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Speech and Prosody Characteristics of Children with Autism Spectrum Disorders

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Speech and Prosody Characteristics of Children with Autism Spectrum Disorders

by

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Dedication

To my friends, family, and love of my life.

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This project would have not happened if it weren't for Dr. Davis and Dr. Franco's Autism Spectrum Disorders' study. Thank you Dr. Davis for your support when I did not think I could get over the hump of starting this project. Your eccentric personality and love for child speech disorders is one of the greatest reasons I choose you as my thesis advisor. Thank you Dr. Franco for your encouraging words and for your passion working with children on the spectrum.

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To the rest of my family and friends, I did this project that means I am going to graduate!

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Abstract

Speech and Prosody Characteristics of Children with Autism Spectrum Disorders

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The objective of this study was to examine if segmental and prosodic patterns of young children with autism differ from typically developing peers. We compared 4 children with Autism Spectrum Disorder (ASD) to their developmentally-age matched peers. ASD participants in this study did not demonstrate segmental deficit patterns as much as language delays. Excessive, misplaced, and reduced stress and slowed articulation rate in utterances were the two greatest prosodic deficits ASD participants in this study demonstrated. These prosodic deficits, or delays, were quantitatively assessed, and seemed to be the qualitative characteristics often associated with ASD children in previous research. Our findings suggest that early intervention approaches for prosodic differences could be beneficial for children with ASD and their families with a concise, standardized diagnostic tool to assess prosodic differences more accurately.

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Introduction

ASD AND SPEECH SOUNDS DEFICITS

Autism Spectrum Disorder (ASD) is defined by the Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition (DSM-V; American Psychiatric Association, 2013) as "persistent deficits in social communication and social interactions across multiple contexts" including deficits in social-emotional reciprocity (e.g., abnormal social approach, difficulties with back-and-forth conversation, failure to initiate or respond appropriately, reduction in sharing common interests), deficits in nonverbal communication behaviors (e.g., abnormal or lack of eye contact and body language), and deficits in developing, maintaining, and understand relationships (e.g., problems adjusting behavior depending on the social context, lacking in imaginative play with peers, uninterested in others).

The available research on children with ASD has suggested a higher frequency of speech sound disorders compared to the prevalence of child speech disorders in children between 5 to 7 years old who are not diagnosed with ASD. Children in this age range are found to show developmental speech delay (DSD) in a wide range of prevalence (i.e., 2.3% to 24.6%, Law, Boyle, Harris, Harkness, & Nye, 2000). Cleland and colleagues (2010) found that a minority of children (12%) with ASD were diagnosed with a moderate level of DSD compared to 29% of children with ASD who experienced a mild level of DSD. These prevalence rates are higher than total population estimates of DSD in children generally (3.6% by age 8; Wren et al., 2009).

ASD AND PROSODIC DEFICITS

A second aspect for definition involves the dimensions of characterization for speech production as they may relate to patterns observed in children with ASD. Speech, linguistically, is composed of two prominent characteristics: segmental and prosodic (Paul, 2005). Segmental aspects of speech include organization, temporal order, and production accuracy of the speech sounds (i.e., consonants and vowels) of a person's language (Paul, 2005). Prosodic aspects of speech incorporate all other aspects of speech including allowing the speaker to adapt his/her voice according to the circumstances of the listener giving each speaker a unique vocal quality (Paul, 2005). Prosody is composed of stress (i.e., placed on smaller units within the speech signal), intonation (i.e., pitch of the voice), and the duration of the speech signal enhancing the speaker's meaning (Lahiste, 1970; Shriberg, Kwiatkowski, & Rasmussen, 1990; Shriberg et al., 2001).

Further, available research has indicated that children who are diagnosed with ASD may show a potentially significant impairment in the prosodic as well as segmental components of speech (Diehl & Paul, 2013). However, available studies focus on children 4 or older (Shriberg et al, 2001). Research on younger children could help to understand the early manifestations of this component of speech delay in children who are diagnosed with concurrent DSD and ASD. The aim of this study is to compare segmental and prosodic aspects of speech in children with ASD/DSD with patterns in developmentally matched typically developing children. Fuller understanding of patterns of both segmental and prosodic errors in children with ASD/DSD may assist understanding of their unique profile to support development of early assessment and treatment protocols for this population.

PROSODIC PATTERNS IN CHILDREN WITH ASD

Prosody can be divided into 3 types: grammatical, pragmatic, and affective (Shriberg et al., 2001). Grammatical prosody is used when a person wants to indicate syntactic information within utterances (e.g., *pre'*sent as a noun versus pre*sent'* as a verb) (Warren, 1996). Pragmatic prosody occurs when the speaker must convey information beyond the syntax of the utterance (e.g., usage of stress to express importance) (Van Lancker, Canter, & Terbeek, 1981; Winner, 1988). Lastly, affective prosody, has more global functions compared to the two aforementioned prosody types; this prosody type enables persons to talk to listeners in different registers depending on the social context (i.e., talking to a professor versus talking to a peer) (Bolinger, 1989; Hargrove, 1997).

Reportedly, speakers with ASD have demonstrated segmental, or articulatory, aspects of speech that are comparable with other areas of development (Bartolucci, Pierce, Streiner, & Tolkin-Eppel, 1976; Pierce & Bartolucci, 1977; Tager-Flusberg, 1981 or that are somewhat delayed (Bartak, Rutter, & Cox, 1975; Rutter, Maywood, & Howlin, 1992). Persons with ASD have also been frequently identified as having abnormal prosody when speaking (Baltaxe & Simmons, 1985, 1992; Fay & Schuler, 1980; Ornitz & Ritvo, 1976; Paul, 1987; Pronovost, Wakstein, & Wakstein, 1966; Rutter & Lockyer, 1967;Tager-Flusberg, 1981). Studies have noted these prosodic differences as monotone or robotic-like, deficits using pitch and controlling volume, insufficiencies in vocal quality, and abnormal stress patterns (Shriberg et al., 2001). For instance, Simmons and Baltaxe (1975) discovered four out of seven adolescents with autism had prominent differences in their prosodic aspect of speech.

Shriberg et al. (2001), summarized 10 studies comparing grammatical versus pragmatic prosody; it was determined that only 9 of the 10 studies provided grammatical prosody data, and out of these 9 studies only 3 demonstrated differences between typical speakers compared to the ASD participants (Fine, Bartolucci, Ginsberg, & Szatmari, 1991; Thurber & Tager-Flusberg, 1991; Baltaxe, 1981; Baltaxe, 1984; Baltaxe & Guthrie, 1987; Baltaxe & Simmons, 1985; Fay, 1969; Fine et al., 1991; McCaleb & Prizant, 1985). Shriberg et al. (2001) demonstrated a range of prosodic characteristics using 15 male speakers with High Functioning Autism (HFA) participants and 15 male speakers with AS compared to typically developing male speakers. There were prosodic differences between the participants and the controls, but the differences were not very prominent.

Segmental Speech Patterns in Children with ASD

Speech production errors are a measure of phonological abilities in children who are typically developing (TD) as well as developmentally delayed (McCleery et al., 2006). Based on previous research, some consonants are produced earlier than others in typically developing infants and children (Robb & Bleile, 1994; Vihman, Ferguson, & Elbert, 1986) as well as children with language-learning difficulties (not associated with ASD) (Leonard, 1998). Voiced sounds (e.g., “b”, “d”) have been shown to develop first before voiceless sounds (Hodson & Paden, 1991a, 1991b). During the first year of life, specific speech sounds perceptions begin to develop at 6-7 months in TD infants.

According to Werker and Tees (1999), infants were able to make distinctions of phonemic contrasts regarding sounds in their native and nonnative languages at 6-7 months; however, children 10-11 months were unable to make these distinctions. In other words, language during the first years of life is critical for early phonemic development in infants (McCleery et al., 2006).

On the other hand, it has been found that infants with ASD pay less attention to voices and faces compared to their typically developing peers (Baranek, 1999; Osterling & Dawson, 1994; Werner, Dawson, Osterling, & Dinno, 2000) and developmentally delayed controls (Osterling, Dawson, & Munson, 2002). Particularly, Maestro et al. (2002) found that infants as young as 6 months old who were later diagnosed with ASD paid less attention compared to their typically developing peers. Therefore, the aforementioned data suggests that early social differences commonly found in ASD may cause increase likelihood for a deficit of speech processing and perception (Wetherby, Yonclas, & Bryan, 1989). Wetherby, Yonclas, and Bryan (1989) investigated three pre-verbal children with ASD; their finding suggested that many of the children's vocalizations contained a discrepancy of consonants produced. Specifically, these 3 pre-verbal infants with ASD lacked vocal acts containing consonants. Likewise, Wolk and Edwards (1993) studied language skills of a verbal 8-year-old boy with ASD, and found the child had normal phonology, but some unusual speech sound production patterns with early occurring phonological processes (i.e., final consonant deletion—an early speech process) with production of later occurring speech sounds (i.e., /z/). More recently, Wolk and Giesen (2000) conducted a study on 4 siblings with ASD. They found various phonological deficits (i.e., cluster reduction, labialization, final consonant deletion, frication of liquids, and chronological mismatch). Wolk and Giesen (2000) suggest that not all children with ASD follow typical sound pattern development.

Other research has shown that children with ASD may not have a phonological impairment. For instance, two studies found that children with ASD had normal, but delayed phonological development (Bartolucci & Pierce, 1977; Bartolucci, Pierce, Streiner & Tolkin-Eppel, 1976). McCleery et al. (2006) conducted a study with severely language-delayed children with ASD because of the limited amount of research done on these children. The goal of the study was to document consonant production in 14 young severely impaired children with ASD compared to 10 typically developing infants based on language age. Their consonant output was then compared to a group of TD children matched on language production and comprehension skills. McCleery et al. (2006) examined both errors produced in spontaneous speech and in imitated speech. Consonants were categorized based on their developmental difficulty documented (Hodson & Paden, 1991a, 1991b; Robb & Bleile, 1994; Vihman et al., 1986). Sounds noted to be developmentally early included: /d/, /b/, /h/, /m/, and /n/; sounds including /dʒ/, /l/, /n /s/, and /t/ were considered to be later developing sounds. It was found that participants in the study were phonologically delayed, but followed to normal developmental track as TD and language learning impaired children.

SEGMENTAL SPEECH CHARACTERISTICS IN CHILDREN WITH ASD

One of the first articulation studies involving children with ASD occurred by Bartak, Rutter, and Cox (1975). Participants in the study involved a group of boys, 5 to 10 years old. Results showed participants with ASD demonstrated slower than normal articulation development. Bartolucci, Pierce, Streiner, and Tolkin-Eppel (1976), found that distribution of phoneme frequency and phonological errors of children with ASD was similar to mentally handicapped and nonverbal TD children. The less frequently a phoneme was used within the participant's language, the greater the likelihood of the errors for these less prevalent phoneme.

Rapin, Dunn, Allen, Stevens, and Fein (2009) demonstrated that 62 school-aged children ASD did present with impaired speech that was determined via the Photo Articulation Test (PAT; Pendergast, Dickey, Selmar, & Soder, 1984); 24% experienced severe phonological deficits, yet no analysis was done of the actual speech errors that occurred. However, Kjelgaard and Tager-Flusberg (2001) studied a large sample of children with ASD ranging from 4-14 years old and found that despite differences in language skills, articulation skills were spared across all children.

Cleland et al. (2010) qualitatively examined speech errors in children age 5-13 with HFA and Asperger's syndrome (AS). No controls were used during the study. Data was established via the Goldman Fristoe Test of Articulation (GFTA-2; Goldman & Fristoe, 2000) Sounds in Words subtest; accuracy of all consonants was found in the initial, medial, and final position. The most common phonological processes noted were gliding (25% errors, 7 children), cluster reduction (15% errors, 3 children), and final consonant deletion (10% errors, 2 children). According to Dodd, Hua, Crosbie, & Holm (2002), gliding resolves around 5;11, cluster reduction resolves around 4;11, and final consonant deletion resolves by 2;0; therefore, this may be indicative of a delayed pattern of development for ASD. Overall, 41% of the ASD group produced some speech errors.

Shriberg, Paul, Black, & van Santen (2011) studied a group of children between the ages of 4-7 years old diagnosed with ASD. They compared the group to three other groups: typically developing (TD), speech delayed (SD), and childhood Apraxia of speech (CAS). Shriberg and colleagues defined SD according to the Speech Disorders Classification System (SDCS; Shriberg et al., 2010b), children between the ages of 3-9 years old, mild to severe intelligibility deficits regarding speech processes including deletions, substitutions, and distortions. They also defined the term speech errors (SE) according to the SDCS as children between the ages of 6-9 years old with one or two distorted speech sound or classes. Speech patterns in the participants were correlated to the comparison groups using a speech sample Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord, Rutter, DeLavore, & Risi, 2000). An average of 15.2% of the children with ASD demonstrated a speech delay indicating that speech delay is concomitant in children with ASD commensurate with levels found in the general population. Participants between the ages of 6 to 7-year-old demonstrated 31.8% of speech errors. Speech delay and speech errors were higher in the participants with ASD compared to previous research (Wren, Roulstone, Miller, Emond, & Peters, 2009). Wren et al. (2009) found through a robust sample size that 8 years old with ASD had a much smaller prevalence of speech errors, 7.9%.

SUMMARY AND CRITIQUE OF SEGMENTAL SPEECH RESEARCH

Language development for an infants' life is crucial for phoneme discrimination. Prior research (Baranek, 1999; Osterling & Dawson, 1994; Werner, Dawson, Osterling, & Dinno, 2000) suggests that infants with ASD demonstrate lower attention to people's voices and faces in their environments, which may lead to later speech processing and perception difficulties. However, there is conflicting evidence if children with ASD produce speech errors or if they are actually delayed phonologically. Studies with preverbal children with ASD (Wetherby et al., 1989; Wolk & Edwards, 1993; Wolk & Giesen, 2000) have demonstrated abnormal production of consonants and chronological phonological processing mismatch. Rapin et al. (2009) found school-aged children with ASD to have severe phonological deficits. On the other hand, research of children with ASD has demonstrated a lack of phonological impairment but did demonstrate a delay in phonological development (Bartolucci & Pierce, 1977; Bartolucci, Pierce, Streiner & Eppel, 1976) and slower than normal articulation development indicative of a delayed pattern of development for ASD (Bartak, Rutter, & Cox, 1975; Cleland et al., 2010). Kjelgaard and Tager-Flusberg (2001) found articulation skills were spared in children regardless of language differences. The less a phoneme is produced in a child's language, the greater the likelihood in the number of errors found for each phoneme. Shriberg et al. (2011) found, however, both speech delay and speech errors were higher in children with ASD (31.8%) compared to previous research (7.9%; Wren et al, 2009).

PROSODIC PATTERNS IN CHILDREN WITH ASD

Shriberg et al. (2011) noted that ASD participants exhibit significantly higher rates of inappropriate prosody and voice consistent with the speech attunement framework. This framework suggests the acquisition of articulation and appropriate prosody requires the child to "tune-in" to communication within the community and "tune-up" phonological and phonetic behaviors for an intelligible and appropriate voice (Shriberg et al., 2011). The origin and persistence of speech errors in children with no neurodevelopmental disorder are suggested to be based on this theory. According to the DSM-V (American Psychiatric Association, 2013), individuals with ASD may experience difficulties integrating gesture, eye contact, facial expression, and prosody for social communication (American Psychiatric Association, 2013). Prosody is often mentioned when describing individuals with ASD, but limited research has been completed in previous studies related to autism (McCann & Peppé, 2003).

McCann & Peppé (2003) compiled a prosodic review of persons with ASD, HFA, or AS ranging between the ages of children (4;4) to adults (59;0). Diagnosis within each study differed; 10 studies needed a diagnosis for ASD, 3 studies needed a diagnosis of HFA and AS, 1 study only used males with HFA, and 1 study only needed participants to be autistic-like. 10 out of the 15 of the studies used participants under 18; of these 10 studies, 7 studies used contained the youngest participants ranging between 4;4-12;3. Overall, the researchers found discrepancies in reports on prosody patterns may be a result of the number subgroups of ASD; a large number of subjects matched with TD matched-peers was rare; target groups contained varying age ranges; problems defining terms such as *prosody* and *stress*; create a definitive meaning between typical and atypical prosody.

Grossman, Bemis, Plesa-Skwerer, & Tager-Flusberg (2010) found that 16 children with High Functioning Autism (HFA) compared to 15 TD peers were as capable as their TD peers to perceive and complete tasks appropriately with lexical stress (i.e., emphasizing one syllable over another to convey or ascertain meaning) and affective prosody (i.e., speaker varying pitch and rate of utterance to indicate emotions). However, despite the fact that the target HFA group was able to differentiate lexical stress patterns, they presented with more frequent atypical productions (i.e., a reduction in naturalness).

Paul, Bianchi, Augustyn, Klin, & Volkmar (2008) found that children and adult 7;4-28;7 participants with ASD produced stress in nonsense syllables during an imitation task with small, but significant differences when perceived by listeners blind to the subjects' diagnostic category. Their results suggest an underlying difficulty in perceptual and/or motor apparatus involved in speech production.

Peppé, McCann, Gibbon, O'Hare, and Rutherford's (2006) aim was to determine the nature and extent of receptive and expressive prosodic deficits with participants with HFA. 66 participants were used: 46 with ASD and 20 with TD ranging in age between 7;4 to 28;7. For children with ASD to qualify, they needed a verbal IQ score of 70 or greater as well as fluent language. Overall, participants performed worse than TD peers on 11 out of 12 prosody tasks. Receptive and expressive prosody scores of the participants corresponded with each other especially with grammatical prosody.

Pitch patterns of children with ASD between the ages of 4-10 years old were analyzed and compared by Sharda et al. (2010) with age-matched TD peers and mothers of TD infants. They found that the participants exhibited exaggerated pitch, pitch range, pitch excursion, and pitch contours that were not observed in peers; patterns of speech reflected a possible developmental delay of verbal skills regarding the ASD group. It was noted that the exaggerated pitch patterns of mothers with their TD infants had no significant difference compared to the participants. Available research has shown that the developmental of speech in TD children between 0-5 years old pitch decreases (Amano, Nakatani, & Kondo, 2006). Participants in Sharda et al. (2010) demonstrated pitch characteristics of TD children around the ages of 2-3 years old suggesting a delayed developmental trajectory according to Eguchi and Hirsh (1969).

PROSODY AND SPEECH RESEARCH IN ASD

Few studies have incorporated both prosody and speech for ASD. However, research within these sparse studies has demonstrated the importance of both segmental and prosodic components necessary for communicative input and output. For instance, Shriberg et al. (2001) found residual articulation errors in HFA and AS participants between the ages of 10 to 50 years, all of whom exhibited a higher prevalence of speech sound distortions (i.e., /r/, /l/, /s/), 33%, compared to Flipsen (1999) with the general population prevalence of 1-2%. Revisions and repetitions of phrases related to prosody were 20% more for adults with AS compared to HFA. Stress was placed inappropriately in the utterance rather than it being incorrectly placed grammatically or lexically in multisyllable words. Results also demonstrated that both target groups presented with louder and higher pitch (not by as much though). Shriberg et al. (2001) suggests that future research related to ASD and prosody should be conducted to further assess speech and prosody-voice characteristics in young speakers diagnosed with ASD.

More recently, Schoen, Paul, and Chawarska (2011) examined phonology and vocal behavior of 30 children, 1;5 to 3 years old, with ASD compared to age-and-language matched control groups. Speech samples of the participants were obtained. The Communication and Symbolic Behavior Scales (CSBS-DP; Wetherby & Prizant, 2002) were used to collect vocalization samples for both the participants and controls. Vocalizations were separated into two classifications, speech-like and non-speech. Children with ASD produced speech-like vocalizations similar to their language-matched peers; however, produced a higher proportion of atypical non-speech vocalizations compared to both age and language-matched control groups.

SUMMARY AND CRITIQUE OF RESEARCH ON PROSODY

Past research often describes children with ASD as having "inappropriate" or "monotone" prosody; however, limited research has been done on this subject. One hypothesis is that children with ASD have higher prosody and voice related to the speech attunement framework. This framework suggests one acquires appropriate prosody, and phonologic and phonetic behaviors by "tuning-in" and "tuning-up" communication within his/her environment for an intelligible, appropriate voice. The origin and persistence of these speech errors in children with ASD is based on this theory (Shriberg et al., 2011). Several discrepancies found within the limited research in ASD and prosody include: inconsistent terminology (i.e., *prosody* and *stress*), defining typical versus atypical prosody, and large sample sizes with TD matched-peers. Children with HFA compared to their TD peers mainly present with a higher proportion of atypical prosodic speech (Grossman et al., 2010). Children and adults with ASD may be unaware of their prosodic differences involved in speech production (Paul et al., 2008). Grammatical prosody is especially difficult for children and adults with ASD to expressively discriminate (Peppé et al., 2006). Children with ASD demonstrate pitch differences not found in TD peers and mothers of TD infants. Few studies have demonstrated the importance of incorporating both speech and prosodic deficits of children with ASD.

SUMMARY OF SEGMENTAL AND PROSODIC RESEARCH

The speech attunement framework suggests one acquires appropriate prosody, and phonologic and phonetic behaviors by "tuning-in" and "tuning-up" communication within his/her environment for an intelligible, appropriate voice. Similarly, the origin and persistence of speech errors in children with ASD is based on this theory. It has been shown that infants with ASD demonstrate lower attention to people's voices and faces within their environments leading later to possible speech processing and perceptual difficulties and differences. Previous segmental research regarding children with ASD is conflicting. Some research has demonstrated that children with ASD produce speech errors (i.e., abnormal consonant production, chronological phonological mismatch) while other research suggests children with ASD are only delayed phonologically. However, current research suggests that perhaps children with ASD have both speech delay and atypical speech errors present. Prosodic deficits in children with ASD are mentioned frequently using descriptors including: “robotic-like”, “monotone”, and “inappropriate”; however, limited research has actually tried to quantify and qualify these terms and abstract ideas.

Overall, children with ASD compared to their TD peers present with more atypical prosodic speech, unaware of these differences, and difficulties using grammatical prosody. Sparse research incorporating both segmental and prosodic differences in ASD suggest infants with ASD demonstrate higher atypical non-speech vocalizations compared to TD groups, and children and adults with HFA and AS demonstrate higher speech sound distortions compared to the general population, revisions and repetitions of phrases related to prosody occurred more in adults with AS compared to HFA, stress placed inappropriately on utterance, louder and higher pitch. This study incorporates both prosody and segmental components to compare young children with ASD to their developmental age-matched peers to understand how speech errors and prosodic difference impact intelligibility so that clinicians and future research transfer this information and importance into the clinical setting.

Establishing more concise ways to describe prosodic and segmental articulation patterns in younger children with ASD/DSD can help to describe speech patterns impacting intelligibility more precisely. This information will help to create early intervention assessment and intervention protocols for children with ASD.

The current study will examine the following question:

Do segmental and prosodic patterns of young children with autism differ from typically developing peers? To examine this question, we will evaluate variability and patterns of segmental, word/syllable level, and prosodic output inventories and accuracy for consonants, vowels, word and syllable shapes, stress, and intonation in utterances produced by typically developing children between 1;11 and 2;5 compared to ASD/DSD children between the developmental age of 1;11-2;5 years old.

Methods

Source and Recruitment of Participants and Controls

Participants with ASD were a part of a larger study to elicit and improve speech intelligibility in children with ASD who have a co-existing articulation disorder. Controls for this study were located using the Child Language Data Exchange System (CHILDES), a database that is publically available to identify already completed speech transcripts and audios files of typically developing children (MacWhinney & Snow, 1984). Transcripts and audio files of the typically developing children (obtained from CHILDES) were developmentally- and gendered-matched to participants.

Description of Participants

Participants included 4 children (1 female, 3 males) between the chronological ages of 3;10 and 6;3 diagnosed with ASD and DSD. They were termed the ASD/DSD group. Severity of ASD was determined using the *Childhood Autism Rating Scale-Second Edition* (CARS, Schopler et al., 2010). Presence and severity of DSD was established using the *Hodson Assessment of Phonological Patterns: Third Edition* (HAPP-3; Hodson, 2004). Developmental ages of the ASD/DSD group were determined using the Reynell Developmental Language Scales: Expressive Subsection (Reynell & Gruber, 1990)

Table 1: ASD/DSD Group

Participants	Gender	Developmental Age	Chronological Age	DSD Severity
ASD 1	Female	2;5	3;10	Moderate
ASD 2	Male	1;11	6;3	Mild
ASD 3	Male	2;4	5;5	Moderate
ASD 4	Male	1;11	4;1	Moderate

DESCRIPTION OF CONTROLS

Four children who were developing typically served as controls for this study. They were matched based on developmental language age and gender with DSD/ASD group. These children were termed the "typically developing" control group (TD). Background knowledge of the controls was based on CHILDES Transcript Browser (MacWhinney & Snow, 1984). Typical development of speech for the ASD/DSD group was described in Davis & MacNeilage (1995) stating normal development was established through parent case history report. In addition, each infant was administered the *Battelle Developmental Screening Inventory* (Guidubaldi, Newborg, Stock, Svinicki, & Wneck, 1984) and hearing screening using sound field techniques.

Table 2: TD Group

Control	Gender	Chronological Age	Audio	# of utterances
TD 1	Female	2;5.13	#39	200
TD 2	Male	1;11	# 11	190
TD 3	Male	2;4	# 33	58
TD 4	Male	1;11	#49	201

DATA ANALYSIS

Transcripts of the TD group were obtained from CHILDES and matched by developmental-age and gender to the ASD/DSD group. Transcripts of the ASD/DSD group were obtained from the completed data set from the aforementioned study. Utterances produced by each participant and control were written orthographically by us, followed by the transcription of the utterance in International Phonetic Alphabet—Standard American English (IPA, Shriberg & Kent, 2002). Target utterances were written adjacent to the phonetic broad transcription of each utterance produced (Shriberg & Kent, 2002). A broad transcription of each ASD/DSD participant's speech sample was based on a minimum of 50 utterances (depending on the number of sessions it took to collect 50 utterances). Each TD control's speech sample was based on 1 session containing a minimum of 50 utterances; these speech samples were already phonetically transcribed (MacWhinney & Snow, 1984).

Reliability of transcripts from both groups was checked against there original audio files, and used to code for the prosody section of this study. Imitation was coded with an asterisk (*). No more than 3 playbacks per utterance were allowed. Diacritics included primary and second stress marked on the broad transcriptions of the controls and participants. The other codes used for the prosody section of this study can be found the in the Appendix 2.

SPEECH MEASURES

Once transcribed, all speech samples (both TD and ASD/DSD) were analyzed for the following indices of speech patterns for segments and word complexity. Speech measures included the following:

1) *Percent consonants correct-revised (PCC-R)/ percent vowels correct-revised (PVC-R)*: PCC-R was calculated via the number of consonants correct divided by the total number of consonant targets, and multiplied by 100, and finally the score was compared to a chart of normal developing PCC-R compared to speech delayed children; a percentage of both measures were found and compared against one another (Shriberg et al., 1997; Campbell et al., 2007). PVC-R was calculated the same way using vowels and diphthongs. Only the first 2 repetitions of a word were counted, unless the word was pronounced with different consonants or vowels. For

instance, if “animal” was said 3 times as /ænʌ/, /ænʌ/, and /æmʌ/, then each of the 2 variations would be counted for both PCC-R and PVC-R. PCC-R and PVC-R were used to establish the amount of consonant and vowel sounds that were articulated correctly; consonant and vowel accuracy is important to describe phonemic accuracy of each target word compared to the output of the child.

2) *Phonological mean-length utterance (PMLU)*): PMLU measures both the length of child’s words and number of correct consonants (Ingram, 2002). PMLU is important because it focuses on the length of the child’s words as well as the number of correct consonants focusing on the whole-word production rather than the segments; one is able to compared how the child’s productions to the target words. The length of the utterance makes it similar to MLU; however, it differs because it includes an additional measure of the proportion of correct consonants. A minimum of 25 words, but preferably 50 words should be used over the whole sample (i.e., a select portion of words covering the *entire* sample). No more than 50 words per participant/control’s speech samples were used for this speech measurement. PMLU encompasses various rules for inclusion and exclusion of words within a given speech sample. The Lexical-Class Rule states that words often used by adults in normal conversation should be included; conversely, words such as “mommy”, “daddy”, “tata”, etc. should be excluded (i.e., counting childish words can *increase* the PMLU score—found in Appendix I). The Compound Rule states that compound words written as single words only count as 1 word, but compound words written, as two

words should count as 2 words. Based on the Variability Rule, the most common production for each word is counted once. For each consonant and vowel produced, regarding the Production Rule, 1 point is given; nevertheless, not more than in the target. Specifically, each vowel and consonant produced per target is not counted more than the adult word target (e.g., "hwut" for "foot" would receive 3 points *not* 4). Lastly, the Consonants Correct Rule provides additional points per each *correct* consonant and vowel. After the aforementioned rules were followed, the PMLU was calculated by the acquired number of points (i.e., total number of phonemes child produced plus consonants produced accurately) divided by the total number of words (i.e., no more than 50). PMLU was listed in the results section as an average of a maximum of 50 non-repeated words in a given child's speech sample(s). These means were compared within each control and participant group as well as across group to discern similarities and differences between both groups.

3) Proportion of Whole-Word Proximity (PWP), Proportion of Whole-word Corrections (PWC), & Proportion of Whole-word Variation (PWV): After the PMLU was calculated, 3 other proportions related to this computation were determined for participants and controls including: PWP, PWC, and PWV. PWP captures how well a child approximates the target (i.e., adult form), indirectly measuring intelligibility. PWP is determined by dividing the child's PMLU score by the PMLU of the target words; this calculation contained the same number of words used to evaluate PMLU (i.e., focusing only on amount of target consonants the child produced correctly).

PWC equals the proportion of the child's words that are produced *correctly* out of the entire speech sample. Schmitt, Howard, and Schmitt (1983) studied PWC, referring to it as Whole-Word Accuracy, of children between the ages of 3 to 7 years old. They found that specially between the ages of 3 to 3;6 years old there is a spike in whole word accuracy. No data exists of children below 3 years old. With this study, we aim to look at these numbers particularly will all participants and controls below this age either developmentally and/or chronologically. PWC is found by dividing the number of whole-words produced correctly by the total number of words produced; this calculation contained words from the whole speech sample(s) unless the child's targets were unintelligible. PWV is helpful since children are not always consistent with productions; this measure gives an indication of the consistence (or lack thereof) of which target forms were produced. PWV is calculated when multiple occurrences of word are examined that is found by the number of different forms divided by the number of attempts. Scores range from 0.00-1.00. If a child produces 3 words the exact same way, PWV equals 0.00 (i.e., indicating no different forms were used); however, if a child produces a word (e.g., "dog") 3 times as "gog" (i.e., 1 time) and "doggie" (i.e., 2 times), the PWV would equal 0.67 (i.e., 67% of different forms used for the word "dog"). Once each word was scored, an average of *all* the words with single or multiple attempts was obtained to yield a single PWV value for the entire sample. PWC, PWP, and PWV of each participant/control were all calculated based percentages of whole speech transcription; each proportion was compared within each group and across group to finding trends and differences.

4) *Word Complexity Measure (WCM):* WCM measures phonetic complexity of a word (Stoel-Gammon, 2010). WCM is calculated with a sample range usually between 35 to 100 words. Each word in a sample is given a complexity score based on an approach assessing the different levels of the child's phonological system consisting of word patterns, syllable structures, and sound parameters. WCM scores that are higher suggest more complex and later acquired phonological parameters based on findings of early phonological acquisition (e.g., Stoel-Gammon, 1985; Robb & Bleile, 1994) and developmental norms (e.g., Prather, Hedrick, & Kern, 1975; Smit, Hand, Freilinger, Bernthal, & Bird, 1990). The importance of using WCM is to describe the inventory of sound types and combinations within a person's repertoire, not the accuracy relative to the target words. Points for WCM are accumulated based on 8 complex parameters:

Table 3: WCM's 8 Complex Parameters

Word patterns
1. More than 2 syllables = 1 point 2. Stress on any syllable but the first = 1 point
Syllable structures
3. Productions with word-final consonant = 1 point 4. Consonant clusters (i.e., 2+ consonants within syllable) = 1 point *per cluster*
Sound classes
5. Velar consonant productions = 1 point *per velar* 6. Each liquid, syllabic liquid (i.e., liquid filling vowel slot in unstressed syllable), or rhotic vowel (i.e., 'vowel-r') produced = 1 point 7. Fricative or affricate = 1 point *per production* 8. Voiced fricative or affricate = 1 point *per production*

After assigning points to each word, WCM is determined by a ratio comparing the number of the child's acquired points divided by the number of total words produced in the target form (i.e., number of acquired points divided by the number of tokens). The words chosen to calculate WCM were determined via PCC-R and PVC-R repetition rule mentioned earlier. Children with phonological delay/disorder typically present with profiles that differ greatly compared to typical children—lower WCM ratios. Therefore, it was hypothesized that the ASD/DSD group would have lower WCM scores compared to the TD group.

5) *Index of Phonetic Complexity (IPC*): IPC quantifies a child's speech in small steps so that it may be documented over time (Jakielski, 2000). IPC is found by following 8 production parameters known as "complexity points" listed in the table below. IPC is an important measure because it quantitatively provides evidence of the child's output regarding the relationship between more complex phoneme production and consonant combinations. The higher to level of points, the more phonetically complex the child's output. IPC is calculated for all words in a sample by dividing the number possible points accumulated by the total target points. IPC was analyzed for both ASD/DSD and TD groups.

Table 4: Complexity Points Production Parameters for IPC

Rule	Point assigned for:	1 point for each:	*No points for:*
1	Place	Dorsal (i.e., k, g, ŋ)	*Labials, coronals, glottals*
2	Manner	Fricative (i.e., f, v, s, z, ʒ, ʃ, θ, ð, h) Affricate (i.e., tʃ, dʒ) Liquid (i.e., l, r)	*Stops, nasals, glides*
3	Vowel	Rhotic (i.e., 'vowel-r')	*Monophthongs, diphthongs*
4	Word Shape	Word ending in a consonant	*Words that end in a vowel*
5	Word Length (syllables)	Word with 3 or more syllables	*1 or 2 syllable words*
6	Singleton consonants by place variegation	Variegated singletons	*Reduplicated singletons, if variegation of one of the consonants is included in cluster (e.g., "school" /skul/ =0 pts)*
7	Contiguous (i.e., touching) consonants	Consonant Cluster	*No cluster*
8	Cluster Type	Heterorganic cluster (i.e., variation between 2 consonants when place is different)	*Homorganic cluster*

6. *The Prosody-Voice Screening Profile (PVSP)* (Shriberg, Austin, Lewis, & McSweeney, 1997; Campbell, Janosky, & Adelson, 2007; Ingram, 2002; Stoel-Gammon (2010); Shriberg, Kwiatkowski, & Rasmussen, 1990):

To measure prosody in both the ASD/DSD group and controls, the *PVSP*, a standardized assessment, was used (Shriberg, et al., 1990). Shriberg, Paul, McSweeny, Klin, Cohen, and Volkmar (2001) also used this measurement as a prosody-voice assessment for male speakers with HFA and Asperger syndrome (AS) between the ages of 10 to 50 years old. This study replicated Shriberg et al. (2001) prosody-voice protocol via the *PVSP* except with young children. The *PVSP* examines six prosodic areas: Phrasing, Rate, Stress, Loudness, Pitch, and Quality. The procedure for this standard assessment is intricate; hence, the limited usage of this assessment protocol and the computation of abstract prosodic components in speech. 5 steps are necessary to complete the *PVSP* including: (a) a continuous speech sample (at least 12 codable utterances), (b) a written gloss (i.e., orthographically) and segment each speech sample (segmentation rules in the Appendix), (c) identifying utterances that meet the criteria for exclusion (exclusion rules in the Appendix), (d) coding the remaining utterances (inclusionary rules in the Appendix), and (e) calculating and recording data with a decision on the scoring form. A maximum of 25 utterances were used for both participants and controls. The *PVSP* was used to quantify the prosodic components for both the ASD/DSD and TD groups giving a final score for each of the 6 sections regarding prosody: phrasing (i.e., flow of word and phrase groups appropriate for the speaker's age), rate, stress, loudness, pitch, and quality (i.e., resonance). Each participant/control's scores were averaged to give one total score.

The *PVSP* was used appropriately regarding the exclusionary and inclusionary codes for 1 of the 4 controls; an exclusionary code requiring at least 50% of the utterances to be 4 or more words in length was only able to be used for one of the controls. More than 50% of the other 3 controls' utterances were less than 4 words. Therefore, the *PVSP* exclusionary code was modified for those controls. It should be noted the control (i.e., TD 1) for which the exclusionary code was used appropriately with the screener's rules was also the oldest TD child. In regards to participants, more than 50% of their utterances were also less than 4 words in length; therefore, more than half of utterances included were less than 4 words. Of the controls and participants, only one control (i.e., TD 3) had less than 100 utterances in a speech sample. 2 transcripts were used for each ASD participant compared to the TD controls who only required 1 transcript because of amount of utterances required to meet the measures need. In accordance with the *PVSP* rules, a minimum of 12 coded utterances were used for each child in the ASD/DSD and TD group, except for one control and participant who only received 10 and 11 codable utterances, respectively. To score each child, only the utterances that passed the exclusionary criteria were used for section and composite scores. We then listened to each approved utterance then labeled it according to Appendix 3: Inclusionary Codes. The percentages for each section of the PVSP were found by dividing the acceptable (i.e., typical) utterances by the total number of approved utterances. After each score form was completed for both controls and participants, a score for each of the 6 components (i.e., phrasing, rate, stress, loudness, pitch, quality) involving prosody and voice were combined for a total percentage to compared the TD controls and the ASD participants. Each percentage for all 6 sections of the PVSP as well as total percentage for each child were compared and contrasted to one another. Shriberg et al. (1997) purposefully choose a 90% cutoff criterion to discriminate prosody-voice difficulties more accurately; however, a score of less than 90% does not mean a child has a clinically significant prosody problem. A “pass” was given if a child performed at or above the 90% criterion cut-off; a “fail” was given if a child performed below the 90% percentile for each of the 6 sections.

LANGUAGE MEASURES

Language measures included Mean Length of Utterance (MLU; Brown, 1973) and Type-Token Ration (Templin, 1957; Watkins & Kelly, 1995).

1.) MLU measures the morphological and syntactical skills of a child. The language measure MLU was found for both participants and controls by averaging the total number of morphemes (i.e., smallest unit of meaning) produced by the child divided by the totally number of utterances produced. Rules used to calculate MLU were based on Retherford (2000).

2.) Type Token Ratio (TTR): TTR measures the vocabulary variation within a child’s speech. TTR was also found for both groups using a ratio comparing the different number of words used over the total number of words produced. The frequency of each word produced was totaled and ranked from most to least used. Finally, each word and its variations (i.e., counted as one word) was divided by the total number of words in the transcript equaling the TTR.

Results

INTRODUCTION

Speech and language calculations were used to evaluate variability and patterns of speech and language output in utterances produced by TD children between 1;11 and 2;5 compared to ASD/DSD children between the developmental language age of 1;11-2;5 years old. ASD/DSD children had differing chronological ages (See Tables 5-12). The specific measures analyzed to consider speech patterns in the two groups included: PCC-R, PVC-R, PMLU, PWP, PWC, PWV, WCM, IPC, PVSP, MLU, and TTR.

SPEECH MEASURES

Percentage of Consonants Correct-Revised (PCC-R) and Percentage of Vowels Correct-Revised (PVC-R)

PCC-R and PVC-R were evaluated to understand consonant and vowel accuracy patterns. Children with ASD, who were chronologically older but developmentally matched with TD children, demonstrated higher PCC-R and PVC-R mean values compared to TD controls. However, TD control's PCC-R and PVC-R ranges were more variable than children with ASD. The TD controls' PCC-R and PVC-R scores were similar except for TD 2 (i.e., PCC-R of 47.3% and PVC-R 70.2%). PCC-R scores for all ASD children were higher compared to their PVC-R scores. Three of the 4 ASD participants' PCC-R scores were higher than the TD controls. TD 1 and ASD 1 demonstrated the closest PCC-R and PVC-R percentages of any other participant-control match; TD 1's PCC-R and PVC-R were both higher compared to ASD 1's. The only other TD control whose score was higher than his developmental age-matched peer was TD 3 scoring approximately 5% higher on the PVC-R. TD 4 scored lowest on PCC-R and PVC-R; however, he was one of the younger TD controls.

TD control and ASD participant PCC-Rs were compared across various predicative ages to TD children from Campbell et al. (2007) using 16 different age groups (see Appendix 1). This comparison established a few key patterns of relationship: PCC-R increases with age and standard deviations decrease with age. Comparing these children's PPC-R scores to the Campbell et al. (2007) data, participant-control matches at 23 months (i.e., ASD 2-TD 2 and ASD 4-TD 4) should have been somewhere in the range of 67.19%-71.91%. ASD 2 achieved a much higher range than expected for his developmental age. However, when compared to his chronological age of 75 months, he did not achieve his chronological; age target PCC-R range of 93.98%-97.38% by approximately 5%. ASD 4 was found to be within the expected range for his developmental age; however, in comparison to his chronological age (i.e., 53 months), he demonstrated a delay in expected PCC-R of approximately 25% (i.e., range of 90.85%-95.07%).

TD 2 and TD 4 are TD, yet scored approximately 22%-40% below the average PPC-R for children around 23 months, respectively. According to Campbell et al. (2007), participant-control matches (i.e., ASD 1-TD 1 and ASD 3-TD 3) between 28-29 months developmentally, should have achieved a PCC-R score between 77.80%-81.38%; only ASD 3 was found to have a PCC-R score within this range. However, TD controls ASD

1, TD 1, and TD 3 all scored within 15% of this range. However, these children are older compared to the other control-participant matched groups. ASD 1 and ASD 3's chronological ages are 46 and 65 months, respectively; similar to ASD 2 and ASD 4, these participants performed with a delayed PCC-R of approximately 18% and 13%. It should be noted as ASD 1 and ASD 3's chronological age increased so did the difference between their PCC-R score and the target range for their developmental ages. ASD 1 and ASD 3's developmental age range difference with their target PCC-R range was approximately the same when compared ASD 2 and ASD 4's. Results of PCC-R and PVC-R can be found in Table 5.

Table 5: PPC-R and PVC-R scores for participants and controls

Participants	**DA/CA**	**PCC-R**	**PVC-R**	**Controls**	**DA-CA**	**PCC-R**	**PVC-R**
ASD 1	2;5/3;10	72.1%	71.3%	TD 1	2;5	74.6%	72.6%
ASD 2	1;11/6;3	88.2%	77.6%	TD 2	1;11	47.3%	70.2%
ASD 3	2;4/5;5	80.9%	56.6%	TD 3	2;4	62.5%	60.9%
ASD 4	1;11/4;1	67.0%	71.5%	TD 4	1;11	30.4%	38.0%
		Mean PCC-R	**Mean PVC-R**			**Mean PCC-R**	**Mean PVC-R**
		77.1%	69.3%			53.7%	60.4%
		Range PCC-R	**Range PVC-R**			**Range PCC-R**	**Range PVC-R**
		67%-88%	57%-78%			30%-75%	38%-73%

Overall, it was found that PCC-R tended to be higher compared to PVC-R overall across groups. ASD children had higher PCC-R compared to their TD peers, yet PVC-R for 2 of the 4 TD controls was higher compared to ASD participants. Individual differences were apparent within the overall group trends found. Individual differences were mainly related to developmental and chronological ages of controls and participants. For instance, ASD 4 performed with the lowest PCC-R compared to other children with ASD, but had one of the higher PVC-R scores out of the other children with ASD.

Phonological Mean Length of Utterance (PMLU) & Proportion of Whole-Word Proximity (PWP)

PMLU and PWP were analyzed to consider the length of each child's words, the number of accurate consonants produced, and intelligibility. *As a group,* children with ASD showed a higher mean and greater PMLU range compared to TD age-gender matched controls. Ingram (2002) described the similarity of PMLU to MLU by suggesting "single-segment additions over time" consisting of possible stages of PMLU based on Table 6:

Table 6: Possible Stages Based on PMLU (Ingram, 200

Stages	Range	Midpoint
I	2.5-3.5	3.0
II	3.5-4.5	4.0
III	4.5-5.5	5.0
IV	5.5-6.5	6.0
V	6.5-7.5	7.0
Beyond V		

Based on Ingram's (2002) stages, all participants with ASD were considered to be in PMLU Stages III and IV. In contrast, the TD controls values ranged between PMLU Stages I and III. Based on the means of each group, the ASD participants were functioning in Stage III compared the TD children whose mean was in Stage II.

There are no normative age correlates to compare the developmental versus chronological ages of the children with ASD. However, 3 of 4 ASD participants demonstrated higher PMLU scores compared to the TD controls. However, again there were individual difference within the cohort ASD 1 and TD 1 (an ASD-TD pair) demonstrated the most similar PMLU scores. TD 1 was the only child to score above her matched ASD peer. ASD 3 had a smaller PMLU score difference compared to his TD control compared to the other 2 participants. This could be because he was the second oldest participant. TD 2 and TD 4, two TD controls, are the same chronological age and had similar numerical differences to their age-matched participants. Only 1 age-matched participant-control dyad (i.e., ASD 3 and TD 3) scored the second highest PMLU score in each of their participant-control group.

Since, inclusionary criteria for PWP were identical to PMLU for analyses, it seemed appropriate to compare them. Half of the TD controls performed with the lowest PWP scores (i.e., 64.2% and 67.8%). Since PWP and PMLU are based on the same inclusionary criteria, we looked further to establish any trends. Two of the older ASD participant-TD control group dyads achieved both higher PMLU and PWP scores. However, ASD 4 (ASD participant) had a higher PMLU score than ASD 1; however, ASD 1 results demonstrated a higher PWP score compared to ASD 4. In other words, PWP is a percentage of how close a child is to his/her target PMLU score. The child with the highest PMLU and PWP score (i.e., ASD 2) was also the oldest child chronologically, yet developmentally was considered one of the younger participants. Results of PMLU and PWP can be found in Table 7.

Table 7: PMLU and PWP

Participants	**DA/CA**	**PMLU**	**PWP**	**Controls**	**DA-CA**	**PMLU**	**PWP**
ASD 1	2;5/3;10	4.34	86.6%	TD 1	2;5	4.98	86.1%
ASD 2	1;11/6;3	5.86	95.1%	TD 2	1;11	3.88	64.2%
ASD 3	2;4/5;5	5.3	89.8%	TD 3	2;4	4.29	81.5%
ASD 4	1;11/4;1	5.1	81.0%	TD 4	1;11	3.15	67.8%
		Mean PMLU	**Mean PWP**			**Mean PMLU**	**Mean PWP**
		5.15	88.1%			4.08	74.9%
		Range PMLU	**Range PWP**			**Range PMLU**	**Range PWP**
		4.34-5.86	81.0%-95.1%			3.15-4.98	64.25%-86.1%

Overall, children with ASD demonstrated a smaller range and overall higher PMLU average compared to TD controls. However, TD control's PMLU range was less variable. More children with ASD were considered accurate at producing consonants based on their higher PWPs compared to their TD peers. Individual differences were related mainly to participants and controls independently based on differences between chorological and developmental ages. For instance, ASD 2 achieved a higher PWP score compared to all of the TD controls despite being one of the chronologically younger participants. Thus, it can be asserted that the developmental-chronological relationship was not consistent for this group of participants overall.

Percentage of Whole-Word Correctness (PWC) & Percentage of Whole-Word Variation (PWV)

While PWC measures if a word is produced correctly or incorrectly overall, PWV measures the number of variations within a child's output. Both PWC and PWV are calculated based on the child's entire transcript. The rationale for analyzing PWC and PWV was to evaluate how many words each child produced correctly and to determine consistency or inconsistency of these word productions. Each TD control performed with a higher PWV compared to his/her ASD matched peer, consistent with the findings on the PMLU analyses above. Three of the 4 participants' PWC scores were higher compared to their PWV scores. However, only half of the TD controls' PWC scores were higher than their PWV scores. Despite limited research on PWC and PWV measurements, Ingram (2002) suggests that children are more concerned with approximating targets than actually saying them correctly. However, only 3 of these 8 children produced a PWC greater than 50% correlating to Ingram (2002)'s hypothesis. Results of PWC and PWV can be found in Table 8.

Table 8: PWC & PWV Scores

Participants	DA/CA	PWC	PWV	Controls	DA-CA	PWC	PWV
ASD 1	2;5/3;10	54.7%	13.2%	TD 1	2;5	62.0%	21.6%
ASD 2	1;11/6;3	64.0%	11.9%	TD 2	1;11	28.9%	34.8%
ASD 3	2;4/5;5	26.1%	13.8%	TD 3	2;4	27.0%	15.1%
ASD 4	1;11/4;1	24.2%	26.1%	TD 4	1;11	15.6%	33.7%
		Mean PWC	**Mean PWV**			**Mean PWC**	**Mean PWV**
		42.3%	16.3%			33.4%	26.3%
		Range PWC	**Range PWV**			**Range PWC**	**Range PWV**
		24.2%-64.0%	11.9%-26.1%			15.6%-62.0%	15.1%-34.8%

Overall, all TD controls performed with a higher PWV compared to their age-matched ASD peer. This finding indicates that all TD controls produced each target word with more variation than their ASD peer. Chronologically younger children (i.e., TD controls) demonstrated more approximations of words than their developmental age-matched, chronologically older ASD peers. Most ASD participants produced more words accurately in their target forms, ultimately achieving a higher PWC score than their TD matches. These results may be most likely because ASD participants had higher chronological ages.

Word Complexity Measure (WCM) & Index of Phonetic Complexity (IPC)

WM and IPC measure productions of words yielding a single number to compare and track children. This is important because WCM & IPC helped to understand the word level and segmental level phonetic complexity a child was capable of producing, regardless of accuracy. IPC scores were higher for participants with ASD compared to their TD controls. Each participant scored higher than his/her control. IPC is a more in depth calculation (i.e., including variegated singletons and heterorganic consonant clusters based on the place of articulation) compared to WCM, which may explain why IPC scores for ASD participants were higher than TD controls. Ranta and Jakielski (1999) found that children 16 to 20 months old targeted simpler phonetically words approximately 50% of the time compared to children 23 months and older who targeted phonetically easier words only 26% of the time. Therefore, we assumed that chronologically older TD controls would have higher IPC scores. A significant finding was that all ASD participants' IPC scores were correlated to their chronological instead of their developmental ages. All ASD participant and TD control WCM and IPC scores were found to be within a small range of values. The closest control-participant WCM and IPC scores were TD 1 and ASD 1. TD 1 achieved a higher WCM score than ASD 1. ASD 1 scored a higher IPC score. All other ASD participant-TD control matches displayed a significant difference between WCM and IPC scores.

According to Stoel-Gammon (2009)'s analysis of TD children, the average WCM ranges were between 0.60-1.49 for children ages 17 to 22 months old. In this study, only one child was found to be older than this age range (i.e., TD 4 at 23 months), but performed lower than expected. It should be noted that this child was one of the youngest TD controls in this study. Stoel-Gammon (2009) also looked at phonologically delayed and disordered children and found their WCM's were much lower compared to the TD children she studied, 0.22-0.66. This information suggests that one of the TD controls may be delayed at acquiring more complex word patterns. Results of WCM and IPC can be found in Table 9.

Table 9: WCM & IPC Scores

Participants	**DA/CA**	**WCM**	**IPC**	**Controls**	**DA-CA**	**WCM**	**IPC**
ASD 1	2;5/3;10	1.43	1.66	TD 1	2;5	1.57	1.53
ASD 2	1;11/6;3	2.26	2.61	TD 2	1;11	0.75	0.96
ASD 3	2;4/5;5	2.07	2.32	TD 3	2;4	0.7	0.93
ASD 4	1;11/4;1	1.67	1.84	TD 4	1;11	0.43	0.89
		Mean WCM	**Mean IPC**			**Mean WCM**	**Mean IPC**
		1.86	2.11			0.86	1.08
		Range WCM	**Range IPC**			**Range WCM**	**Range IPC**
		1.43-2.26	1.66-2.61			0.43-1.57	0.89-1.53

IPC scores were higher for ASD participants since this calculation seemed to be a more depth calculation for phonetic complexity in regards to place of articulation (i.e., something that older children have greater mastery of compared to younger children). Individual differences such as TD 1's slightly higher WCM score than her IPC score may be because of the lack of words with consonants based on place and variegation.

Prosody Voice Screener Profile (PVSP)

PVSP is a standard assessment measuring prosodic characteristics. The PVSP score was found by dividing the number of acceptable (i.e., typical) utterances by the total number of approved utterances. Each of the sections scores was also combined for a total score of prosody and voice to compare TD controls and ASD participants. The rationale for *PSVP* was used to measure prosody in TD and ASD/DSD children's utterances to examine whether children with ASD differ significantly from TD children in use of prosodic characteristics in spontaneous output. The following information contains ASD participant and TD control's composite and section scores of the *PVSP*.

PVSP Composite Scores

Generally, ASD participants achieved an approximately 17% lower mean *PVSP* score than their TD controls. ASD participants' *PVSP* range was almost twice as variable compared to TD. Both developmentally older ASD participants (i.e., ASD 1 and ASD 3) scored higher than the other two developmentally younger ASD participants. Each ASD participant's cumulative *PVSP* score was correlated to his/her developmental-chronological ages except for ASD 2's *PVSP* score, which was lower than ASD 4's *PVSP* score despite ASD 4 being younger chronologically

Individual differences of mean scores from the PVSP included ASD 1 performing higher than all other ASD participants; ASD 1 also performed higher than her TD developmentally age-matched peer, TD 1. However, TD 1's *PVSP* results do not seem to be indicative of a prosody-voice disorder. Besides ASD 1, each ASD participant performed lower compared to his developmentally-age matched TD control peer. Results of the *PVSP* Total Scores can be found in Table 10.

Table 10: *PVSP* Total Scores

Participants	DA/CA	PVSP	Controls	DA-CA	PVSP
ASD 1	2;5/3;10	75%	TD 1	2;5	73%
ASD 2	1;11/6;3	53%	TD 2	1;11	81%
ASD 3	2;4/5;5	73%	TD 3	2;4	82%
ASD 4	1;11/4;1	65%	TD 4	1;11	85%
		Mean PVSP			**Mean PVSP**
		67%			80%
		Range PVSP			**Range PVSP**
		53%-75%			73%-85%

PVSP's Prosody-Voice Sections

Each participant-control match's *PVSP* was assessed further by individually examining each of the 6 sections of the *PVSP*: phrasing, rate, stress, loudness, pitch, and quality (see Table 11).

Phrasing

Phrasing was considered appropriate for 3 of the 4 participants. The lowest scoring participant received a score lower than 90% based on producing sound/syllable and word repetitions in the same utterance. None of the ASD participants' phrasing was considered to be appropriate; since all participants and controls had varying prosodic-voice output averages. The most common 'phrasing' characteristics of the ASD participants included (from most to least common): sound/syllable repetition, more than one word repetition, and single word repetition, See Figure 1 below.

Rate

Only 1 of the 4 TD controls 'rate' scores was considered appropriate; the most common rate characteristics amongst TD controls included: slow articulation, pause time, and fast articulation. 'Rate' scores for all ASD participants were considered inappropriate; the key characteristics of for rate amongst ASD participants were similar to TD controls' rate attributes. Characteristics such as fast articulation seemed appropriate for most children during typical play sessions. Slow articulation was the most common rate characteristic exhibited in ASD participants.

Stress

The most common 'prosodic stress' attributes found in ASD participants and TD controls were excessive/misplaced and reduced stress. However, ASD participants produced approximately seven times more utterances with excessive/misplaced stress and two times more utterances with reduced/equal stress compared to TD controls.

Loudness

'Loudness' features most commonly produced by ASD participants and TD controls were soft and loud utterances; each ASD participant produced soft utterances at least once during his/her language sample. ASD participants produced approximately 4 times more utterances softly than TD controls. However, TD controls produced loud utterances approximately twice as often as ASD participants.

Pitch

The ASD participants produced both high and low-pitched utterances. The most common' voice quality' characteristics produced by ASD participants included strained and nasopharyngeal resonance. Nasopharyngeal resonance was also a common attribute found in TD controls; however, was considered 1.5 times more likely to occur for the ASD participants. Results of *PVSP* Section Averages can be found in Table 11.

Figure1: PVSP Section Averages Comparing TD Controls and ASD Participants

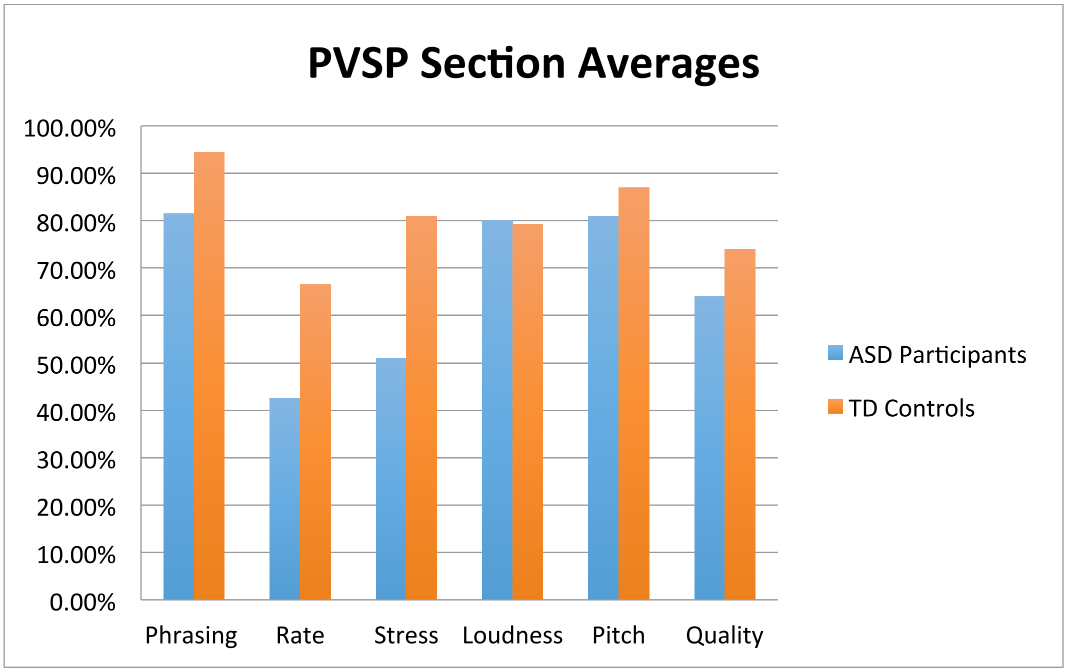


Table 11: *PVSP* Participant-Control Match (sections of Prosody and Voice)

Participant-Control Match								
Utterance Data (%)	ASD 1 - TD 1		ASD 2 - TD 2		ASD 3 - TD 3		ASD 4 - TD 4	
Phrasing	80%	100%	82%	92%	88%	86%	76%	100%
Rate	68%	40%	18%	92%	28%	64%	56%	70%
Stress	88%	100%	28%	78%	36%	86%	52%	60%
Loudness	88%	53%	64%	78%	96%	86%	72%	100%
Pitch	88%	73%	64%	92%	96&	93%	76%	90%
Quality	40%	73%	64%	54%	96%	79%	56%	90%

Through the PVSP analyses showed that TD controls achieved a higher mean PVSP score and a smaller PVSP range. TD controls performed with higher phrasing, rate, stress, pitch, and voice quality averages compared to the ASD participants. TD controls performed the highest with phrasing utterances, yet ASD participants performed with an even higher utterances phrasing accuracy and the greatest out of all 6 prosodic-voice components. ASD participants performed relatively the same as the TD controls regarding loudness, but performed the lowest on the stress and rate of utterance production. ASD participants performed relatively well with pitch production.

Some scoring on the PVSP should be assessed carefully. For instance, TD 1, the oldest TD control, achieved the lowest PVSP of 74%. However, she was the only child in the study with at least 50% of her codable utterances being 4 words or longer. Most of TD 1's utterance errors included: fast rate, loudness, high pitch, and nasopharyngeal quality. 3 of 4 of TD 1's inaccurate utterance qualities are often associated with excitement and play. Hence, it seems not valid to suggest that TD 1 has a prosody-voice deficit.

Overall, ASD participants exhibited the following deviant prosody-voice qualities: more than 1 word repetitions, slow articulation, excessive/misplaced and reduced stress, soft utterances, and nasopharyngeal resonance. The largest prosody-voice discrepancy between controls and participants was utterance stress by approximately 30%. Individual differences were related to the disparity between many ASD participants chronological age difference compared to their developmental age.

LANGUAGE MEASURES

MLU and TTR were used to evaluate language patterns seen in both ASD participants and TD controls. Language samples of the ASD participants were based on 2 transcripts compared to TD controls that only included 1 language sample transcription.

Mean Length of Utterance (MLU)

MLU analyses were completed to understand morphological length of each child compared for his/her chronological/development ages. Two of the 4 TD control children had higher MLUs compared to their ASD matched participant. TD 1 scored the highest MLU of the TD controls. She was the chronologically oldest TD control. ASD 1 exhibited the longest MLU. However, she was the chronologically youngest participant. ASD 1 was the only female; hence, a possible a reason she showed a longer MLU compared to her male ASD counterparts. It should be noted that ASD 1 was developmentally the most advanced ASD participant. ASD 1 also achieved a higher MLU than TD 1. It should be noted that, ASD 1 is chronologically older than TD 1 by approximately 17 months. ASD 3 exhibited a slightly higher MLU than his TD control, TD 3. Likewise, ASD 3 is chronologically older than TD 3.

According to Brown (1973), between 15 and 30 months, a child is expected to have a MLU of approximately, 1.5-2.0. Almost all ASD participants and TD control MLUs were within the range based on developmental age expectations based on Brown. Only 2 TD children were below 1.75 (both 23 months old). The chronological age expectations of the ASD participants are as follows: 1 ASD participant should be in Stage IV of Brown's Morphemes (MLU between 3.0-3.7). The other 3 ASD participants should be in Stage V (MLU between 3.7-+). Only the chronologically youngest participant (i.e., ASD 1) was within her MLU range. The other 3 participants were delayed by about 1-2 morphemes. Results of MLU calculations for ASD participants and TD controls can be found in Table 12.

Table 12: MLU of ASD participants and TD Controls

ASD Participants	**DA/CA**	**MLU**	**TD Controls**	**DA-CA**	**MLU**
ASD 1	2;5/3;10	3.36	TD 1	2;5	2.92
ASD 2	1;11/6;3	2.02	TD 2	1;11	1.40
ASD 3	2;4/5;5	2.19	TD 3	2;4	2.14
ASD 4	1;11/4;1	1.99	TD 4	1;11	1.44
		Mean MLU			**Mean MLU**
		2.39			1.98
		Range MLU			**Range MLU**
		1.99-3.36			1.40-2.92

Overall, children with ASD demonstrated higher MLU scores compared to their TD peers. Developmentally, 6 out of 8 children were developmentally on target for MLU. The 2 children who had MLUs lower than their developmental ages were both TD, but were only delayed by a third of a morpheme. Chronologically, though, 3 of 4 ASD participants were delayed in morpheme length by approximately 1-2 morphemes suggesting limited utterance length and smaller morphologically complex word usage.

Type-Token Ratio (TTR)

TTR calculations analyses were implemented to consider vocabulary variation in children in their spontaneous speech and language sample. Mean TTRs of ASD participants were higher and showed a narrower range of values than TD controls. However, TD 3, was closer to the TTR scores of the ASD participants than the other TD controls This could be because TD 3 was one of the chronologically older controls. However, TD 1 was the chronologically oldest TD control, but scored the lowest TTR compared to any child in this study indicating a lower vocabulary variation. Despite the limited information on norms for TTR (i.e., below 0.25 is considered restricted, anything at or above 0.80 is considered highly varied vocabulary), this calculation should be expected to increase with age. As children gain more knowledge and language skills, vocabulary naturally should increase the more a child is immersed into new and habitual parts of his/her environment. However, this pattern did not occur within either the ASD participant or the TD control groups. No child was below 0.25; therefore, no child demonstrated an extremely restricted vocabulary. However, no child had a highly varied vocabulary (i.e., TTR above 0.80). The mean TTRs for both groups were only variable by a few points. The mean TTR for the ASD participants was higher compared to the controls. However, this is most likely due to their higher chronological ages and having more environmental, school, and personal experiences to increase the number of different words used. Results of TTR can be found in Table 13.

Table 13: TTR Scores for ASD Participants and TD Controls

ASD Participants	DA/CA	TTR	TD Controls	DA-CA	TTR
ASD 1	2;5/3;10	0.45	TD 1	2;5	0.27
ASD 2	1;11/6;3	0.46	TD 2	1;11	0.30
ASD 3	2;4/5;5	0.48	TD 3	2;4	0.43
ASD 4	1;11/4;1	0.47	TD 4	1;11	0.28
		Mean TTR			**Mean TTR**
		0.47			0.32
		Range TTR			**Range TTR**
		0.45-0.48			0.27-0.43

Children with ASD demonstrated an extremely close TTR range regardless of chronological age. TTR of TD controls were more variable most likely due to developmental and chronological ages being equal (i.e., less environmental, peer interaction). Individual differences, for instance TD 1, may be indicative of lack of resources necessary for an infant to have an increased vocabulary variation compared to her TD peer. TD 3, achieved a TTR score almost double TD 1's.

OVERALL SUMMARY OF RESULTS

Findings from this study suggest that children with ASD show higher consonant accuracy in their spontaneous speech production output compared to their TD developmental age-matched peers. PMLU was more variable, but complex for children with ASD than their TD matched peers. TD children were considered to have higher word variability as they demonstrated more word approximations than their ASD counterparts. TD children performed with more appropriate prosodic-voice attributes compared to their ASD peers. ASD children struggled most with achieving an appropriate rate of speech and had the biggest prosodic differences from typical age expectations compared to their TD peers regarding stress (i.e., a topic often suggested and discussed, but rarely studied). ASD participants also exhibited the following deviant prosodic-voice qualities: more than 1 word repetitions, slow articulation, soft utterances, and nasopharyngeal resonance. Language scores for ASD children were higher, yet were considered delayed morphologically by approximately 1-2 morphemes relative to chronological age expectations. Figures 2 and 3 show the average speech and language measures as well as the composite speech and language averages comparing ASD participants and TD controls.

Figure 2: Average Speech and Language Measures (*not including WCM and IPC)

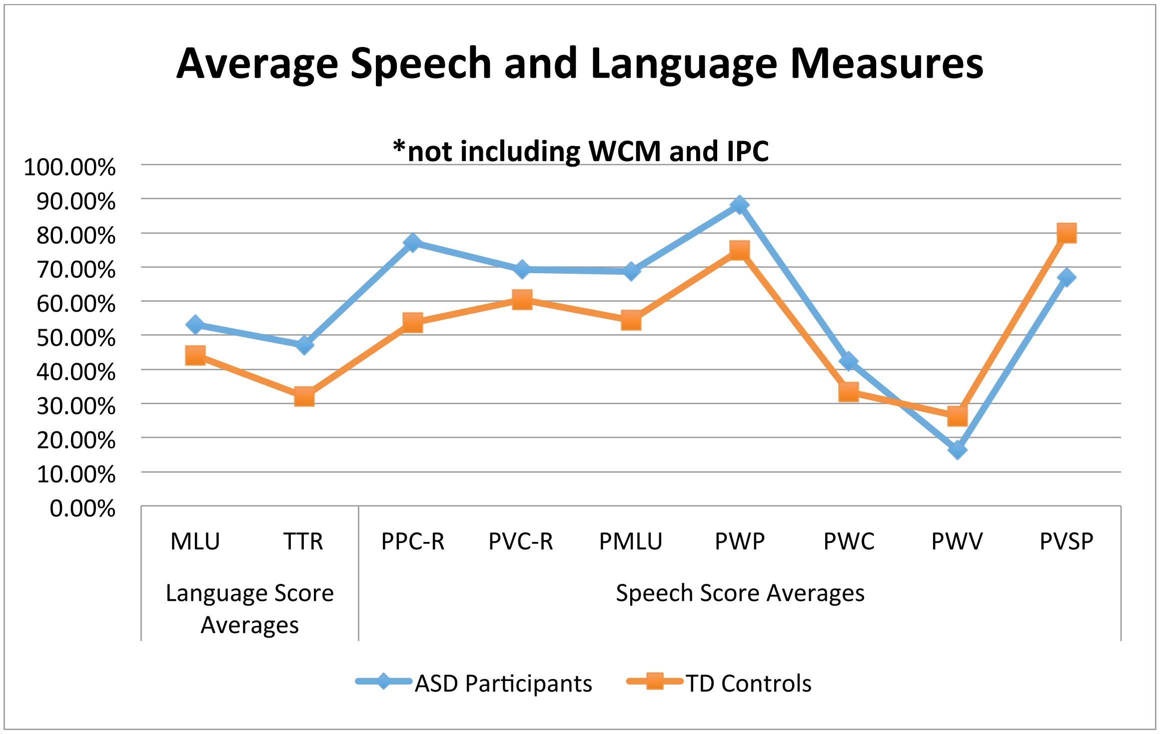
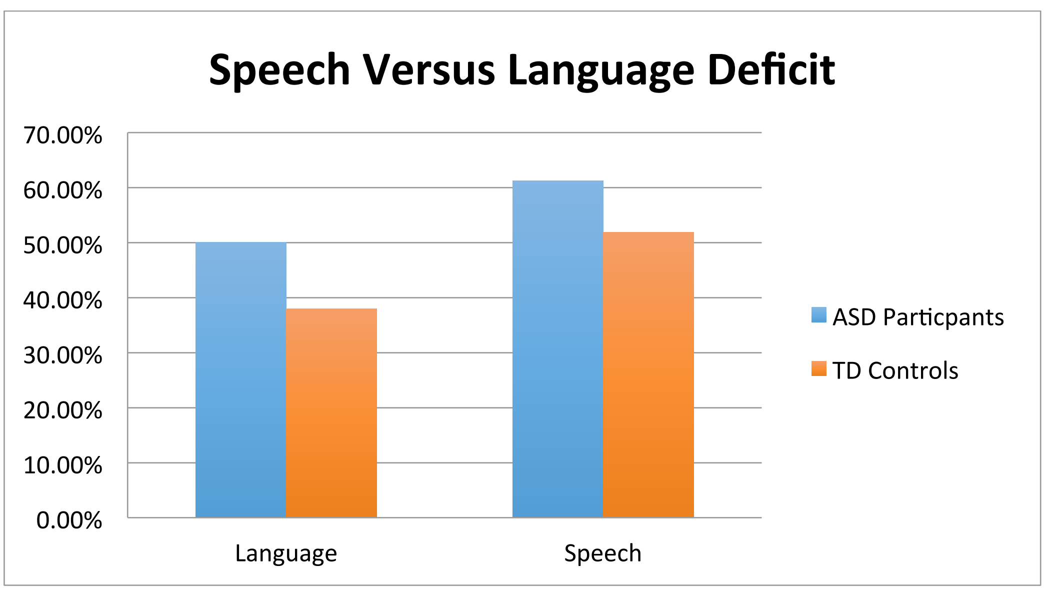


Figure 3: Speech Versus Language Deficit



Discussion

The goal of the current study was to examine segmental and prosodic patterns in spontaneous speech and language output in young children with ASD as they compare with age and gender matched TD peers. To examine this issue, variability and patterns in speech and language produced by TD children between 1;11 and 2;5 compared to ASD/DSD children between the developmental age of 1;11-2;5 years old were evaluated. Metrics used for comparative evaluation included PCC-R, PVC-R, PMLU, PWP, PWC, PWV, WCM, IPC, MLU, TTR, and *PVSP*.

There were 3 main findings in this study. First, a quantitative measure (PVSP) showed prosody discrepancies in ASD participants compared to TD controls. Second, language delays appeared more significant than speech delays in these ASD children. Last, a more standardized, efficient measurement should be constructed as a prosody screener for persons with ASD.

ASD Prosody Discrepancies

Prosody findings were expected since many researchers have commented on qualitative differences in prosodic pattern of children with ASD (Bartolucci, Pierce, Streiner, & Tolkin-Eppel, 1976; Pierce & Bartolucci, 1977; Tager-Flusberg, 1981; Baltaxe & Simmons, 1985, 1992; Fay & Schuler, 1980; Ornitz & Ritvo, 1976; Paul, 1987; Pronovost, Wakstein, & Wakstein, 1966; Rutter & Lockyer, 1967; Tager-Flusberg, 1981). One theory, the speech attunement framework (Shriberg et al., 2011), suggests that for a child to acquire appropriate prosody and segmental components of speech output in their input language, he or she must “tune-in” and “tune-up” to the speech input in his/her environment; this skill that has been found to be difficult for infants later diagnosed with ASD. Sharda et al. (2010) analyzed pitch patterns of children with ASD between the ages of 4-10 years old compared to their age-matched TD peers and the mothers of those TD infants. The authors found that ASD children exhibited exaggerated pitch, pitch range, pitch excursion, and pitch contours that were not observed in TD peers.

Compared to TD developmentally matched peers, ASD participants demonstrated a lower overall PVSP mean score. Specific prosody deficits included excessive, misplaced, and reduced stress in utterances. There was approximately 30% prosodic difference between ASD participants compared to TD controls. Previous literature suggests that persons with ASD have been frequently identified qualitatively as having monotone or robot-like speech (Shriberg et al., 2001). Specifically Shriberg et al. (2001) described male children and adults (i.e., 10;0-50;0 years) with ASD as having deficits in using appropriate pitch, controlling volume, insufficient vocal quality, and abnormal stress patterns. It was apparent, quantitatively and qualitatively, that these four ASD participants demonstrated abnormal stress patterns (i.e., excessive, misplaced, and reduced stress). This was one of the greatest discrepancies between both ASD participants and TD controls. ASD participants performed with an extremely low accuracy of utterance production (i.e., slow articulation rate) as well, yet was a characteristic not mentioned by Shriberg et al. (2001). However, it should be noted that ASD participants performed with slightly higher phrasing accuracy compared to the TD controls, but also exhibited a greater production of 1 or more word repetitions; this was also noted by Shriberg et al. (2001) as revisions and repetitions of phrases occurring related to prosody were 20% more for adults with AS compared to HFA. Controlling volume was also noted as a difference in this study; ASD participants demonstrated softer utterances versus normal or louder ones. In this study and in Shriberg et al. (2001), it was found that the vocal quality was insufficient due to nasopharyngeal resonance. ASD participant prosody deficits in this study seem to suggest a delayed, but different when compared to TD peers.

ASD Language Delay

Some research has demonstrated that children with ASD produce speech errors (i.e., abnormal consonant production, chronological phonological mismatch) (Wetherby et al., 1989; Wolk & Edwards, 1993; Wolk and Giesen, 2000; Cleland et al. 2010; Shriberg et al., 2011). In contrast, other research suggests children with ASD are only delayed phonologically (Rapin et al., 2009; Bartolucci & Pierce, 1977; Bartolucci, Pierce, Streiner & Eppel, 1976) or may have a greater incidence of both disorder and delay in speech output patterns for segments (Bartak, Rutter, & Cox, 1975; Cleland et al., 2010; Shriberg et al., 2011). However, in the present group of four ASD participants, language seemed to be more of a deviant outcome compared to speech output, even though it was not a fundamental focus in this study. Language delays in these four ASD participants were unexpected; therefore, further research is warranted. Likewise, there is no information regarding a standardized assessment (only a structured assessment—*PVSP*) for measuring prosodic quality; therefore, this finding was also expected.

Lower MLU scores of between approximately 1 to 2 morphemes compared to their chronological ages were found to be prominent in the ASD participants. Kwok, Brown, Smyth, & Cardy (2015) compiled 74 studies reporting on expressive and receptive language of children and adolescents with ASD. They found that children with ASD were roughly 1.5 standard deviations (SD) below chronological age matched peers who were typical developed. For instance, certain language measures such as TTR indicate that after 3;10 (the lowest age of one of the participants), vocabulary acquisition for the participants with ASD plateaued; indicating a differing trajectory for vocabulary acquisition for these children. This supposition should be tested longitudinally in a larger cohort of ASD children.

Kwok et al (2015)'s findings compared our current study's findings suggest that children with ASD are developmentally delayed in language milestones for their chronological age; however, to make the comparison between ASD participants and TD controls seems troubling because of the developmental language age-matching process used in analysis. It seems it would've been more helpful to match the children with ASD both chronologically and developmentally the TD peers. Perhaps using younger ASD participants would have given more accurate comparative results.

Clinical Implications for PVSP use

In the current study, participants with ASD did not display delayed consonant and phonological acquisition compared to developmentally age-matched TD peers. Instead, the ASD participants demonstrated prosodic-voice deficits. These findings for four children with ASD and developmentally matched TD controls suggest that an important clinical focus should relate to maintaining appropriate rate, phrasing, increased loudness of utterances, and lessening nasopharyngeal resonance. A high priority in speech therapy should be emphasis on accuracy of stress marking. Making children aware of variations in stress and how this variation impacts successful communication effectiveness could increase the likelihood of success in intervention and consequent functional communication success overall. In this regard, establishing a more concise standardized prosodic measurement could help to describe speech patterns impacting intelligibility more precisely leading to earlier intervention assessment (rather than later) and intervention protocols for children with ASD more broadly than just focusing on segmental and word complexity levels of clinical differences. The PVSP did not take into account TD and ASD children's utterance qualities (i.e., loud, fast, high pitch) based on age milestones appropriate for a child's developmental age. As a result, this analysis procedure did not result in valid scores for the TD and ASD children.

Future Research

Speech measures, such as PMLU and *PVSP*, should be further examined and/or standardized to determine potential developmental stages or milestones for TD children to compare to ASD children for intervention focused research studies. Future studies should include a larger sample size of young children with ASD. To maximize validity and reliability, future research should incorporate a larger sample size of children with ASD as well as a larger research group for consensus regarding scoring for the *PVSP*. The *PVSP* is an extensive, cumbersome structured analysis. It took several hours and practice to understand and appropriately use this screener. This structured assessment seems unreasonable for a Speech-Language Pathologist (SLP) to use on a daily basis. Therefore, revised version of this analysis is strongly suggested to provide a more concise, standardized diagnostic tool for both SLPs and researchers.

Comparing two groups of children selected and matched by their developmental language ages was extremely difficult. It was a problem in making the comparison between various speech and language measures depending on the same or different chronological-developmental ages for ASD participants and TD controls. Therefore, it has been suggested that future research on ASD children instead of being grouped by developmental or chronological age, ASD children could be compared to TD children based their ability to equate performance on carefully designed control tasks with clearly defined group differences per each task (Jarrold, & Brock, 2004).

Future research should also compare and contrast the production and perception of children with ASD regarding the different types of prosody (i.e., grammatical, pragmatic, affective). Focusing on the specific types of prosody would be of use since these were not focuses of the current study, but may be of practical use within the therapy room and real world environment for children with ASD. Eventually, understanding the different subsets of prosody, may help speech therapists and researchers be more equipped to treat and assess the reduction of naturalness of prosody often associated with children with ASD.

Likewise, future research should focus on both the speech and the language deficits of young children with ASD to understand which component of language is most responsible for their lack of age appropriate communication abilities in language based communications.

Overall, ASD participants in this study demonstrated language differences that were more apparent than speech differences. Excessive, misplaced, and reduced stress in utterances and slowed articulation rate were the two greatest deficits ASD participants in this study demonstrated. A revised *PVSP* or newly structured prosody diagnostic tool is heavily advised early intervention purposes and increase of ASD likelihood amongst children increasing across the U.S. and non-U.S. countries by approximately 1% of the population (Brugha et al., 2001).

Appendices

APPENDIX 1: PPC-R VALUES BY AGE IN MONTHS (CAMPBELL ET AL., 2007)

Age (mos.)	*M*	*SD*	*SE*	Lower	Upper
18	51.31	5.36	2.82	48.48	54.12
19	56.13	5.34	2.60	53.53	58.73
20	60.25	5.32	2.43	57.82	62.68
21	63.79	5.30	2.42	61.37	66.21
22	66.87	5.28	2.37	64.50	69.24
23	69.55	5.26	2.36	67.19	71.91
24	71.90	5.24	2.32	69.58	74.22
25	73.98	5.22	1.14	72.84	75.12
26	75.82	5.21	1.14	74.68	76.96
27	77.46	5.20	1.14	76.32	78.60
28	78.93	5.19	1.13	77.80	80.06
29	80.25	5.17	1.13	79.12	81.38
30	81.44	5.17	1.13	80.31	82.57
31	82.51	5.16	1.13	81.38	83.64
32	83.49	5.15	1.12	82.37	84.61
33	84.38	5.14	1.12	83.26	85.50
34	85.19	5.14	1.12	84.07	86.31
35	85.94	5.13	1.12	84.82	87.06
36	86.62	5.13	0.84	85.78	87.46
37	87.25	5.12	0.77	86.48	88.02
38	87.82	5.14	0.86	86.96	88.68
39	88.36	5.16	0.98	87.38	89.34
40	88.85	5.18	1.23	87.62	90.08
41	89.31	5.20	1.23	88.08	90.54
42	89.74	5.25	1.24	88.50	90.98
43	90.14	5.28	1.89	88.25	92.03
44	90.51	5.32	1.19	89.32	91.70
45	90.86	5.36	1.20	89.66	92.06
46	91.18	5.40	1.21	89.97	92.39
47	91.48	5.43	1.21	90.27	92.69
48	91.77	5.46	0.96	90.81	92.73
49	92.04	5.49	0.73	91.31	92.77
50	92.29	5.52	1.38	90.91	93.67
51	92.52	5.55	1.63	90.89	94.15
52	92.75	5.57	1.64	91.11	94.39
53	92.96	5.59	2.11	90.85	95.07
54	93.16	5.61	1.64	91.52	94.80
55	93.35	5.63	1.65	91.70	95.00
56	93.53	5.65	1.65	91.88	95.18
57	93.69	5.66	1.65	92.04	95.34
58	93.85	5.68	1.66	92.19	95.51
59	94.01	5.69	1.66	92.35	95.67
60	94.15	5.70	1.67	92.48	95.82
61	94.29	5.71	1.67	92.62	95.96
62	94.42	5.72	1.67	92.75	96.09
63	94.55	5.73	1.67	92.88	96.22
64	94.67	5.74	1.68	92.99	96.35
65	94.78	5.74	1.68	93.10	96.46
66	94.89	5.75	1.68	93.21	96.57
67	94.99	5.75	1.42	93.57	96.41
68	95.09	5.76	1.69	93.40	96.78
69	95.19	5.76	1.69	93.50	96.88
70	95.28	5.77	1.70	93.58	96.98

Age (mos.)	*M*	*SD*	*SE*	Lower	Upper
71	95.36	5.77	1.70	93.66	97.06
72	95.45	5.77	1.70	93.75	97.15
73	95.53	5.77	1.70	93.83	97.23
74	95.60	5.78	1.70	93.90	97.30
75	95.68	5.78	1.70	93.98	97.38
76	95.75	5.78	1.71	94.04	97.46
77	95.82	5.80	2.57	93.25	98.39
78	95.88	5.80	2.57	93.31	98.45
79	95.95	5.80	2.57	93.38	98.52
80	96.01	5.80	2.57	93.44	98.58
81	96.06	5.80	2.57	93.49	98.63
82	96.12	5.80	2.57	93.55	98.69
83	96.18	5.80	2.57	93.61	98.75
84	96.23	5.80	2.57	93.66	98.80
85	96.28	5.80	2.57	93.71	98.85
86	96.33	5.80	2.57	93.76	98.90
87	96.37	5.80	2.57	93.80	98.94
88	96.42	5.80	3.12	93.30	99.54
89	96.46	5.80	3.48	92.98	99.94
90	96.51	5.77	3.46	93.05	99.97
91	96.55	5.75	3.45	93.10	100.00
92	96.59	5.72	3.43	93.16	100.02
93	96.63	5.70	3.42	93.21	100.05
94	96.66	5.68	3.41	93.25	100.07
95	96.70	5.66	3.40	93.30	100.10
96	96.73	5.65	3.39	93.34	100.12
97	96.77	5.63	3.38	93.39	100.15
98	96.80	5.62	3.37	93.43	100.17
99	96.83	5.61	3.37	93.46	100.20
100	96.86	5.60	3.86	93.00	100.72
101	96.89	5.59	3.86	93.03	100.75
102	96.92	5.58	3.85	93.07	100.77
103	96.95	5.58	3.85	93.10	100.80
104	96.98	5.57	3.84	93.14	100.82
105	97.01	5.56	3.84	93.17	100.85
106	97.03	5.56	3.83	93.20	100.86
107	97.06	5.55	3.83	93.23	100.89
108	97.08	5.55	3.83	93.25	100.91
109	97.11	5.55	3.82	93.29	100.93
110	97.13	5.54	3.82	93.31	100.95
111	97.15	5.54	3.82	93.33	100.97
112	97.17	5.51	3.80	93.37	100.97
113	97.20	5.48	3.78	93.42	100.98
114	97.22	5.46	3.77	93.45	100.99
115	97.24	5.44	3.75	93.49	100.99
116	97.26	5.42	3.74	93.52	101.00
117	97.28	5.40	3.73	93.55	101.01
118	97.29	5.39	3.72	93.57	101.01
119	97.31	5.37	3.71	93.60	101.02
120	97.33	5.36	3.70	93.63	101.03
121	97.35	5.35	3.69	93.66	101.04
122	97.36	5.34	3.68	93.68	101.04
123	97.38	5.33	3.68	93.70	101.06

Appendix 2: Words to include or exclude from PMLU, WCM, and PCC-R

WORD	***NOTES***
"Ex" -- like closing computer	Exclude for all calculations
3-d	Include for all calculations
A-Choo	Exclude for all calculations
Ah	Exclude for all calculations
Aha	Exclude for all calculations
Alrighty	Include for all calculations
Aw	Exclude for all calculations
Bah (sheep sound)	Exclude from PMLU, but include others
Band-aid	Should be written as 1 word
Batman	Include for all calculations
Beep/Beeps	Include for all calculations
Big Bird	Include for all calculations
Bing	Exclude for all calculations
Birdie	Exclude from PMLU, but include others
Bock bock (chickens)	Exclude from PMLU, but include others
Boing	Exclude for all calculations
Bong	Exclude for all calculations
Bonk	Exclude for all calculations
Boo	Include for all calculations
Boom	Include for all calculations
‘Bout	Include for all calculations
Bro	Exclude for all calculations
Buggie	Include for all calculations
Buh (as in "Buh Bye")	Include this in the transcript
Bunny	Include for all calculations
Butt	Include for all calculations
Bye bye	Include for all calculations
Candy bar	Should be written as 2 words
Candy corn	Should be written as 2 words
Care Bears	Include for all calculations

Cartoony	Include for all calculations
Cause	Include for all calculations
Cheese cutter	Should be written as 2 words
Cheeseburger	Should be written as 1 word
Chicka chicka boom boom	Chika: exclude from all calculations
Choo choo/Chugga Chugga	Exclude from PMLU, include for others
Cinder-elephant	Include for all calculations
Clean up	Should be written as 2 words
Clean up song	Include for all calculations
Cock a doodle doo	Exclude from PMLU, but include others
Cookie Monster	Include for all calculations
Curious George	Include for all calculations
Cut out	Should be written as 2 words
Cute headed	Include for all calculations
Cuttable	Include for all calculations
Cuz	Include for all calculations
Dada	Exclude from PMLU, but include others
Daddy	Exclude from PMLU, but include others
Dah	Exclude for all calculations
Ding/Dinging	Exclude from PMLU, but include others
Doc	Include for all calculations
Doin'	Include for all calculations
Doll house	Should be written as 2 words
Door knob	Should be written as 2 words
Dragonfly	Should be written as 1 word
Drawbridge	Should be written as 1 word
Ducky	Exclude from PMLU, but include others
Dump truck	Should be written as 2 words
Dumper	Include for all calculations
Elmo	Include for all calculations
Em	Include for all calculations
Ernie	Include for all calculations

Ew	Exclude for all calculations
Excuse me	Should be written as 2 words
Field trip	Should be written as 2 words
Finish line	Should be written as 2 words
Fire truck	Should be written as 2 words
Fishes	Include for all calculations
Fishy/fishies	Exclude PMLU, but include for others
Flagless	Include for all calculations
Foods	Include for all calculations
French fry	Should be written as 2 words
Frosty	Include for all calculations
Fuzzy	Include for all calculations
Game board	Should be written as 2 words
Gimmie/gimme	Include for all calculations
Go-kart	Should be written as 1 word
Gobble	Exclude PMLU, but include for others
Gonna	Include for all calculations
Good night	Should be written as 2 words
Goodbye	Should be written as 1 word
Gooey	Include for all calculations
Gotcha	Include for all calculations
Grasses	Include for all calculations
Grown up	Should be written as 2 words
Ha/haha (laughing)	Exclude for all calculations
Hah	Exclude for all calculations
Hamburger	Should be written as 1 word
Head, shoulders, knees and toes song	Include all calculations
Heigh ho song (from Snow White)	Include for all calculations
High five	Should be written as 2 words
Hill man	Include for all calculations
Hiyah	Exclude for all calculations
Hmm	Exclude for all calculations

Hooray	Include for all calculations
Hoppy	Exclude from PMLU, include for others
Horsey/horsies/horsy	Exclude from PMLU, include for others
Hot dog	Should be written as 2 words
How'd	Include for all calculations
Huff	Include for all calculations
Huh	Exclude for all calculations
I'ma (like "I'm gonna")	Exclude from all
Ice cream	Should be written as 2 words
Icky	Include for all calculations
It'd	Include for all calculations
Itchy	Include for all calculations
Jack in the box	Should be written as 2 words
Jelly bean	Should be written as 2 words
Jingle Bells song	Include for all calculations
Jump rope	Should be written as 2 words
Kiddin'	Include for all calculations
Kitty	Exclude from PMLU, include others
Kitty cat	Should be written as 2 words
Kitty train	Kitty: Exclude from PMLU include for others
Ladybug	Should be written as 1 word
Leafy	Exclude from PMLU, but include others
Light bulb	Should be written as 2 words
Lily pad	Should be written as 2 words
Littler	Include for all calculations
Lulu (a name)	Include for all calculations
Lunch time	Should be written as 2 words
Ma	Exclude from PMLU, but include for others
Makin'	Include for all calculations
Mama/Momma	Exclude from PMLU but include others
Meatballs	Should be written as 1 word
Meow	Exclude from PMLU, but include others

Mhmm	Exclude for all calculations
Mommy	Exclude from PMLU, but include others
Moo	Exclude from PMLU, but include others
Nah	Exclude for all calculations
Nail polish	Should be written as 2 words
Neigh (horse sound)	Exclude from PMLU, but include others
Nemo	Include for all calculations
Nevermind	Should be written as 1 word
Nope	Include for all calculations
Oh	Exclude for all calculations
Oink	Exclude from PMLU, but include others
Ol'	Include for all calculations
Old Mcdonald's song	Include for all calculations
On your mark, get set, go	Include for all calculations
One by one	Should be written as 2 words
Oooh /u/	Exclude for all calculations
Oops	Include for all calculations
Oopsy	Exclude from PMLU, but include others
Ouch	Include for all calculations
Ouchy/ouchie	Exclude from PMLU, but include others
Ow	Exclude for all calculations
Peanut butter	Should be written as 2 words
Pee	Include for all calculations
Peek-a-boo	Include for all calculations
Peoples	Include for all calculations
Perry the platypus	Include for all calculations
Piggy	Exclude from PMLU, but include others
Piggy bank	Piggy: Exclude from PMLU but include others
Piggyback	Exclude from PMLU, but include others
Pine corn	Should be written as 2 words
Play-doh	Should be written as 1 word
Playground	Should be written as 1 word

Pointy	Include for all calculations
Pokemon names	Include for all calculations
Poop	Include for all calculations
Pop	Include for all calculations
Pop up	Should be written as 2 words
Potty	Exclude from PMLU, but include others
Puppy	Include for all calculations
Quack	Exclude from PMLU, but include others
Racecar	Should be written as 1 word
Racetrack	Should be written as 1 word
Ready set go	Should be written as 2 words
Ribbit/ribit/ribbet	Exclude from PMLU, but include others
Ring around the Rosies song	Include all but "Rosies" for PMLU
Roar	Exclude from PMLU, but include others
Wocket ball	Should be written as 2 words
Rocket Ship	Should be written as 2 words
Rocket thingy/rocket like thingy	Thingy: exclude from PMLU, keep for others
Row, row, row your boat song	Include for all calculations
Rubber duck	Include for all calculations
Rubber ducky	Exclude "ducky" from PMLU, keep for others
Ruff (dog barking)	Exclude from PMLU, but include others
San Antonio	Should be written as 1 word
San Diego	Should be written as 1 word
Sea World	Should be written as 2 words
See Saw	Should be written as 1 word
Set up	Should be written as 2 words
Shakin'	Include for all calculations
Shh	Exclude for all calculations
Silly	Include for all calculations
Silly goose	Include for all calculations
Slimy	Include for all calculations
Smelly	Include for all calculations

Smokey	Include for all calculations
Soapy	Include for all calculations
Spikey head	Include for all calculations
Squiggle	Include for all calculations
Squish	Include for all calculations
Squishy	Exclude from PMLU, but include others
Stretchy	Include for all calculations
Sucker	Include for all calculations
Switcher	Include for all calculations
Switchy switch	Exclude from PMLU, but include others
Ta da	Exclude for all calculations
Takeoff	Should be written as 1 word
Tata	Exclude for all calculations
Teddy bear	Include for all calculations
Teeny tiny	Include for all calculations
Telled	Include for all calculations
Thank you	Should be written as 2 words
Yhat'd	Include for all calculations
Thingy/thingies	Exclude from PMLU, but include others
Thomas (the train engine)	Include for all calculations
Thunderball	Include for all calculations
Thunderbowl	Include for all calculations
til	Include for all calculations
Tiny	Include for all calculations
Toot	Exclude from PMLU, but include others
Train track	Should be written as 2 words
Trash can	Should be written as 2 words
Tree house	Should be written as 2 words
Trick or treat	Include for all calculations
Twinkle twinkle little star song	Include for all calculations
Uh	Exclude for all calculations
Uh-oh	Exclude for all calculations

Um	Exclude for all calculations
Upside down	Should be written as 2 words
Vroom	Exclude from PMLU, but include others
Wa-ooh	Exclude for all calculations
Wah	Exclude for all calculations
Wee	Exclude for all calculations
What're	Include for all calculations
Whatchu	Include for all calculations
Whiteboard	Should be written as 1 word
Whoo	Exclude for all calculations
Whoop	Exclude for all calculations
Whoops/woops	Exclude for all calculations
Whoopsies	Exclude for all calculations
Whoosh	Include for all calculations
Wiener	Include for all calculations
Wiggle	Include for all calculations
Wingless	Include for all calculations
Woah	Exclude for all calculations
Wobble	Include for all calculations
Woo	Exclude for all calculations
Wuwee	Exclude for all calculations
Ya (as in "See ya")	Include for all calculations
Yay	Exclude for all calculations
Yeah	Include for all calculations

APPENDIX 3: THE PROSODY-VOICE SCREENING PROFILE

a. Segmentation Rules:

   i. Divide utterance into 2 when a pause of 2 seconds or more occurs, or if examiner interrupts

   ii. Intonation at the end of a word string (e.g., rising, falling) is *not* considered in the definition of an utterance

   iii. Any conjunction (i.e., "and", "then", "or", "because") after a completed thought and followed by a pause longer than 2 seconds

   iv. Lists connected by "and" are included in only 1 utterance (e.g., "Green and red and blue are my favorites"=1 utterance), if unintelligible include it as only one utterance

   v. "And" that occurs as the first word is not counted (e.g., "And I went to the store and mom got some milk" =1 utterance)

   vi. Orphaned strings—occurs at the beginning, middle, or end of speaker's turn

   vii. Run-on strings—lengthy string of words or ideas

      1. If no conjunctions in string, segment the utterance into separate thoughts (pause ~ less than 2 seconds)

      2. If mazes occur refer below

   viii. Fillers (e.g., "um", "oh"), separating two utterances and occur in close proximity to both utterances assigned to beginning of 2nd utterance

   ix. Isolated fillers (e.g., "oh", "oh boy") are considered exclamations and are passed over in glossing and coding

   x. "Yeah" used to confirm examiner's gloss is counted as separate utterance

      1. Doesn't count if separated by a pause for more than 2 seconds

xi. Strings that reflect repeated attempts to convey meaningful though (i.e., mazes) are separated into 2 or more utterances
    1. A new utterance begins when audible inhalation has been heard regardless of 2 second pause
    2. If audible inhalation immediately follows part-word repetitions, do not begin a new utterance until original thought completed
    3. Separate utterances based on thought groups, whether or not contain two-second pause or conjunction (in this latter case only, each utterance must contain subject + verb)

xii. Elaborate phrases are considered a new thought (e.g., "I got a new balloon" /"It's red.")

xiii. Phrase modifiers—"I got a balloon." / "It mine! It mine!"

xiv. Use asterisk (*) to represent:
    1. Unintelligible syllables/words
    2. Inaudible words
    3. Linguistic sounds and syllables

    When phonetic transcription cannot be determined; all other identifiable phonetic strings, gloss the sounds using closest available orthographic symbol

b. Exclusion Criteria for Utterances:
    i. Content/Context Codes:
        1. C1: Automatic Sequential
        2. C2: Back Channel/Aside
        3. C3: "I don't know"
        4. C4: Imitation
        5. C5: Interruption/Overtalk
        6. C6: Not 4(+) Words

7. C7: Only 1 Word
8. C8: Only Person’s Name
9. C9: Reading
10. C10: Singing
11. C11: Second Repetition
12. C12: Too many unintelligible

ii. Environmental Codes:
1. E1: Interfering Noise
2. E2: Recorder Wow/Flutter
3. E3: Too Close to Microphone
4. E4: Too Far from Microphone

iii. Register Codes:
1. R1: Character Register
2. R2: Narrative Register
3. R3: Negative Register
4. R4: Sound Effects
5. R5: Whisper

iv. Intermittent State Codes:
1. S1: Belch
2. S2: Cough/Throat Clear
3. S3: Food in Mouth
4. S4: Hiccup
5. S5: Laugh
6. S6: Lip Smack
7. S7: Body Movement
8. S8: Sneeze
9. S9: Telegraphic *only use for partial telegraphic speech*
10. S10: Yawn

c. Inclusion Criteria for Utterances:

   i. Phrasing:

      1. PV2: Sound/Syllable Repetition
      2. PV3: Word Repetition
      3. PV4: Sound/Syllable and Word Repetition
      4. PV5: More than One Word Repetition
      5. PV6: One Word Revision
      6. PV7: More than One Word Revision
      7. PV8: Repetition and Revision

   ii. Rate:

      1. PV9: Slow Articulation/Pause Time
      2. PV10: Slow/Pause Time
      3. PV11: Fast
      4. PV12: Fast/Acceleration

   iii. Stress:

      1. PV13: Multisyllabic Word Stress
      2. PV14: Reduced/Equal Stress
      3. PV15: Excessive/Misplaced Stress
      4. PV16: Multiple Stress Features

   iv. Loudness:

      1. PV17: Soft
      2. PV18:Loud

   v. Pitch:

      1. PV19: Low Pitch/Glottal Fry
      2. PV20: Low Pitch
      3. PV21: High Pitch/Falsetto
      4. PV22: High Pitch

   vi. Laryngeal Quality:

      1. PV23: Breathy

2. PV24: Rough
3. PV25: Strained
4. PV26: Break/Shift/ Tremulous
5. PV27: Register Break
6. PV28: Diplophonia
7. PV29: Multiple Laryngeal Features

vii. Resonance:

1. PV30: Nasal
2. PV31: Denasal
3. PV32: Nasopharyngeal

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