AN EXPLORATORY COMPARISON OF UTTERANCE DURATIONS BETWEEN CHILDREN WITH AUTISM SPECTRUM DISORDER AND CHILDREN WITH DEVELOPMENTAL DELAYS

A Thesis by

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The following faculty members have examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Arts, with a major in Communication Sciences and Disorders.

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Douglas F. Parham, Committee Chair

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Trisha Self, Committee Member

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Elaine Bernstorf, Committee Member

DEDICATION

To my parents, Cathy and Rick Stevenson, to my sister, Rebecca Stevenson, and to my partner, Lydia Roemer, for your endless encouragement and your faith in me.

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ABSTRACT

There are several acoustic variables of interest in the speech output of children with Autism Spectrum Disorder (ASD). These variables include fundamental frequency (perceived as pitch), intensity (perceived as loudness), and the duration of sounds. This study examined the differences in the duration of speech productions in young children with ASD compared to young children with developmental delay (DD) without ASD. Utterance durations were determined from audio recordings of six two-year-old children (3 diagnosed with ASD and 3 diagnosed with DD). Descriptive statistics were calculated for the durations and the number of utterances for each child. These included means, standard deviations, minimums, maximums, and medians. For each child, the utterance durations were graphed across the entire session to explore whether durations changed over time. Finally, the number of utterances per minute were calculated for each child. The children with DD produced a higher number of utterances per minute than the children with ASD. The children with DD produced numerically more utterances than the children with ASD. All of the children appeared to produce utterance durations with comparable descriptive statistics. The visual representation of utterance duration over time for the individual children showed that four of the five children produced variable utterance lengths throughout the session. Although statistical testing for differences was not appropriate, it appeared that the children with DD produced a higher number of utterances per minute than the children with ASD. Future research in this area should include larger scale studies with more children in each cohort to determine if patterns exist within and between groups. Future studies should also consider recording sessions in environments with limited background noise to improve the quality of audio recordings and make it possible to examine additional prosodic elements of speech.

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LIST OF ABBREVIATIONS

ADOS	Autism Diagnostic Observation Schedule
AIDT	Autism Interdisciplinary Diagnostic Team
ASD	Autism Spectrum Disorder
ASHA	American Speech-Language-Hearing Association
CARS	Childhood Autism Rating Scale
CBCL	Child Behavior Checklist
CSBS-DP	Communication and Symbolic Behavior Scales Developmental Profile
DD	Developmental Delay, Developmentally Delayed
ITSP	Infant/Toddler Sensory Profile
LTAS	Long Term Average Spectrum
M-CHAT-R/F	Modified Checklist for Autism in Toddlers, Revised with Follow-Up
NOS	Not Otherwise Specified
SLP	Speech-Language Pathologist, Speech-Language Pathology
TD	Typical Development, Typically Developing
WNL	Within Normal Limits.

CHAPTER 1

INTRODUCTION

1.1 Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a developmental disability characterized by deficits in social communication and interaction and by restricted, repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). Communicative impairments in ASD range from reduced or abnormal social approach and back and forth conversation to a complete lack of initiation of social interaction (Irvine, Eigsti, & Fein, 2016; Paul, Shriberg, McSweeny, Cicchetti, Klin, & Volkmar, 2005). Deficits are also apparent in nonverbal communication and the ability to develop and maintain relationships (Morett, O'Hearn, Luna, & Ghuman, 2016).

1.2 Speech impairments in ASD

Research on communication in individuals with ASD suggests that communication impairments exist not only in language use, but also in speech production and perception (Filipe, Frota, Castro, & Vicente, 2014). Several studies have focused on the prosody processing and production patterns of persons with ASD (Nadig & Shaw, 2012; Paul, Augustyn, Klin, & Volkmar, 2005; Russo, Larson, & Kraus, 2008). Some research has found that children with ASD are within the range of typical development in perceiving prosody (Chevalier, Noveck, Happé, & Wilson, 2011; Grossman, Bemis, Skwerer, & Tager-Flusberg, 2010).

Chevalier and colleagues (2011) studied the theory of mind, prosody processing abilities of 16 adolescents with ASD and 16 with typical development (TD). The researchers created a framework to organize the vocal cues being used by the amount of mindreading required to identify them. They tested the abilities of the participants to identify various manners of speech, physical states, and mental states solely from vocal cues while in engaged in a single task or in dual (high or low demanding) tasks. The children with ASD performed similarly to the children with typical development in their speed and accuracy in processing prosodic cues, in all levels of meta-representational complexity in both single and low-demanding dual tasks. During the higher-demanding dual task, the adolescents with ASD continued to perform at a similar level of accuracy as the TD group, but demonstrated a slower response rate. The results of this study contradict previous research that found that individuals with ASD have a specific impairment in their ability to recognize emotions related to theory of mind. The researchers concluded that children with ASD may have increased difficulty identifying prosodic cues, in general, when under higher cognitive load, compared to their typically developing peers.

Studies focused on the prosodic nature of vocal productions of individuals of ASD have found an impaired ability to produce prosodic patterns within the normal range expected in conversation (Grossman et al., 2010; Diehl & Paul, 2013; Shriberg, Paul, McSweeny, Kiln, Cohen, & Volkmar, 2001). This also includes differences in tonal languages, such as Mandarin Chinese (Chan & To, 2016; Jiang, Liu, Wan, & Jiang, 2015; Yu, Fan, Deng, Huang, Wang, & Zhang, 2015). Diehl and Paul (2013) and Grossman and colleagues (2010) found that children with ASD produced atypically long utterances. In their study of adults with high functioning autism, Shriberg and colleagues (2001) found that adults with high functioning autism and Asperger's disorder produced utterances that were inappropriate in phrasing, stress and resonance.

Another speech domain, for which differences have been found for individuals with ASD is pitch. Sheinkopf, Iverson, Rinaldi, and Lester (2012) investigated the cry acoustics of 21 ASD-risk and 18 low-risk infants. They found that infants at high risk for ASD produced pain related cries with higher and more variable fundamental frequency than infants at low-risk for ASD. Bonneh, Levanon, Dean-Pardo, Lossos, and Adini (2011) compared the long term average spectrum (LTAS) and pitch variability of 41 children with ASD and 42 with TD while they named daily life pictures. The children with ASD had more shallow and less harmonic LTAS than the controls. They also demonstrated larger pitch range and variability over time. Diel and Paul (2013) found that children with ASD had higher pitch ranges and pitch variance than children with TD.

Researchers also concluded that some children with ASD produce atypical vocal quality (Sheinkopf, Mundy, Oller, & Steffens, 2000) and have a greater prevalence of speech-sound distortions than is found in the typical population (Shriberg et al. 2001). Van Santen, Prud'hommeaux, Black, and Mitchell (2010) concluded that prosodic differences between people with typical development and people with ASD are not due to weakness of the stress contrast but to an atypical balance of the acoustic features.

1.3 Utterance Duration in Typically Developing Infants

Robb and Saxman (1990) studied bisyllable productions longitudinally in seven infants between 8 and 14 months of life. The infants were recorded once a month for thirteen months. The bisyllables ranged between 0.6 seconds to 1.2 seconds for nonwords, and 0.6 seconds to 1 second.

Parham, Buder, Oller, and Boliek (2011) compared breathing measurements of tidal and syllable-related breathing cycles of infants in the second year of life. The researchers also compared measurements of duration between unarticulated syllables (i.e., vowels and vowel-like sounds) and canonical syllables (i.e., syllables with at least one consonant margin and resonant vowels). Nine infants participated in this study in which speech and breathing data was collected as an experimenter elicited vocalizations with the assistance of the infant's parent. Utterance boundaries were identified from the audio recordings and then syllable types were coded and breathing measurements were calculated. Unarticulated syllable cycles and canonical syllables cycles did not differ significantly from each other in duration. All utterances ranged from approximately 0.5 seconds to 1.5 seconds. The children in the study by Parham and colleagues (2011) were typically developing and under two years of life. Moreover, all utterances were single syllables.

The way in which utterance duration develops to a mature level is unknown. Therefore, it is important for researchers to study and track the duration of utterances in prelinguistic and early linguistic infants and toddlers to help create a solid base of research that can support early identification and intervention for young children with delayed development. Ramsdell-Hudock, Stuart, and Parham (2018) investigated the utterance duration in typically developing infants. They examined the relationship between utterance duration and communicative variables including vocal type, facial affect, gaze direction, and age of 15 typically developing infants, six males and nine females. Participants were recorded monthly for one hour while playing with their parents in an infant vocal developmental laboratory. Utterance boundaries were determined through coding to calculate utterance duration and to further code for vocal type, facial affect, and gaze direction. The majority of the utterance produced by the infants and included in this study were vowels. Vowel utterances had the shortest average duration while cries had the longest average duration. Vowels were longer in utterances produced by infants at the oldest age than in utterances produced by infants at younger ages. Regarding the relationship between utterance duration and facial affect, utterances produced by infants with a neutral facial affect had the shortest average duration while utterances produced by infants with a negative facial affect had the longest average duration. At the oldest age, utterances produced with a positive facial affect were longest in duration. Utterances produced while the infants' gaze was not directed at a person were shortest in average duration while utterances directed at a person were longest in average duration.

1.4 Speech Differences in Young Children with ASD

Many of the previously mentioned behaviors are limited to children who have reached a certain developmental level. That leads to the question of what communicative differences are present in infants and toddlers who are diagnosed with ASD (Schoen, Paul, & Chawarska, 2011).

Many studies have examined the speech and language of young children with ASD compared to children with typical development. The focus of much research is in expressive language outcomes (Kover & Weismer, 2014; Tager-Flusberg et al., 2009), but some studies examine the acoustic and/or gestural content of communication in these children. In a study by Sheinkopf and colleagues (2000), preschool age children with ASD and DD were compared to determine their rates of atypical vocalizations and the relationship between production of atypical vocalizations and joint attention use. The children with ASD produced a higher proportion of syllables with atypical vocal quality than the children with DD. The children with ASD were less likely to respond to or initiate acts with joint attention. No significant correlation was found between atypical vocalizations and joint attention in the group with ASD. The independence of vocal quality and joint attention, establishes clinical significance to use both as evaluation tools in ASD. More research should be done to determine to what degree vocal quality adds incrementally to the behavioral description of autism in young children.

Plumb and Wetherby (2013) compared the vocalizations of children between the ages of 18 and 24 months with Autism Spectrum Disorder (50), developmental delay (25), and typical development (50). The researchers coded the vocalizations into communicative and non-communicative acts as well as transcribable and nontranscribable vocalizations. They found that the children with ASD demonstrated a significantly lower proportion of transcribable vocalizations, and higher proportions of atypical and distress vocalizations than TD. Children with ASD with a higher proportion of transcribable vocalizations had better communications skills as measured by a language assessment, the Communication and Symbolic Behavior Scales Developmental Profile (CSBS-DP), in the second year of life.

Shumway and Wetherby (2009) examined the communicative acts of 50 children with ASD (18-24 months of age), 25 children with developmental delay, and 50 children with typical development. They found that children with ASD used a significantly lower rate of communicative acts than children with DD and TD. Children with ASD also used a lower proportion of communicative acts for joint attention than children with DD and TD. Overall, the children with ASD used fewer communicative gestures than both the DD and TD groups. Children with ASD relied on more primitive gestures and used a smaller proportion of deictic gestures (i.e., gestures that require some context to understand). The rate of communication in children with ASD late in the second year, was a strong predictor of verbal and nonverbal outcomes in the third year of life. The results indicate that a core deficit in children with ASD is the rate of communication and that children with ASD communicate more for behavior regulation than for more social acts such as joint attention.

1.5 Early Diagnosis and Intervention

Several researchers have studied the relationship between early speech productions and later language outcomes (Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011; Plumb & Wetherby, 2013; Shumway & Wetherby, 2009; Watt, Wetherby, & Shumway, 2006). In children with typical development, prelinguistic skills, including joint attention, inventory of gestures, comprehension, symbolic play, and inventory of words correlate with receptive and/or expressive language skills at age three (Watt et al., 2006). Paul and colleagues (2011) investigated the speech productions of infants at high risk and low risk for the development of Autism Spectrum Disorder, comparing the number of consonants produced, presence of canonical syllables, and the proportion of non-speech vocal behavior. They found that infants at high risk for ASD produced fewer consonants, fewer speech-like vocalizations, and more non-speech vocalizations than the low-risk for ASD group. Differences in the characteristics of vocal productions of infants in the high risk group had significant associations to the outcomes of provisional diagnosis of ASD in the second year of life. Therefore, atypical early vocal behavior may be an indicator of heightened risk for autistic symptoms in infants with a family history of ASD (Paul et al., 2011). Identifying these differences earlier also can help parents by providing better strategies for communication, such as avoiding telegraphic speech (Venker, Bolt, Meyer, Sindberg, Weismer, & Tager-Flusberg, 2015).

The achievement of developmental milestones, across domains, is more likely to be delayed in infant siblings of children with ASD, and infants at high risk for ASD also are at risk for other developmental disabilities (Iverson & Wozniak, 2007). Continued research is needed to expand and strengthen the knowledge base of early interventionists in order to promote early detection, differential diagnosis, and evidence based treatment.

1.6 Research Limitations and Current Focus

There are several acoustic variables of interest in the speech output of children with ASD. These variables include fundamental frequency (perceived as pitch), intensity (perceived as loudness), and the duration of sounds. To measure these variables, it is critical to record the children's speech output in environments that allow for quality recordings. This means that environments should be relatively quiet, children should remain stationary as much as they can, and there should be a limited number of other speakers in the room where the recordings take place. Unfortunately, none of these conditions are assured when recordings are made as a part of an interdisciplinary diagnostic session. In these situations, there is environmental noise, children have difficulty remaining in one place, and other participants can include parents, speech-language pathologists, student clinicians, and sometimes a child's siblings. For the current study, the focus of the research questions focused only on speech durations. The measurement of utterance durations was the acoustic variable that was the most robust to the recording limitations encountered during a diagnostic recording. The study examined the differences in the duration of speech productions in young children with ASD compared to young children with developmental delay. It also was important to measure the number of utterances produced across an entire recording session.

CHAPTER 2

STATEMENT OF THE PROBLEM

2.1 Summary of Introduction

Children with ASD have an impaired ability to engage in social communication and interactions. This can manifest itself in many ways, including language use as well as speech production and perception. Research has suggested a relationship between early speech production and language outcomes later in life (Paul et al., 2011; Plumb & Wetherby, 2013; Shumway & Wetherby, 2009; Watt et al., 2006). Because of the importance of early detection and intervention for children with ASD and other developmental disabilities, research should focus of the identification of early markers of ASD. It is also important to explore the acoustics of speech production in children with ASD to see how they differ from other children, as well as provide guidance for data collection and analysis for clinicians who need to record children's speech production as a part of the diagnostic process. This is important for both clinicians and parents of children with ASD in terms of developing developmental strategies for speech and language outcomes (Tager-Flusberg et al., 2009).

2.2 Utterance Duration

As stated in the previous chapter, there are many variables related to speech production that are of interest to studying utterances of children with ASD. The problem with acoustic analysis is that it requires good recordings. Two acoustic variables—fundamental frequency and intensity—are most negatively affected by noisy environments. However, utterance duration is an acoustic variable measured with less difficulty, even when the recordings take place in noise.

2.3 Focuses of the Current Study

The exploratory study looked at four different but related questions by comparing acoustic recordings of a small cohort of children diagnosed with Autism Spectrum Disorder and a small cohort of children diagnosed with a developmental delay.

2.3.1 Research Focus 1: Overall Duration and Utterance Results

Are there differences in the number of utterances between children diagnosed with ASD and those diagnosed with a developmental delay?

2.3.2 Research Focus 2: Descriptive Statistics for Utterance Durations

Are there differences in the descriptive statistics of utterance durations between children diagnosed with ASD and those diagnosed with a developmental delay?

2.3.3 Research Focus 3: Visual Representation of Utterance Durations for Each Child

Through visualizing each child's utterance durations across an entire recording session, are there differences in the patterns of utterance durations between children diagnosed with ASD and those diagnosed with a developmental delay?

2.3.4 Research Focus 4: Utterances per Minute

Vocalization rate is an important factor in identifying toddlers at risk for ASD (Chenausky, Nelson, & Tager-Flusberg, 2017). This current study looked at potential differences in the number of utterances per minute between children diagnosed with ASD and those diagnosed with a developmental delay.

CHAPTER 3

METHODS

3.1 IRB Approval

The Institutional Review Board at Wichita State University approved this study (IRB No. 1425; Project Title: "Vocalization and Speech Breathing in Infants and Adults"; see Appendix A). Each child's parent or guardian signed a consent form permitting the recording. Families participating in the study received compensation for the recording session (see Appendix B).

3.2 Study Participants

The children who participated in this study were a subset of a larger group of participants recorded as part of Wichita State University's Autism Interdisciplinary Diagnostic Team (AIDT; Self, Mitchell, Hess, Marble, & Swails, 2016). The purpose of the AIDT is twofold:

> (1) to train undergraduate and graduate students via a hands-on interprofessional education (IPE) model, to better recognize the characteristics of ASD, as well as screen, assess, and refer children who demonstrate signs of ASD and their families; and (2) provide a highly needed to service to children and families throughout South Central Kansas ("WSU Community Partners," 2018).

Each of the children involved in the AIDT project underwent a pre-diagnostic evaluation and a full interdisciplinary evaluation to rule out Autism Spectrum Disorder. For this current study, six children were included based on age and availability of utterance data. The included participants' parents were asked to provide information related to demographic variables such as age and gender (Table 1), birth-related variables (Table 2), and pre-AIDT diagnostic variables (Table 3).

TABLE 1

PARTICIPANTS' AGE, GENDER, AND NUMBER OF SIBLINGS

Child	Age at evaluation	Gender	Number of siblings
C1	2 years, 2 months	Male	None
C2	2 years, 4 months	Male	1 older brother
C3	2 years, 10 months	Female	2 older brothers
C4	2 years, 6 months	Male	1 older brother
C5	2 years, 7 months	Male	1 older sister
C6	2 years, 7 months	Male	1 older sister

TABLE 2

PARTICIPANTS' PRENATAL, PERINATAL, AND POSTNATAL INFORMATION

Child	Premature	Prenatal care	Birth information	Environmental exposure
C1	No	Yes	Mother almost miscarried at seven months due to heavy bleeding	Tobacco use, abusive father, dropped on head around four months
C2	No	Yes	None	Insulin and Tylenol
C3	No	Yes	Broken collar bone during pregnancy	None
C4	No	Unknown	Water on kidneys during pregnancy; not growing; problem with feeding until ten months	Adopted; Possible prenatal exposure to ethyl alcohol/drugs
C5	No	Yes	Mother took Trileptal for epilepsy throughout pregnancy	None
C6	No	Unknown	Hospitalized for four days due to jaundice	Unknown

TABLE 3

PARTICIPANTS' DEVELOPMENTAL INFORMATION PRIOR TO THE AIDT

Child	Developmental screening	Hearing results	Gross motor AE	Fine motor AE
C1	Unknown	Normal, but no otoacoustic emissions	Demonstrates some age appropriate skills	Appropriate grasp, transferred between hands, demonstrated age appropriate visual motor skills
C2	WNL	WNL	2:5-3:0	Immature pencil grasp; switched between right/left hands; stacked 3-4 blocks; demonstrated finger isolation
C3	WNL	Audiologist suggested mild hearing loss	1:0-1:5	Mature grasp; stacked/lined up blocks; left hand preference; demonstrated put in and put out tasks
C4	WNL	WNL	2:0-2:5	Good pincher grasp; Did not imitate vertical or horizontal line; poor coordination/ strength; no finger isolation was demonstrated
C5	Y-ITSP CBCL 1-5	Adequate for speech and language; may fluctuate due to allergies/ asthma	Age appropriate	Age appropriate
C6	Ages & Stages Screening at 25 months revealed a speech-language delay	WNL	Age appropriate	Skills at the 2-3 year range, no evidence of hand dominance. Preferred to be active versus sitting,

Note. CBCL = Child Behavior Checklist. ITSP = Infant/Toddler Sensory Profile. WNL = Within Normal Limits.

Parents also were asked to provide information related to the children's pre-existing diagnoses (if available, previous screenings related to Autism Spectrum Disorder), and the parents' initial complaints, namely, the purpose for having the child be seen by the AIDT. This information is found in Table 4.

TABLE 4

PARTICIPANTS' SCREENING INFORMATION AND PARENT COMPLAINT

Child	Pre-existing diagnosis	ASD prescreening	Initial parent complaint
C1	None	No screening	"Help and understand child's needs with autism"
C2	Developmental Delay	No screening	"No words spoken; potential Autistic Disorder"
C3	None	No screening	"Lack of communication and understanding. She doesn't talk, only makes sounds and she is about to be 3 years old. She looks up and away at nothing and waves her hands. Every time she gets mad she tries to hit her head with everything. I have three other kids and never had these kinds of reactions."
C4	Expressive language disorder at 2.5 years old	No screening	"Speech and behavioral concerns"
C5	Disruptive Behavior Disorder NOS	No screening	"Poor coordination, tantrums, sensory avoidance"
C6	None	M-CHAT-R/F at 26 months	"Concerned about his speech and language skills and his lack of words (20-30)"

Note. M-CHAT-R/F = Modified Checklist for Autism in Toddlers, Revised with Follow-Up. NOS = Not Otherwise Specified.

Based on results of the AIDT process, each child underwent full diagnostic testing. Following the testing, each child received a confirmatory diagnosis to rule out or confirm Autism Spectrum Disorder. For the six participants included in this current study, three children were diagnosed with Autism Spectrum Disorder and three were diagnosed with a developmental delay without Autism Spectrum Disorder. The test results and the diagnoses for the participants are presented in Table 5.

TABLE 5

PARTICIPANTS' ASD DIAGNOSTIC RESULTS

Child	ADOS module and score	CARS score	Final medical diagnosis[a]
C1	Module 1: Comparison Score-9-HIGH; Classification: Autism	44	Autism active; Developmental delay
C2	Module 1: Comparison Score-10-HIGH; Classification: Autism	42	Autism active; Developmental delay
C3	Module 1: Comparison Score-10-HIGH; Classification: Autism	41	Autism active
C4	Module 1: Comparison Score-1-Minimal-to-no evidence; Classification: Non-spectrum	21	Developmental speech disorder
C5	Module 2: Comparison Score-2-Minimal-to-no evidence; Classification: Non-spectrum	22.5	Developmental delay
C6	Module 1: Comparison Score 2-Minimal-to-no evidence; Classification: Non-spectrum	10	Developmental delay

Note. ADOS = Autism Diagnostic Observation Schedule. CARS = Childhood Autism Rating Scale
[a]"Final Medical Diagnosis" designates a diagnosis received from a developmental pediatrician.

3.3 Setting

The pre-diagnostic sessions were audio-recorded at the two-room Speech Development and Communication Lab at Wichita State University's Eugene M. Hughes Metropolitan Complex (Wichita, KS). The children, their families, and the clinicians met in the observational playroom (designed as a family-friendly living room). A second room contained the recording equipment and was coupled to the observational playroom via a one-way mirror.

3.4 Instrumentation

The children's speech output was captured using a Sennheiser Evolution G2 100 Series wireless microphone system (Sennheiser Electronic Corporation, Old Lyme, CT). A lapel microphone was attached to each child's shirt.

The lapel microphone signals were captured using a USB-based data acquisition module (Data Translation, Inc., Marlboro, MA) and digitally recorded on a computer with the software program "Time-frequency analysis for 32-bit Windows" (TF32: Lab Automation Level) (Milenkovic, 2001). A second high-quality digital audio recorder captured an additional audio signal (at 96,000 samples per second). The entire sessions were recorded for subsequent analysis.

3.5 Study Protocol

Each of the participating families was briefed prior to the pre-diagnostic session about the purpose of the recordings and the activities that the child would experience. The lead AIDT investigator and two to three student clinicians organized the session. The pre-diagnostic session consisted of different skilled speech therapy activities, including informal and formal language testing, turn-taking opportunities, and free play. The audio recordings took place throughout the session. The lapel microphone was placed on each child's shoulder, pointing towards the child's face, at a typical distance of six inches. The placement was to help prevent the child from pulling the lapel microphone off the front of the shirt. The digital recorder was positioned on another table at a standardized distance (36 inches) in front—or to the side—of the child. The parent or guardian was interviewed by a student clinician during the testing. Recordings lasted between one and two hours, depending on the demeanor of the child and speed of the diagnostic protocol. The order of diagnostic protocols was adjusted if a child became visibly upset during the sessions or needed a break from the session. After each recording, the child's parents or guardians were debriefed about the session and the purpose of the pre-diagnostic recording.

3.6 Data Analysis

The acoustic signal of each session was examined to identify utterances produced by the child. The audio recordings were viewed as waveforms in the TF32 software program (Milenkovic, 2001). In order to compare the children across similar recording times and thus reduce the possibility that longer recordings would reflect fatigue effects in children, the data within the first hour of the recordings were analyzed. This limit only affected the recording of Child 5, whose session lasted almost two hours.

Coders were asked to identify unambiguous examples of each child's speech production, including preverbal sounds, syllables, words, and multi-syllable utterances. Coders used the TF32 software labeling function to identify the beginning and end of each utterance. They placed cursors around each utterance; the software program automatically saved and tabulated these measurements. Analysis was confined to utterances of 10 seconds or less to maintain consistency in type of utterances for analysis. Utterances over 10 seconds in duration were chains of utterances that coders were unable to subdivide. The number of excluded utterances above the 10-second ceiling were as follows: Child 1, 1; Child 2, 7; Child 3, 11; Child 4, 1; Child 5, 7; and

Child 6, 6. The completed coding files were exported into more advanced software programs for further analysis and graphing (e.g., Microsoft Excel).

3.7 Statistical and Visual Analysis

Because of the small number of children in the study, inferential statistical comparisons were not appropriate for this dataset. The research questions were explored using descriptive statistics which were calculated for the durations and the number of utterances for each child. These included means, standard deviations, minimums, maximums, and medians. For each child, the utterance durations were graphed across the entire session to explore whether durations changed over time. Finally, the number of utterances per minute were calculated for each child. This was done by dividing the number of utterances by the number of minutes in the entire recording session. As indicated above, utterances longer than 10 seconds were not included in this analysis, and thus did not influence any of the descriptive statistics or calculations.

CHAPTER 4

RESULTS

4.1 Research Focus 1: Overall Duration and Utterance Results

All six children produced a sufficient number of analyzable signals (e.g., at least 25 each). Table 6 shows the duration of each recording, the total number of each child's utterances (excluding those above 10 seconds), and the total duration of all utterances in each session.

TABLE 6

DURATION AND RECORDING INFORMATION FOR EACH CHILD

Child	Recording time	Total utterances	Total utterance duration
Children with ASD			
C1	23 min, 55 s	26	0 min, 47 s
C2	53 min, 22 s	213	7 min, 34 s
C3	35 min, 19 s	85	5 min, 20 s
Children with Developmental Delay			
C4	47 min, 11 s	464	10 min, 7 s
C5	50 min, 0 s	439	19 min, 40 s
C6	28 min, 2 s	175	7 min, 55 s

4.2 Research Focus 2: Descriptive Statistics for Utterance Durations

Descriptive statistics were calculated for the utterance durations for each child (excluding those above 10 seconds). These included means, standard deviations, minimums, maximums, and medians. These are presented in Table 7.

TABLE 7

DESCRIPTIVE STATISTICS FOR UTTERANCE DURATIONS BY CHILD (IN SECONDS)

Child	*Mean*	*SD*	*Min*	*Max*	*Median*
Children with ASD					
C1	1.83	1.74	0.25	7.61	1.53
C2	2.24	1.91	0.25	9.35	1.51
C3	4.22	2.32	0.85	9.34	3.89
Children with Developmental Delay					
C4	1.33	1.00	0.16	8.50	1.06
C5	2.71	1.37	0.97	9.17	2.44
C6	2.84	1.71	0.42	9.35	2.23

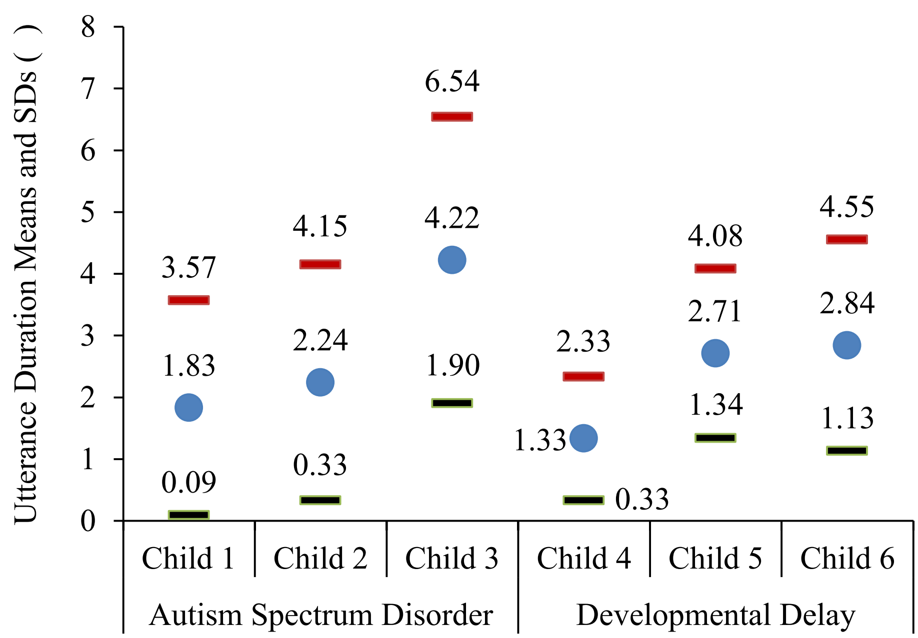

Figure 1. Means and standard deviations (± 1) for utterance durations (measured in seconds) for each child. Mean utterance duration is indicated with a circle. Means ± one standard deviation are indicated with bars.

The means and standard deviations for utterance durations for each child also are presented visually in Figure 1. Child 3 demonstrated the highest mean and standard deviation values, while both values for Child 4's utterance durations were the lowest.

4.3 Research Focus 3: Visual Representation of Utterance Durations for Each Child

For each child, the utterance durations (measured in seconds) were graphed across the entire session (measured in minutes) to explore whether durations changed over time. For the purposes of comparison, these data for the first 30 minutes of each recording for Child 1 through Child 6 are presented in Figures 2 through 7, respectively. The data for each child's entire recording are graphed in Appendix 3. For each Figure, the duration of each utterance and the time that it was produced during the session are graphed across the entire session. The mean utterance duration for each child is indicated with a black line, and the area covering ± one standard deviation is within the gray bar.

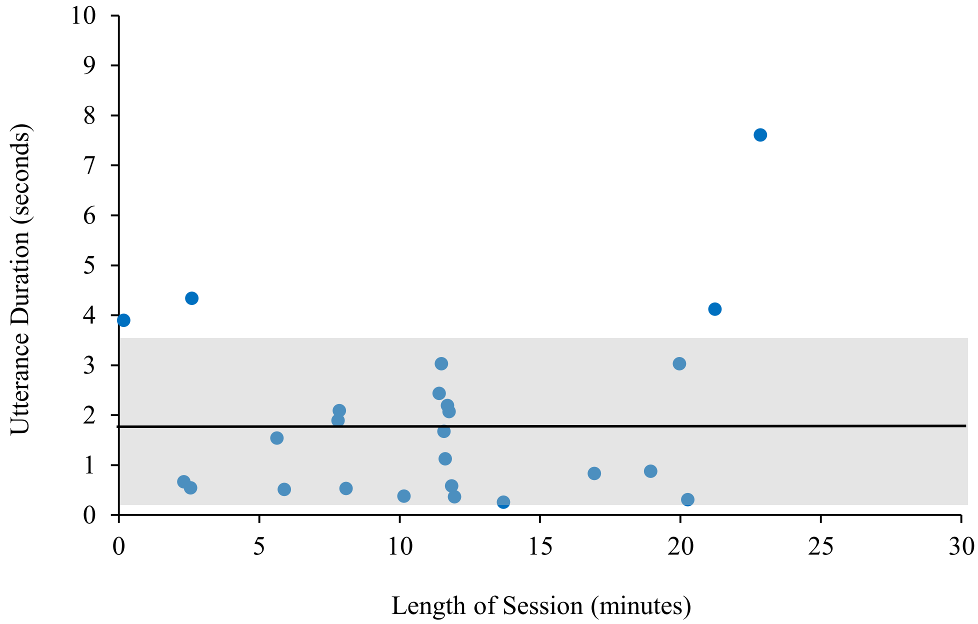

Figure 2. Distribution of utterances for Child 1 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

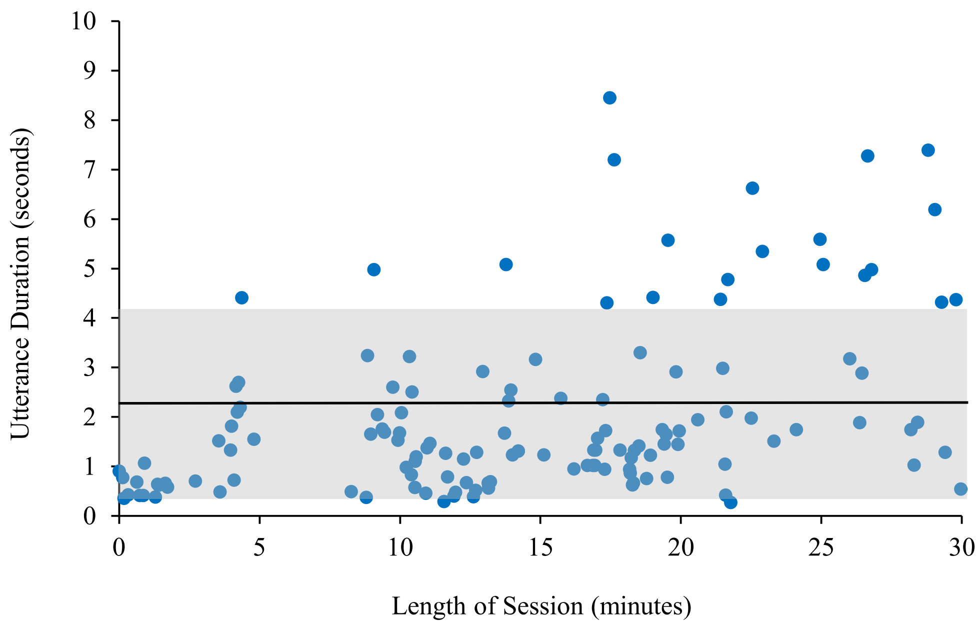

Figure 3. Distribution of utterances for Child 2 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

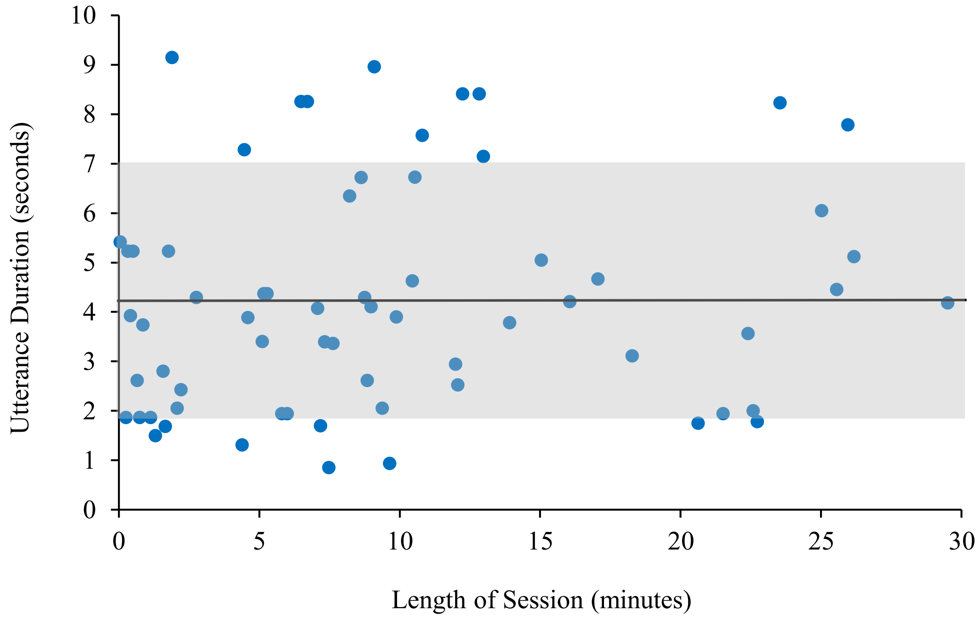

Figure 4. Distribution of utterances for Child 3 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

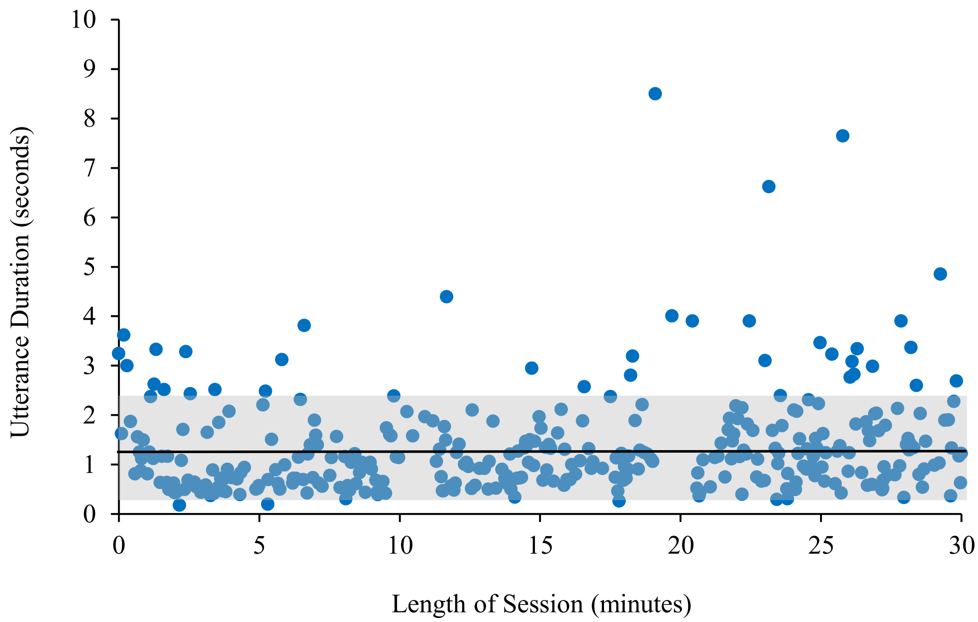

Figure 5. Distribution of utterances for Child 4 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

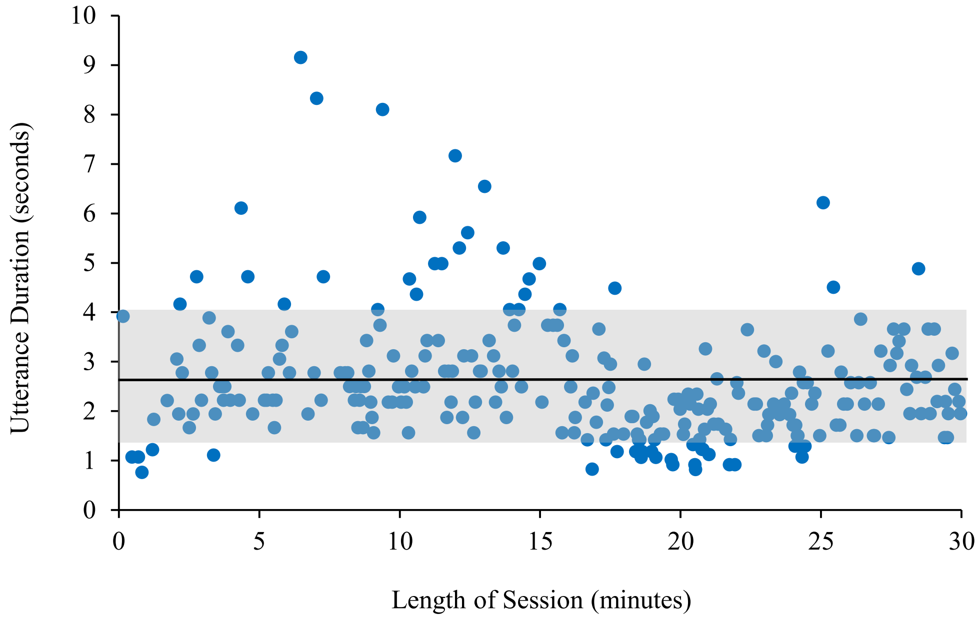

Figure 6. Distribution of utterances for Child 5 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

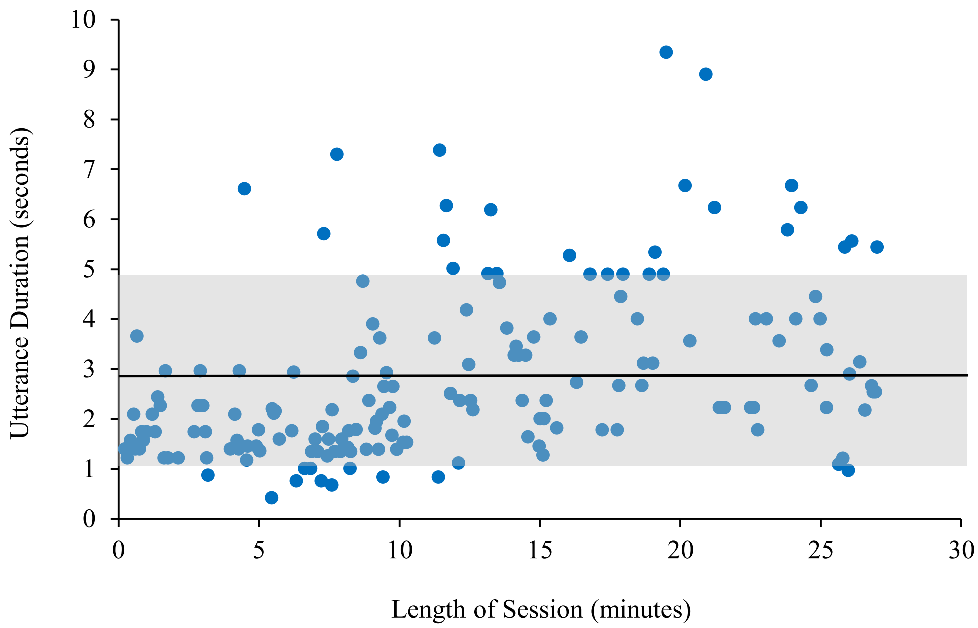

Figure 7. Distribution of utterances for Child 6 for the first 30 minutes of the recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.

4.4 Research Focus 4: Utterances per Minute

Utterances per minute were calculated by dividing the total session duration by the number of total utterances. The children with ASD (C1, C2, and C3) produced 1.09, 3.99, and 2.41 utterances per minute. The children with developmental delay (C4, C5, and C6) produced 9.83, 8.78, and 6.24 utterances per minute; the higher rate of utterances was produced by the children with developmental delay. The small number of children per group did not allow for formal testing to see if the groups were statistically different. Figure 8 shows the numerical data by group.

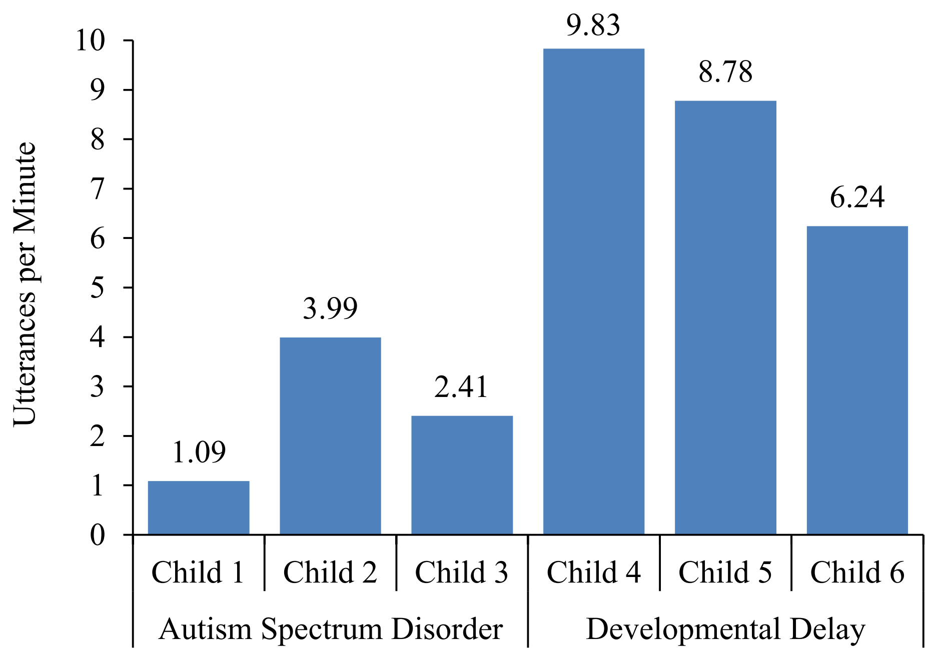

Figure 8. Utterances per minute for each child by group.

CHAPTER 5

DISCUSSION

5.1 Summary of Findings

This study examined the durations and rate of utterance productions of a small number of two-year-old children, three with Autism Spectrum Disorder and three with developmental delay without ASD. The following is a summary of the findings for the four focuses of research. Because of the small number of children, it was not possible to calculate inferential statistics. Descriptive statistics were calculated for the utterance durations and the data was presented graphically to look for patterns.

5.1.1 Research Focus 1: Overall Duration and Utterance Results

Recording durations for the six children ranged from approximately 24 minutes to 53 minutes. When the recording durations and the number of utterances across those durations were compared, the children with developmental delay without ASD produced numerically more utterances than the children with ASD.

5.1.2 Research Focus 2: Descriptive Statistics for Utterance Durations

Given the inappropriateness of inferential statistical analysis of the data, all of the children appeared to produce utterance durations with comparable descriptive statistics. Child 3 demonstrated the highest mean and standard deviation values, while Child 4's descriptive values for utterance durations were the lowest.

5.1.3 Research Focus 3: Visual Representation of Utterance Durations for Each Child

The children in this study performed similarly to other studies in which the results were highly individualized. Two of the children with developmental delays had observably more utterances throughout their sessions than the other four children. Children from both the ASD and the DD groups showed floor effects in their utterance durations. The visual representation of the utterance duration over time for the individual children showed that four of the five children produced variable utterance lengths throughout the session. Child 4 with developmental delay produced clusters of utterances of similar length at various times throughout the session.

5.1.4 Research Focus 4: Utterances per Minute

Although statistical testing for differences was not appropriate, for these six children, those with developmental delay produced a higher rate of utterances per minute than the children with ASD. This means that the children with DD expressed themselves more frequently throughout the recording sessions. Of the four research focuses, this one seemed to reveal the largest observational difference between the three children with ASD and the three children with DD.

5.2 Relationship to Previous Studies

The studies on typically developing infants—particularly the study by Ramsdell-Hudock and colleagues (2018)—provide information that is helpful to understanding the utterance durations of children with ASD. First, utterances in typically developing children increase in duration over the first two years of life. Second, the other variables in the study—typical development in utterance durations, vocal type, facial affect, and gaze direction—have importance for therapy intervention in children with ASD. These studies provide a base of comparison for the data recorded in the current study.

5.3 Limitations

Some limitations exist due to the nature of research involving children. Due to the clinical environment, the children may have produced vocalizations differently than they would have in a more natural environment (e.g., the family home or the child's regular educational setting), thus resulting in data that do not reflect what the children typically do in terms of speech production. Also, the variability of the order and length of diagnostic protocols during each child's recording session may have led to variations in utterance productions by the children. In addition, the small cohort of children limits the generalizability of the data collected.

5.4 Clinical Implications

The information presented in this study suggests that clinicians should be aware of utterance duration and rate of utterance production when evaluating and treating children with ASD. Given the right conditions, prosodic elements of speech could to be included in comprehensive speech and language services for children with ASD as appropriate. Prosodic speech elements already have been researched and could be included in skilled speech therapy that helps children improve self-awareness of prosody (Bonneh et al., 2011; Chevallier, 2011; Diehl & Paul, 2013). This type of skilled speech therapy can assist parents of children with ASD so that they can provide additional support to their children.

5.5 Future Directions

Future research on speech prosody should include larger scale studies with more children in each cohort to determine if patterns exist within and between groups. A protocol for eliciting utterances from the participants may be beneficial in standardizing the environment and creating additional opportunities for utterance production. Future studies also should consider recording sessions in environments with limited background noise to improve the quality of audio recordings and make it possible to examine additional prosodic elements of speech. These prosodic elements could include fundamental frequency, intensity, voice quality, and intonation patterns.

5.6 Conclusion

The current study is a preliminary exploration in the areas of utterance duration and rate of utterance production in two-year-old children with ASD and DD. The data obtained from this study help to visualize and describe the small cohort of children studied. Continued research is needed to determine if the results of this study are comparable to larger populations of children with ASD and DD.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD APPROVAL LETTER

WICHITA STATE UNIVERSITY
RESEARCH AND TECHNOLOGY TRANSFER

Date: August 28, 2017

Principal Investigator: Douglas Parham

Co-Investigator(s): N/A

Department: CSD

IRB Number: 1425

Review Category: Continuing Review

The Wichita State University Institutional Review Board (IRB) has reviewed your application for continuation of the research project entitled, **"Vocalization and Speech Breathing in Infants and Adults".** The IRB has approved the project to continue according to the Federal Policy for the Protection of Human Subjects. As described, the project also complies with all the requirements and policies established by the University for protection of human subjects in research.

This approval is for a period of one year from the date of this letter and will require continuation approval if the research project extends beyond **August 27, 2018**.

Please keep in mind the following:

1. Any significant change in the experimental procedure as described should be reviewed by the IRB prior to altering the project.
2. When signed consent documents are required, the principal investigator must retain the signed consent documents for at least three years past completion of the research activity.
3. At the completion of the project, the principal investigator is expected to submit a ***final report***; the form is attached.

Thank you for your cooperation. If you have any questions, please contact the IRB Administrator at IRB@wichita.edu.

Sincerely,

Michael Rogers, Ph.D.
Chairperson, IRB

Wichita State University, Wichita, Kansas 67260-0007 Telephone: (316) 978-3285 Fax: (316) 978-3750

APPENDIX B

COPY OF THE CONSENT FORM USED FOR THIS STUDY

Wichita State University
Institutional Review Board Approval #1425
08/28/17 –08/27/18

WICHITA STATE UNIVERSITY
COLLEGE OF HEALTH PROFESSIONS
Department of Communication Sciences and Disorders

Consent Form for Adult Participants and Their Children

Purpose: You and your child are invited to participate in a study about speaking and breathing. The purpose of this research is to explore how speaking and breathing develop across different stages of the human life span.

Participant Selection: You and your child are eligible to participate in this study because it focuses on speaking and breathing. Your speech behaviors can be compared with those of other persons across the human life span. It is anticipated that between 20 and 30 children and their families will participate in this study.

Explanation of Procedures:

- This study will take place in the Speech Development and Communication Lab at the Eugene M. Hughes Metropolitan Complex, located at Oliver and 29th Street.
- If you decide to participate, you will be asked to provide basic information related to your child's health, such as the history of ear infections and/or complications during or after birth.
- Your child will be seated in the Lab's observational playroom. You will be seated in a chair near your child.
- You and your child will each wear a microphone, respiratory bands (around the rib cage and abdomen), and body movement sensors. You yourself can opt not to wear the equipment.
- To measure breath volume, you will be asked to blow air into a tube for several minutes and your child will either do the same or breathe into a small face mask.
- You and your child's speech, respiration, and body movements will be recorded. A video recording will also be made of the interaction.
- During the recording session, your child will also interact with a graduate student from the Department of Communication Sciences and Disorders who is associated with the study. The role of the graduate student is to encourage your child to produce speech sounds.
- Each recording session will last between one and two hours, but will be stopped if your child becomes upset or distressed.
- You and your child may be eligible to participate in future recording sessions while this research project is in progress.
- You will also be given the options of having your child's hearing and/or overall development screened. If you are interested in one or both of these screenings, they will be scheduled either as part of the initial recording session or for a separate visit at another time.
- It is possible that the video recording will be used in the future in educational and/or academic settings. Your permission for the educational use of the video recording is an entirely separate issue than your participating in the study. You and your child may agree to be in the study without agreeing to the educational use of the video recording.

Discomfort/Risks: There are no known physical risks to the children or adults participating in this study. The instrumentation systems and the data collection methods are non-invasive and do not pose any direct physical risk to you or your child. Regarding potential emotional risks, your child might express some discomfort being in an unfamiliar setting, interacting with an unfamiliar adult, or wearing a face mask during the first part of the recording session. Your child will not be out of your physical or visual contact, and you may stop the recording session at any time. Although no other risks are anticipated with this study, there is always a small chance of unforeseen risk.

Benefits: By participating in this research, you can be expected to benefit from knowledge gained about human development. The findings of this research will fill in the gaps of the current scientific knowledge of speech development.

Compensation:

- For you and your child's combined participation in each recording session, you will receive a one-time monetary compensation of $20.00.
- Wichita State University does not provide medical treatment or other forms of reimbursement to persons injured as a result of or in connection with participation in research activities conducted by Wichita State University or its faculty, staff, or students. If you believe that you have been injured as a result of participating in the research covered by this consent form, you can contact the Office of Research Administration, Wichita State University, Wichita, KS 67260-0007, telephone (316) 978-3285.

Confidentiality:

- Any information obtained in this study in which you can be identified will remain confidential to the extent permitted by law and will be disclosed only with your permission.
- The data from you and your child will be associated with unique codes known only to the study's research team and will be referenced only by those codes.
- Study-related files will be kept locked away when not in use by the research team.
- Federal agencies such as the Food and Drug Administration (FDA) and the Office for Human Research Protections (OHRP) may review study data as allowed by law.
- You will have the right to decide about the special use of the video recording for educational purposes (see separate form).
- You also reserve the right to have part or all of the recordings of you and your child permanently erased at any time during or after the study.

Refusal/Withdrawal: Participation in this study is entirely voluntary for you and your child. Your decision to participate or not will not affect your future relations with Wichita State University. If you agree to participate in this study, you are free to withdraw from the study at any time without penalty. If the Principal Investigator determines that your participation or your child's participation in the study is causing undue discomfort or distress to you or your child, the recording session will be terminated.

Contact: If you have any questions about this research, you can contact Douglas Parham, PhD, Principal Investigator, at the Department of Communication Sciences and Disorders at Wichita

Wichita State University
Institutional Review Board Approval #1425
08/28/17 –08/27/18

Consent Form for Adult Participants and Their Children 3

State University, Wichita, KS 67260-0075 (Telephone: 316-978-5634; E-mail: douglas.parham@wichita.edu). If you have questions pertaining to your rights as a research subject, or about research-related injury, you can contact the Office of Research Administration at Wichita State University, Wichita, KS 67260-0007 (Telephone: 316-978-3285).

You are under no obligation to participate in this study. You may stop your participation and the participation of your child at any time. Your signature indicates that you have read the information provided above and have voluntarily decided to participate. You will be given a copy of this consent form to keep.

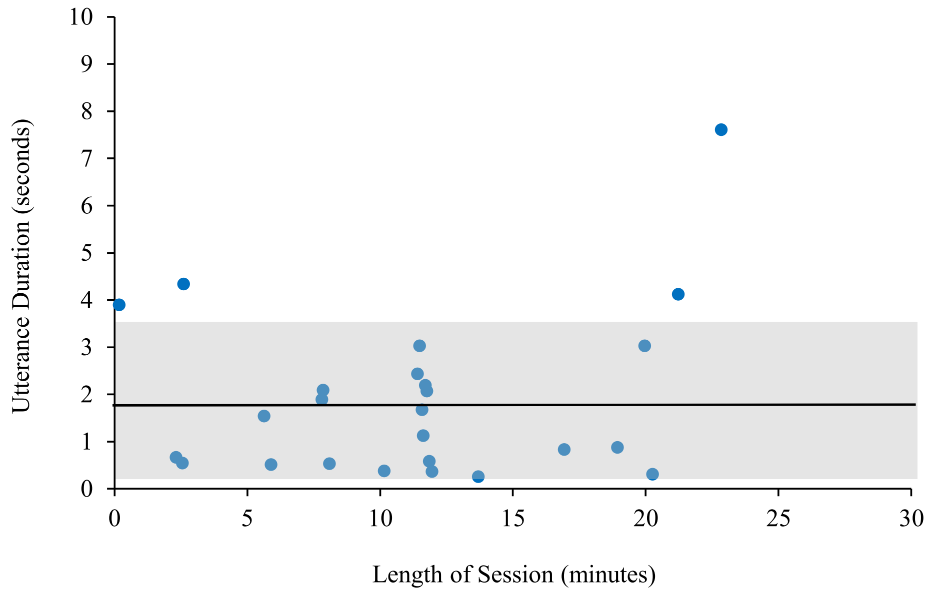
____ ________________
Signature of Parent/Legal Guardian as Participant — Date

____ ________________
Signature of Parent/Legal Guardian to Give Permission For the Child to Be a Participant — Date

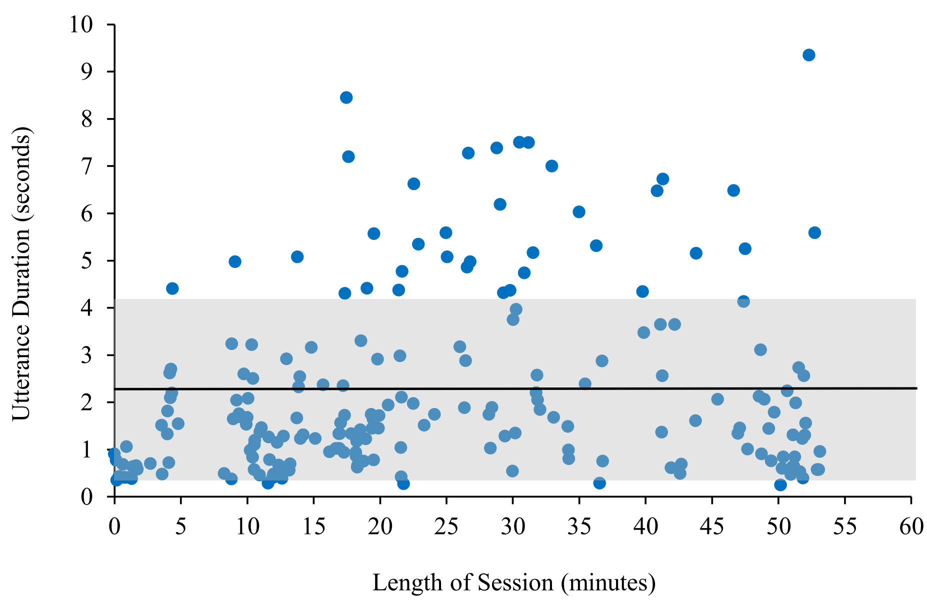
____ ________________
Signature of Person Conducting Informed Consent Discussion — Date

APPENDIX C

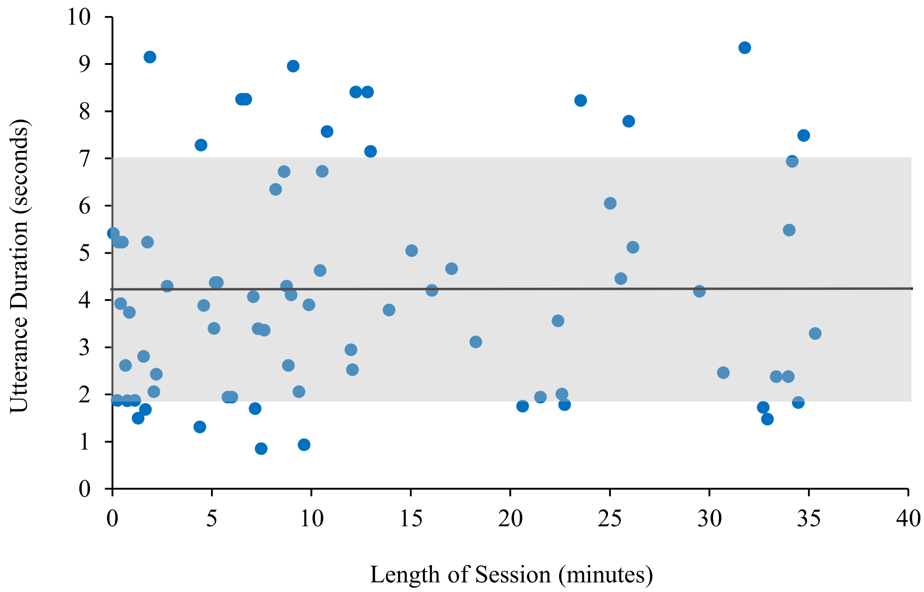
DISTRIBUTION OF UTTERANCE DURATION ACROSS EACH SESSION



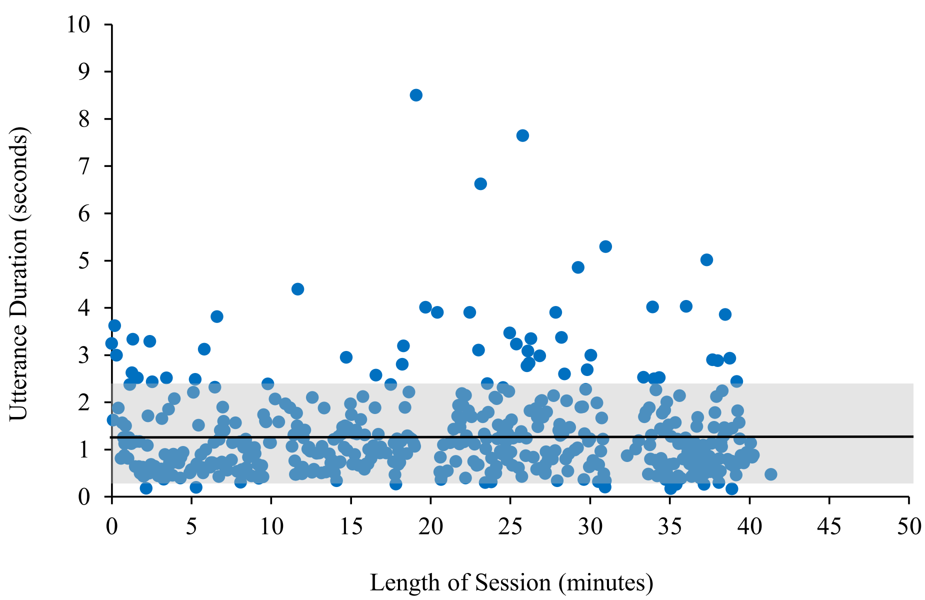
Distribution of utterances for Child 1 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.



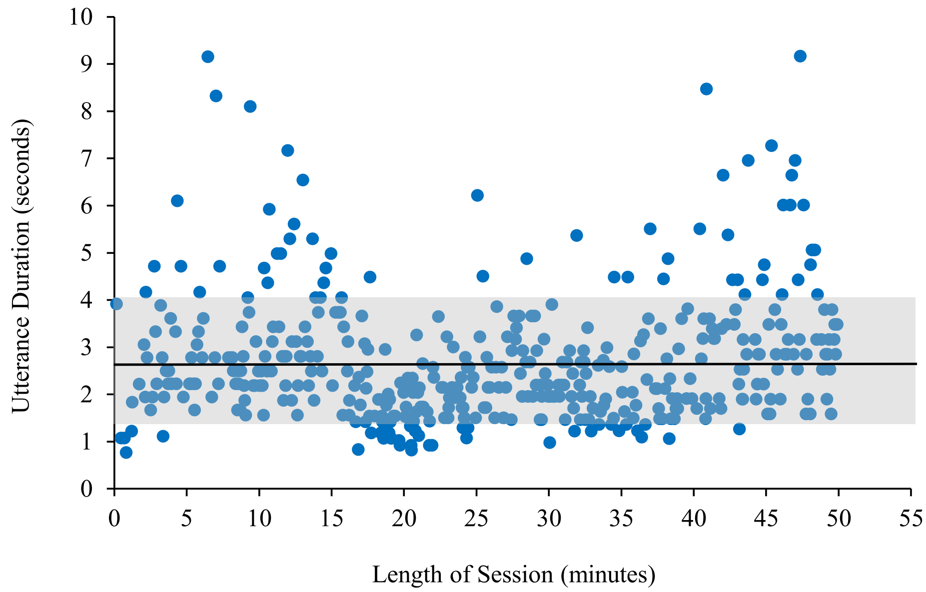
Distribution of utterances for Child 2 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.



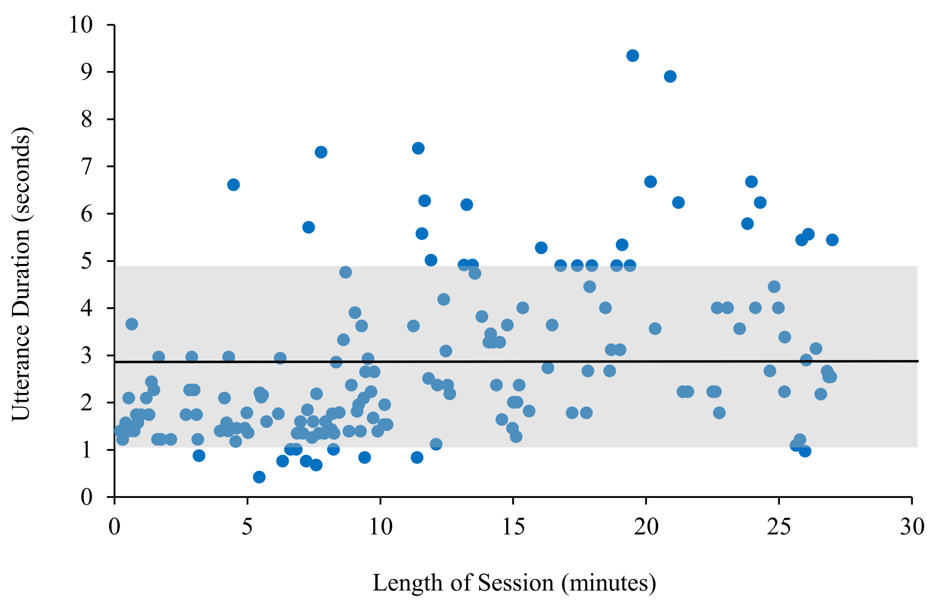
Distribution of utterances for Child 3 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.



Distribution of utterances for Child 4 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.



Distribution of utterances for Child 5 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.



Distribution of utterances for Child 6 across the entire recording. Mean utterance duration is indicated with a black line; the gray area shows ±1 standard deviation.