuttering, using laboratory

stressor measures. However, instead of using acoustic measures and measures of emotion as descriptive factors, it determined their efficacy as predictive variables. This study was a deeper exploration on work done by Trager (2014) that found a significant difference between children who stutter and children who do not in acoustic parameters (F_0 and Jitter) during a social stress task. Other studies by Subramanian et al. (2003), Yaruss et al. (1993), and Hall et al. (1992) found significant difference in acoustic parameters for children and adults who stutter and do not stutter. Subramanian et al. (2003) found that the formant frequencies, how much energy is concentrated around a certain frequency in a speech wave, differ longitudinally in preschool children who stutter, thus it followed to explore an added a longitudinal aspect, whether there was a difference over time with the different statuses of children and their stuttering—borderline stutterers, persistent stutterers, recovered stutters, and never stuttered—that can be detected using acoustic parameters of F_0 and Jitter. Vanryckeghem et al. (2005) and De Nil and Brutten (1991) showed that children were aware of their speech, had developed a negative attitude towards stuttering by school age, and that there was a difference in attitude towards speech for children who stutter and did not stutter. This study explored this idea longitudinally, to see if attitude might affect stuttering prognosis. The findings do not support using acoustic analyses or children's attitudes towards their speech as predictor variables for stuttering prognosis.

This study showed that recovered stutterers had a lower score on the KiddyCAT than persistent stutterers at both timepoints. This indicates that there is a difference in how children who ultimately recover from stuttering and do not recover feel towards their speech. This difference may be because their stuttering is not as severe, their peers and parents have not taken notice, or they are not aware of their stuttering, so they are not treated the same way as their less

fluent peers might be. This score difference also suggests this attitude has an effect on the prognosis of their stuttering, and should be considered when treating stuttering.

Limitations. As the data were collected from a larger longitudinal study, many possible participants were excluded. Had more been included, it would have increased the power of the experiment, and thus the ability to detect differences between groups. Higher power might have been able to show more subtle difference between the groups.

Acoustic data is sensitive, and there are many contributing factors to the differences within the samples themselves than the child's talker group. The audio was taken from AcqKnowledge files for 124 samples to calculate acoustic data, whereas 6 samples were extracted from a video recording of the card stressor task. The children's voices vary in volume, which causes differences in the ability to record and extract data from the sample. It is particularly problematic if a child yells or speaks too softly. The children in this study were young preschool-aged children who are often shy and speak softly. Also, in the task the experimenter says things like "Go faster!" or "Keep going!" and instead of speeding up the task, children usually get louder. Lastly, there is no prescribed location for the microphone, which introduces differences into what is captured in the acoustic samples.

The pitch of a person's voice changes over the lifetime, so personal differences in fundamental frequency could have been an issue, as well. Although matched for age, young age could have affected the children.

Preschool-age children also may have not been exposed to larger social settings with peers or older children and they might not have developed a specific attitude towards their speech, thus making the KiddyCAT a weak measure for them. Children's KiddyCAT scores indicated their attitudes towards their speech were not affected by talker group classification.

However, there were some children who had trouble with speaking, but not because of stuttering. For example, some children who never stuttered scored highly on the KiddyCAT, indicating a negative perception of their own speech, while by diagnostic standards they did not qualify as a child who stuttered. This indicates that they may have problems with other disfluencies and not with stuttering. Therefore, even though this study did not focus on those other speech problems, the children's attitude towards their speech may have been affected by it.

Future Directions. The purpose of this study was to see if acoustic analyses could be used to identify a child's speech prognosis, so other studies should explore avenues besides acoustic analysis. The sensitive nature of acoustic samples prevents them from being the best option, so if a study wished to study acoustic samples, there should be a strict paradigm for the collection of acoustic data to prevent confounding factors.

Perhaps if further research were to be conducted in this vein, it would be beneficial to have a more rigorous protocol for data collection and a questionnaire that measured only stuttering-related perception of speech difficulties, instead of overarching speech problems. This would allow researchers to pinpoint more directly how emotion affected stuttering and vice versa.

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Table 1. Tests of Normality

Variable	Static	df	Sig.
Age at T1 in Months	0.95	61	0.02
Age at T2 in Months	0.97	61	0.09
Speech-associated Attitude Score (KiddyCAT) at T1	0.94	61	0
Speech-associated Attitude Score (KiddyCAT) at T2	0.84	61	0
Fundamental Frequency at T1	0.98	61	0.53
Fundamental Frequency at T2	0.98	61	0.42
Jitter at T1	0.77	61	0
Jitter at T2	0.91	61	0

Table 2. Means and Standard Deviations for Overall and for Each Group

| Group	**Borderline Stutterers**			**Persistent Stutterers**		
Variable	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Age T1	13	47.54	11.46	13	47.15	6.74
Age T2	13	56.85	10.51	13	57.23	7.69
Mean F0 T1	13	302.43	78.53	13	338.68	61
Mean F0 T2	13	309.07	114.56	13	326.02	79.56
Mean Jitter T1	13	1.07	0.46	13	1.91	1.41
Mean Jitter T2	13	1.68	0.99	13	1.5	0.61
Mean KiddyCAT T1	13	2.73	2.18	13	4.42	3.2
Mean KiddyCAT T2	13	2.92	3.09	13	3.5	3.59
Group	**Recovered Stutterers**			**Never Stuttered**		
Variable	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Age T1	13	48.15	8.4	26	47.65	6.41
Age T2	13	57	7.46	26	56.62	6.36
Mean F0 T1	13	309.32	85.09	26	320.75	73.59
Mean F0 T2	13	323.54	81.63	26	300.94	67.57
Mean Jitter T1	13	1.3	0.38	26	1.38	0.6
Mean Jitter T2	13	1.45	0.71	26	1.41	0.74
Mean KiddyCAT T1	13	3.23	2.09	26	3.42	2.61
Mean KiddyCAT T2	13	2.15	2.19	26	2.62	2.97
Group	**Full Sample**					
Variable	N	Mean	Standard Deviation			
Age T1	65	47.63	7.91			
Age T2	65	56.86	7.62			
Mean F0 T1	65	318.39	74.04			
Mean F0 T2	65	312.1	82.45			
Mean Jitter T1	65	1.41	0.81			
Mean Jitter T2	65	1.49	0.78			
Mean KiddyCAT T1	65	129.17	161.2			
Mean KiddyCAT T2	65	159.26	166.31			
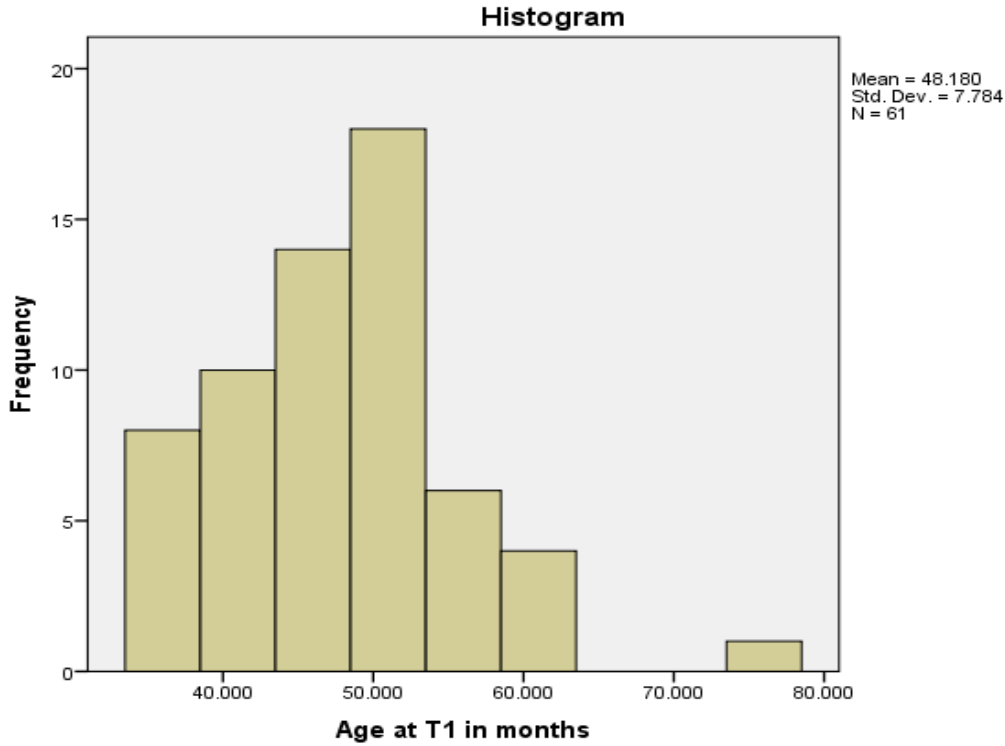
Figure 1. Histogram outlining the non-normal distribution for the full sample for Age at Timepoint 1.
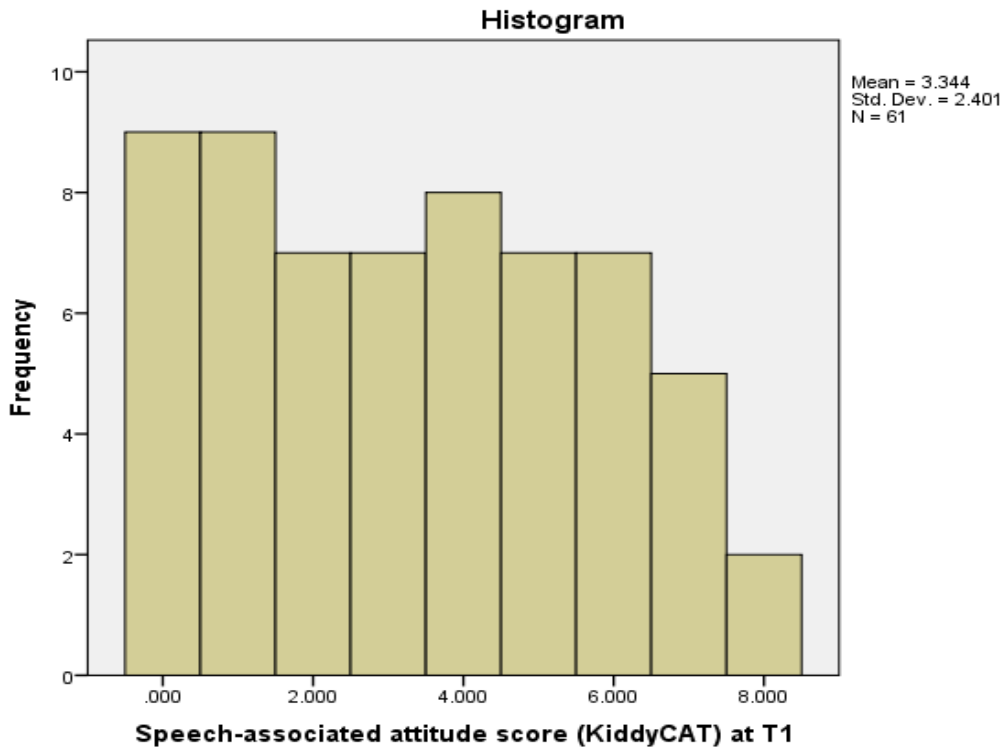

Figure 2. Histogram showing the non-normal distribution for the full sample for KiddyCAT at Timepoint 1.
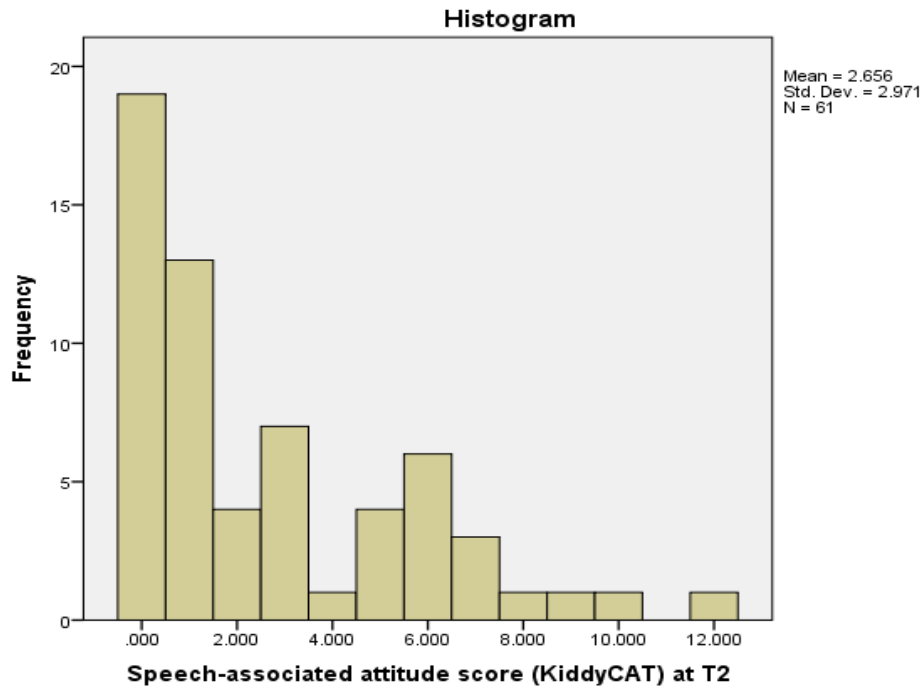
Figure 3. Histogram outlining the non-normal distribution for the full sample for KiddyCAT
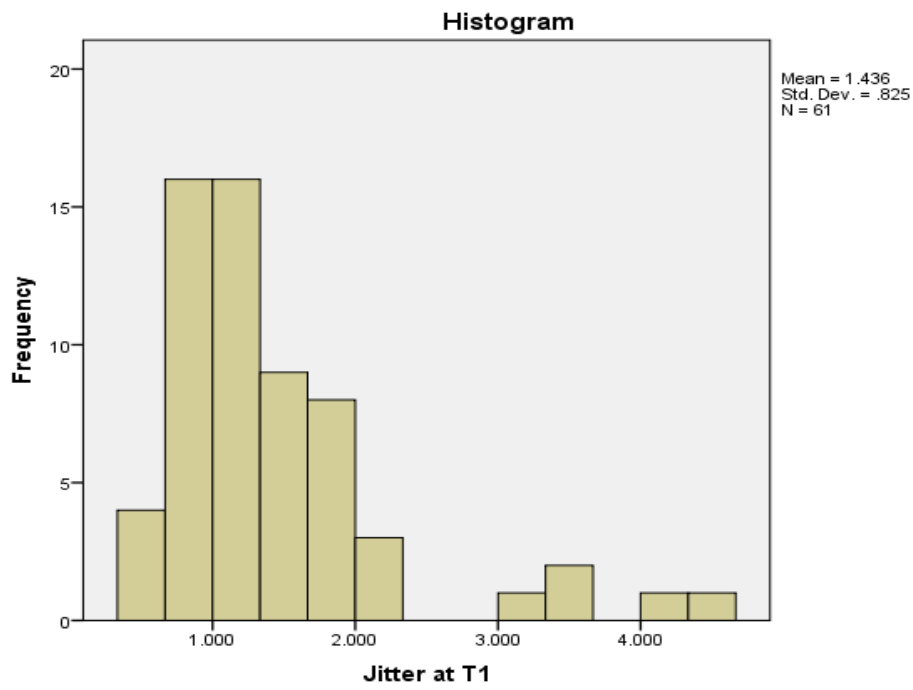
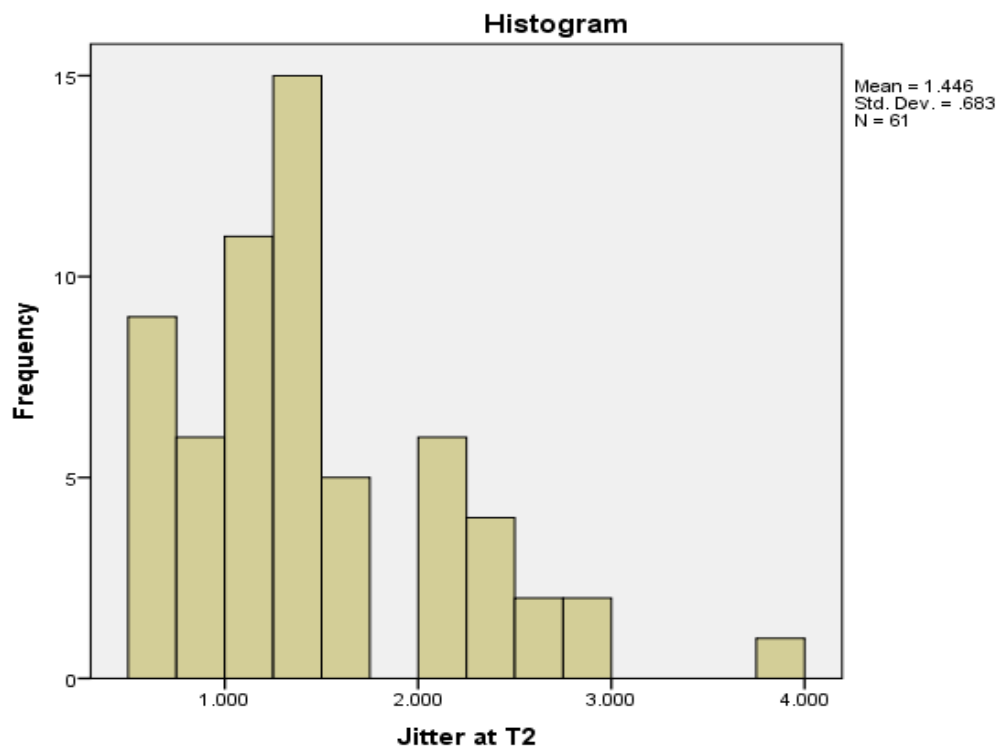score at Timepoint 2. Note the absence of a left tail.

Figure 4. Histogram showing the non-normal distribution of Jitter at Timepoint 1.

Figure 5. Histogram showing the non-normal distribution of Jitter at Timepoint 2.

Appendix A

PRAAT Script for Acoustic Analysis

clearinfo

form Calculate_Acoustic Measures

    #indicate where your sound files and TextGrid are

    sentence input_folder /Users/rockon_rachel/Dropbox/Honors Thesis/PRAAT Script

        #indicate where you want your output to be saved

    sentence output_folder /Users/rockon_rachel/Dropbox/Honors Thesis/PRAAT Script

    #indicate the number of the tier where phrases were annotated

    integer tier 1

    #indicate the symbol used for pause

    word pause

endform

myList = Create Strings as file list... liste 'input_folder$'/*.wav

ns = Get number of strings

line$="FILE'tab$'vowel'tab$'F0'tab$'sdPitch'tab$'jitter'tab$'shimmer'tab$'Intensity'tab$'duration'

    newline$'"

line$>'output_folder$'/output data.txt

for i from 1 to ns

    select Strings liste

    name$ = Get string... 'i'

    Read from file... 'input_folder$'/'name$'

    mySound=selected("Sound")

```
mySound$=selected$("Sound")

nameraw$ = name$ - ".wav"

nametxg$ = nameraw$ + ".TextGrid"

Read from file... 'input_folder$'/'nametxg$'

myTextGrid=selected("TextGrid")

myTextGrid$=selected$("TextGrid")
#sound = Read from file... 'soundFileName$'

select myTextGrid

nInt = Get number of intervals... tier

select mySound

To Intensity... 100 0
n=0
for int from 1 to nInt

select myTextGrid

int$=Get label of interval... tier int
if int$!= pause$

select myTextGrid

start = Get starting point... tier int

end = Get end point... tier int
#AutoCorrelation=optimized for intonation analysis (pitch etc), CrossCorrelation=optimized for

voice analysis (jitter, shimmer etc).
#Pitch Range Settings: The default settings in Praat are 75-500 Hz. For a male, a reasonable

range is 75-300 Hz, for a female, 100-500 Hz. For children ages 4-10: 100-600 Hz
```

(citation: Quantitative Analysis of Pitch in Speech of Children with Neurodevelopmental

Disorders. http://www.cs.rochester.edu/u/emilypx/Interspeech12-GK.pdf)

#These are just estimates, you can determine the pitch range by playing with pitch settings until

you get the pitch line halfway up the window.

#INTONATION MEASURES (PITCH), WE USE AUTO-CORRELATION FOR PITCH

#100 and 600 HZ are the pitch range settings.

select mySound

pitch1 = To Pitch... 0.01 100 600

meanPitch = Get mean... start end hertz

sdPitch = Get standard deviation... start end hertz

#VOICE MEASURES (JITTER, SHIMMER), WE USE CROSS-CORRELATION FOR

JITTER AND SHIMMER

#100 and 600 HZ are the pitch range settings.

select mySound

pitch2 = To Pitch (cc)... 0.01 100 15 no 0.03 0.45 0.01 0.35 0.14 600

plus mySound

pulses = To PointProcess (cc)

plus mySound

plus pitch2

voiceReport$ = Voice report... start end 100 600 1.3 1.6 0.03 0.45

report$ = Voice report... start end 100 600 1.3 1.6 0.03 0.45

jitter_loc = extractNumber (report$, "Jitter (local): ") *100

shimmer_loc = extractNumber (report$, "Shimmer (local): ") *100

```
#INTENSITY

select Intensity 'mySound$'

meanIntensity = Get mean... start end dB

#DURATION

dur = end-start

line$="'mySound$"tab$"int$"tab$"meanPitch:3"tab$"sdPitch:3"tab$"jitter_loc:3"tab$"shimmer_l

        oc:3"tab$"meanIntensity:3"tab$"dur:4"tab$"newline$'"

line$>>'output_folder$'/output data.txt

endif

endfor

endfor
```