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CAREGIVER AND NATURALISTIC LISTENER REPORT OF INFANT VOCALIZATIONS: TOWARD IDENTIFICATION OF VALID METHODOLOGIES

by

Randi J. Killeen

A thesis

submitted in partial fulfillment

of the requirements for the degree of

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Committee Approval

To the Graduate Faculty:

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December 13, 2013

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RE: Your application dated 12/13/2013 regarding study number 4022M: Pre-linguistic Vocalizations in an Infant Sibling and Typically Developing Peer: From the Perspective of Caregivers and Naturalistic Listeners

Dear Ms. Killeen:

I agree that this study qualifies as exempt from review under the following guideline: 4. Analysis of existing data sets. This letter is your approval, please, keep this document in a safe place.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You are granted permission to conduct your study effective immediately. The study is not subject to renewal.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Patricia Hunter (208-282-2179; fax 208-282-4529; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

Phone: (208) 282-2592 • Fax: (208) 282-4723 • www.isu.edu/research

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TABLE OF CONTENTS

List of Tables ix

List of Abbreviations x

Abstract xiii

Chapter I: Introduction 1

Autism Spectrum Disorders 3

ASD-sibs 6

Phonetic Transcription and Caregiver Perception 9

Naturalistic Listeners 14

Proposed Study and Research Questions 15

Chapter II: Methodology 17

Participants 17

Procedures and Materials 17

Caregiver Report 17

Naturalistic Listener Report 19

Phonetic Features 20

Research Design 22

Chapter III: Results 23

Caregiver Report 23

Naturalistic Listener Report 26

Cross-study Comparison 29

Chapter IV: Conclusions 31

Caregiver Report 32

Naturalistic Listener Report 34

ASD-sib versus TD-sib vocalizations 35

Further Limitations 37

Clinical Implications 40

References 42

LIST OF TABLES

Table 1a: Phonetic Features of Caregiver Reports-General 24

Table 1b: Phonetic Features of Caregiver Reports-Place of Articulation & Voicing..... 24

Table 1c: Phonetic Features of Caregiver Reports-Manner of Production..... 25

Table 1d: Phonetic Features of Caregiver Reports-Tongue Position..... 25

Table 1e: Phonetic Features of Caregiver Reports-Syllable Shapes..... 26

Table 2a: Phonetic features of Naturalistic Listener Reports-General 27

Table 2b: Phonetic features of Naturalistic Listener Reports-Place of Articulation & Voicing..... 27

Table 2c: Phonetic features of Naturalistic Listener Reports- Manner of Production..... 28

Table 2d: Phonetic features of Naturalistic Listener Reports-Tongue Position 28

Table 2d: Phonetic features of Naturalistic Listener Reports-Syllable Shapes 28

LIST OF ABBREVIATIONS

ASD -- Autism spectrum disorder

ASD-sibs -- Later born siblings of children diagnosed with autism spectrum disorders

TD-sibs -- Later born siblings of typically developing children

CAREGIVER AND NATURALISTIC LISTENER REPORT OF INFANT VOCALIZATIONS: TOWARD IDENTIFICATION OF VALID METHODLOGIES

Thesis Abstract--Idaho State University (2014)

Early identification of speech/language disorders is critical for early intervention. It is often difficult to measure the vocalizations of infants at risk for speech/language disorders. Later born siblings of children who have autism (ASD-sib) are an at risk population. Here, we compare the longitudinal vocal development in an ASD-sib to an age- and gender-matched peer with a sibling who is typically developing (TD-sib), utilizing new methodologies. Caregiver and naturalistic listener reports of productions from these infants, 7 through 18 months of age, are presented. The ASD-sib is reported to produce fewer types and tokens than the TD-sib across age and listener. The results of this study help to clarify that laboratory listener judgments are similar to caregiver report, and that the reports of vocalizations from an ASD-sib are different than reports from a TD-sib. Clinical implications are discussed.

Chapter I: Introduction

Infants who have siblings diagnosed with autism (ASD-sibs) are at an increased risk for autism spectrum disorder (ASD) or other language impairments (Iverson & Wozniak, 2007; McDuffie & Yoder, 2010; Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011; Yoder, Stone, Walden, & Malesa, E., 2009; Zwaigenbaum et al., 2005). While most cases of ASD have an unknown etiology, evidence suggests the increased risk in this particular population (ASD-sibs) may be attributed to genetics (Geschwind, 2008; Oznoff et al., 2011; Zwaigenbaum et al., 2005). However, researchers have discovered that about only 10% of autism cases account for genetic factors (Geschwind, 2008). Even still, no single biological marker for ASD has been identified. Researchers have concluded that there is no single cause of ASD. Rather, ASD appears to be caused by a combination of three primary factors: neurobiological, environmental, and genetic factors. Further, researchers believe ASD is often caused by a combination of risk genes and environmental factors, which influence the developing brain either in utero or shortly after birth. While environmental factors do not directly cause ASD, when combined with genetic risk factors, these "stresses" in the child's environment increase the occurrence of ASD.

Accordingly, risk genes and behavioral markers of ASD must continue to be researched and identified early in life (Iverson & Wozniak, 2007; Plumb & Wetherby, 2013). Vocalizations are a necessary step in the acquisition of spoken language; therefore, the prelinguistic stage of development is crucial for examination of potential behavioral markers of ASD (Plumb & Wetherby, 2013).

Researchers examining prelinguistic vocalizations in both typically developing and at risk infants have identified correlations between vocal activities and subsequent language abilities (Määttä, Laakso, Tovanen, Ahonen, & Aro, 2012; Watt, Wetherby, & Shumway, 2006; Wetherby, Allen, Cleary, Kublin, & Goldstein, 2002; Wetherby, Goldstein, Cleary, Allen, & Kublin, 2003). However, even with extensive research readily available, analyzing infant vocal behaviors can be a tremendously tedious task. According to the levels of evidence based practice guidelines outlined by the American Speech Language Hearing Association (ASHA, 2014), research should be assessed based on systematic review. In a level III, longitudinal study by Ramsdell, Oller, Buder, Ethington, & Chorna (2012) exploring the vocalizations of 8 infants at 3 ages in early development (8, 10, and 12 months), caregivers and naturalistic listeners were found to report smaller repertoire sizes when compared to traditional phonetic transcription, which yielded much larger repertoires across all infants at each age. Researchers hoping to identify early predictors of language impairment through analysis of prelinguistic vocalizations are faced with countless hours of phonetic transcription, the traditional method of analyzing early infant vocal categories (Ramsdell et al., 2012). By exploring new methodology in this line of research, caregiver[1] and naturalistic listener[2] report of infant vocalizations, researchers may be able to identify atypical patterns in development earlier, perhaps affording better outcomes for infants who are at risk (Määttä et al., 2012; Ramsdell et al., 2012).

[1] For the purposes of this research, caregivers are those individuals, typically parents, but sometimes grandparents or siblings, who invest significant time and effort in the infant's

[2] For the purposes of this research, naturalistic listening is a laboratory methodology designed to simulate caregiver listening.

Caregiver and naturalistic listener reports are perhaps more practical and representative than transcription methodology when exploring prelinguistic infant vocal development (Christensen, et al., 2010; Määttä et al., 2012; McDuffie & Yoder, 2010; Ramsdell et al., 2012). Information gathered from caregiver and naturalistic listener reports could assist researchers in predicting potential speech and language delays in ASD-sibs. Results from Ramsdell et al. (2012), suggest that caregivers and naturalistic listeners may be able to provide more functional reports of early infant vocal categories, in a more time efficient manner. If concerns were raised through such reports, they would prove to be useful towards earlier diagnosis of ASD, or other speech and language disorders. Ultimately, earlier detection would facilitate speech and language treatment and lead to better outcomes for communicative development (Määttä et al., 2012).

Accordingly, the following topics will be covered in this case study. Characteristics and features of ASD will be reported, along with information about ASD-sibs. The use of caregiver report will be justified, and its relevancy in this particular study will be defended. New methodology employing naturalistic listeners in the analysis of infant vocal development will be introduced. Finally, the purpose of the study will be briefly outlined, the methods (including participants, materials and procedure, phonetic analysis, and design) will be covered, and the results and conclusions will be discussed.

Autism Spectrum Disorders (ASD)

Autism spectrum disorder is a multifactorial developmental disability with severe notable deficits in communication and social interaction (Paul, et al., 2011; Volkmar, Lord, Bailey, Schultz, & Klin, 2004). According to estimates from the Center for

Disease Control and Prevention (2014), ASD is among the most common neurodevelopmental disorders with a prevalence of about 1 in every 68 American children meeting the criteria for ASD. These new figure are approximately 30% higher than previous estimates in 2012. Additionally, males are 5 times more likely than females to receive a diagnosis of ASD (CDC, 2014). The most widely accepted system used by clinicians and researchers alike, for the purpose of classification of ASD, can be found in the recently updated *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; *DSM–5*; American Psychiatric Association, 2013). DSM-5 includes the following in its definition of ASD:

A. Persistent deficits in social communication and interaction across multiple contexts; as manifested by the following, currently or by history:
    1. Deficits in social-emotional reciprocity….
    2. Deficits in nonverbal communicative behaviors used for social interaction….
    3. Deficits in developing, maintaining, and understanding relationships….
B. Restricted, repetitive patterns of behavior, interests, or activities, as manifested by at least two of the following, currently or by history:
    1. Stereotyped or repetitive motor movements, use of objects, or speech….
    2. Insistence on sameness, inflexible adherence to routines, or ritualized patterns of verbal or nonverbal behavior….

3. Highly restricted, fixated interests that are abnormal in intensity or focus….
4. Hyper- or hyporeactivity to sensory input or unusual interests in sensory aspects of the environment….

C. Symptoms must be present in the early developmental period (but may not become fully manifest until social demands exceed limited capacities, or may be masked by learned strategies in later life).

D. Symptoms cause clinically significant impairment in social, occupational, or other important areas of current functioning; and

E. These disturbances are not better explained by intellectual ability (intellectual developmental disorder) or global developmental delay…. (American Psychiatric Association, 2013, p. 50-51).

In addition to new diagnostic criteria, the DSM-5 provides severity levels: Level 1 ("requires support"), Level 2 ("requires substantial support"), and Level 3 ("requires very substantial support;" American Psychiatric Association, 2013, p. 52).

Researchers have found several other identifying characteristics of individuals with ASD beyond what is provided in the DSM-5. Children with ASD are more likely than typically developing children to present with movement and postural disorders (Iverson & Wozniak, 2007). Abnormal movement patterns evident during infancy in this population include, hypotonia, postural instability, difficulty maintaining balance while sitting, abnormal posturing, and disorganization of body segments when rolling from a prone to supine position (Iverson & Wozniak, 2007). Dawson, Osterling, Meltzoff, and Kuhl (2000) reported several impairments of motor movement in children with ASD

beginning in the first 6-months and continuing throughout the first year of life. Issues include; disruptions in muscle tone, toe walking, poorly integrated movements, and absence of a coordinated stepping pattern (Dawson et al., 2000; Iverson & Wozniak, 2007).

While movement disorders are more common in children with ASD, language disorders are often the primary focus. However, the language skills in children with ASD are highly variable (Iverson & Wozniak, 2007). According to Paul and colleagues (2011), ASD is accompanied by specific deficits in pragmatic language and social interaction, which include impairments in the ability to form friendships, participate in social play, and interact in conversation. Children with ASD typically display stereotyped, repetitive and restricted behaviors, and areas of interest marked by obsessions and rigidity (Paul et al., 2011; Volkmar et al., 2004). However, the most noteworthy delay is in expressive language development and is evident in children with ASD during the second year of life (Chawarska, Klin, Paul, & Volkmar, 2006; Paul et al., 2011; Wetherby, Watt, Morgan, & Shumway, 2007). Additionally, researchers believe that infants with ASD are, overall, less interactive than typically developing infants, with notably fewer instances of established joint attention (Iverson & Wozniak, 2007). Early detection of behavioral signs of ASD is crucial for timely diagnosis and initiation of various interventions (Zwaigenbaum et al., 2005).

ASD-sibs

ASD-sibs have been widely studied in recent years and are recognized to be at an elevated risk for ASD (Cassel et al., 2007; Dawson et al., 2007; Iverson & Wozniak, 2007; Paul et al., 2011). Previous studies, conducted by Bailey, Phillips and Rutter (1996)

and Zsatmari and colleagues (1998), have discovered that the rates of autism in ASD-sibs are between 3 to 5%, or at least 20 times higher than the rates of autism in the general population. The CDC (2013), reports parents are 2 to 18% more likely to have a second child with ASD if a previous child has received a diagnosis. However, in a recent level III non-experimental study by Oznoff and colleagues (2011), the reoccurrence rate of autism in ASD-sibs was found to be much higher than previous findings. In this prospective longitudinal study, 132 of 664 at-risk ASD-sibs met the criteria for ASD, yielding an estimated reoccurrence rate of 18.7% (Oznoff et al., 2011). Accordingly, just as the prevalence of ASD continues to rise, the number of ASD-sibs diagnosed with ASD continues to rise.

When considering the significant predictors for a later diagnosis of ASD outlined by Oznoff and colleagues (2011), gender of the ASD-sibs, and the number of affected older siblings (multiplex family status) were the two strongest predictors. A family is considered "multiplex" when more than one sibling is affected by ASD. Specifically, male ASD-sibs were found to present with ASD more often than female ASD-sibs: 25.9% compared to 9.6% respectively (Oznoff et al., 2011). In addition, multiplex family status was found to have an additional twofold increase in risk if there was more than one older sibling affected:12.5% of simple (only one older sibling with a diagnosis of ASD) versus 32.2% of multiplex (Oznoff et al., 2011).

Given these facts, which suggest that ASD-sibs are at an increased risk of ASD and other language disorders, researchers have begun performing longitudinal research studies in hopes of identifying various behavioral markers for ASD (e.g., pointing, language, symbolic play, etc.) at an earlier age in development (Iverson & Wozniak,

2007). One of the most well-known, successful predictors of ASD has been observable deviations in nonverbal communication, such as sparse initiation of, and response to joint attention cues of others, within the first and second years of life (Bhat, Galloway, & Landa, 2012; Charman et al., 2005; Chawarska et al., 2007; Landa et al., 2007; Sullivan et al., 2007; Yoder, et al., 2009).

Children with ASD are typically not diagnosed until at least 3-years-of-age (Plumb & Wetherby, 2013). If behavioral markers can be investigated and earlier identified through the analysis of prelinguistic vocalizations, children with ASD may be diagnosed in a much timelier manner, leading to better outcomes for those affected. Other research (Bhat, Galloway, & Landa, 2012) suggests that motor delays in at-risk infants, including ASD-sibs, may also be useful at detecting ASD at an earlier age in development. In a study conducted by Bhat, Galloway, and Landa (2012), significantly more ASD-sibs demonstrated motor delays at 3- and 6-months, than low risk infants. Additionally, the majority of those ASD-sibs who displayed motor delays at 3- and 6-months also displayed subsequent communication delays at 18-months-of-age.

This study, as well as others, suggests that early signs of ASD may become apparent within the motor system and commence as a motor delay (Bhat, Galloway, & Landa, 2012; Esposito, Venuti, Maestro, & Muratori, 2009; Landa & Garret-Mayer, 2006; Oznoff et al., 2008). Further, motor delays apparent in the first year of life in children at risk for ASD have been examined through retrospective analyses of home videos (Adrien et al., 1993; Oznoff et al., 2008; Teitelbaum, Teitelbaum, Nye, Fryman, & Maurer, 1998). These studies examined atypical movements such as abnormal reflexes or asymmetries, as well as delays in motor movements such as rolling, sitting, and

crawling. Research indicates that early motor development facilitates communication development (Bhat, Galloway, & Landa, 2012).

In relation to vocal development, research has suggested that ASD-sibs, who display difficulties with syllable production early on, acquire early stages of vocal development later than TD-sibs (infants with siblings who are typically developing), and are more likely to display language delays at 18-months-of-age (Iverson & Wozniak, 2007), although no specific data about these differences were provided. Furthermore, in a longitudinal study by Paul and colleagues (2011), ASD-sibs and TD-sibs were followed throughout several visits at the Yale School of Medicine from 6- to 12-months-of-age with a follow-up visit at 24 months. Vocalization samples were collected at 6-, 9-, and 12-months through both standardized and non-standardized measures. The samples were separated into two groups, speech-like or non-speech vocalizations, and transcribed. Results of this study found that, on average, ASD-sibs produced significantly fewer speech-like vocalizations, and more non-speech vocalizations than TD-sibs. Further, ASD-sibs were found to produce, on average, significantly fewer consonant types, and fewer canonical syllable shapes than TD-sibs, particularly at 9-months-of-age (Paul et al., 2011). Results from this study suggest that prelinguistic vocal development is a "sensitive indicator of the rate and degree to which infants at risk for ASD are following the developmental path to language acquisition, and, by extension, to expressive communication" (Paul et al., 2011, p. 9).

Phonetic Transcription and Caregiver Perception

Based on previous research surrounding infant vocal development, it is likely ASD-sibs will produce fewer vocalizations and fewer variations of sounds than TD-sibs

(Paul et al., 2011). In a study exploring detailed aspects of prelinguistic vocal development in ASD-sibs by Paul and colleagues (2011), the primary focus was on traditional phonetic transcription and coding of vocalizations, which included exploration of specific consonants, syllable shapes, and prosodic contours. The traditional method of phonetic transcription does not take the perspectives of caregivers or naturalistic listeners into account when analyzing infant vocal development. While phonetic transcription remains the gold standard for exploring infant vocal development, it is not a valid tool for documentation of infant vocalizations as the International Phonetic Alphabet (IPA) was designed for use with mature speech sounds. Because infants do not produce well-formed speech sounds, infant repertoires are artificially inflated. As a result, researchers are led to believe infants are able to produce many sounds, when in fact they cannot possible produce such sounds in a controlled, consistent manner due to immature development of the anatomical structures involved in speech production. Further, reliability between transcribers is impacted as a result of the transcription not accurately measuring the infant vocalizations. Yet several studies have proven the reliability and effectiveness of caregiver reporters at characterizing children's early language skills, which helps researchers identify developmental concerns earlier (Christensen et al., 2010; Feldman et al., 2005; Heilmann, Weismer, Evans, & Hollar, 2005; Korkman, Jaakkola, Ahlorth, Pesonen, & Turunen, 2004; Määttä et al., 2012; McDuffie & Yoder, 2010; Ramsdell et al., 2012; Wetherby, et al., 2002). In fact, it has been suggested that caregiver report may even be more accurate than standard laboratory measures (Ramsdell et al., 2012). In the case of words produced up to 30-months, (Dale, Dionne, Eley, & Plomin, 2000; Fenson et al., 1991) and the onset of canonical babbling (Oller, Eilers, & Basinger,

2001), parent report is considered reliable. Furthermore, Cameron, Livson, and Bayley (1967) and Lyytinen, Poikkeus, Leiwo, and Ahonen (1996) both assert information reported by caregivers may be used as a predictor of speech development. Yet, existing research on the prelinguistic vocalizations of ASD-sibs lacks the perspective of caregivers and naturalistic listeners.

When analyzing the vocal development of prelinguistic ASD-sibs, the perspectives of caregivers may be more relevant and reliable than phonetic transcription alone (Ramsdell et al., 2012). The International Phonetic Alphabet (IPA) was created for documentation of mature speech sounds, and babies do not produce mature speech sounds. Phonetic transcription of infant vocalizations is, therefore, intrinsically problematic due to the immaturity of infant sounds (Ramsdell et al., 2007). As opposed to older children and adults, whose speech sound productions are mature or more developed and can be transcribed consistently across multiple transcribers.

According to Ramsdell and colleagues (2007), one principle difference between infant and mature vocalizations involves articulatory transitions. Infant vocalizations are often slower in production from consonants to vowels, resulting in slow formant transitions (Oller, 1980). Listeners perceive these immature syllables, with slow transitions, as "slurred, fuzzy, indistinct, or distorted" (Ramsdell, Oller, & Ethington, 2007, p.794). As a result, phonetic transcription is less reliable within and across coders when tracking infant vocalizations that tend to be less canonical, more exotic sounding, and possessing aberrant vocal quality (Ramsdell et al., 2007). Because phonetic transcription provides more variable results of vocal behavior, researchers who rely solely on phonetically coded data may be over representing infant vocal repertoires

(Ramsdell et al., 2012; Ramsdell et al., 2007). Due to the noted differences between immature and mature speech sounds, researchers must compensate for potentially unreliably transcribed infant repertoires, by arbitrarily applying rules to limit the number of sounds attributed to the infants (Ramsdell et al., 2012). For example, researchers have required that a sound occur some minimal number of times in a transcribed vocalization sample before accepting it as part of the infant's repertoire (Rvachew, Creighton, Sauve, & Feldman, 2005; Stoel-Gammon, 1988).

In contrast, caregivers may be able to provide us with a more relevant and ecologically valid means of documenting infant repertoires. Caregiver judgment may offer a reasonable method for analyzing the functional repertoires of prelinguistic infants (Ramsdell et al., 2012), rather than arbitrarily applying rules to limit transcribed repertoire sizes. Caregivers interact with their infants on a daily basis and; therefore, intuitively offer more natural reports about the sounds their infants can produce, while also encouraging semantic growth (Papousek, 1994; Ramsdell et al., 2012; Veneziano, 1988).

For reasons such as these, caregiver reports are useful for assessing and tracking language and communication development (Feldman et al., 2005). Certainly caregivers will not attend to their infants at all times, and they will not remember every sound that their infants produce, but they are likely to report frequently produced (repeated or otherwise salient) sounds. Furthermore, what caregivers perceive their infants to be able to produce will shape how they interact with their infants. If a caregiver believes their infant can say "ba", for example, the caregiver is likely to start stressing words like "bottle," "ball," and "blanket" in interactions (Ramsdell et al., 2012). Therefore,

caregiver perception of infant vocalizations is more functional (less arbitrary) than phonetic transcription of infant vocalizations because it provides a direct link to future speech and language development and future word learning (Ramsdell et al., 2012).

In addition, there is a time versus detail trade-off. While phonetic transcription does provide great detail, it requires specialized training and is very time consuming. In contrast, caregivers, without specialized training, can quickly provide information about their infants' vocal behaviors through questionnaires and interviews with clinicians. Many previous studies have found that caregivers provide reliable reports of developmental milestones (Christensen et al., 2010; Feldman et al., 2005; Heilmann, et al., 2005; Korkman, Jaakkola, Ahlorth, Pesonen, & Turunen, 2004; Määttä et al., 2012; McDuffie & Yoder, 2010; Ramsdell et al., 2012; Wetherby, et al., 2002). Previous studies (Fenson et al., 1991) have found parent report to be accurate and reliable for tracking developing behaviors (O'Neill, 2007).

With detailed reports of infant vocal behavior from caregivers, researchers could draw connections between concerns in communicative development and later speech and language delays. Furthermore, according to preliminary studies, observing infant/caregiver interactions appears to reveal pertinent information about the infant's actual, functional, meaningful vocal abilities (Ramsdell et al., 2012).

Researchers who can successfully obtain caregiver reports are likely to save vital time and resources. Those who implement traditional phonetic transcription methods will invest considerably more time, and potentially need to create arbitrary rules to limit repertoire sizes, transcribe, and analyze the results. Researchers have begun to examine prelinguistic infant vocal behaviors from the perception of caregivers (Ramsdell et al.,

2012), but studies of the same sort, concerning ASD-sibs vocalizations, are lacking. Applying this methodology to a group of infants who are at risk for developing speech and/or language disorders might reveal a means for earlier identification. In order to utilize information gained through this method of data collection, more research is needed to translate findings for clinical relevance (Määttä et al., 2012).

Naturalistic Listeners

Since caregivers are busy people, ensuring the well being of one or more children, it would be useful to have another source for gathering information about infant vocalizations in the research laboratory. If caregiver report can be simulated through a naturalistic listening procedure, then caregivers would not need to be involved in the tracking of vocal development. Through audio recorded interactions with infants in a structured, yet natural environment, the vocal behavior of prelinguistic ASD-sibs can be judged by naturalistic listeners in a manner similar to how caregivers would report the same information. Ramsdell et al. (2012) posited that when untrained listeners are presented with a series of infant vocalizations from a recorded sample, they tend to act like caregivers in that they do not attend to, or remember all of the vocalizations that are presented to them. Subsequently, naturalistic listeners are more likely to report vocal characteristics that are more salient (and therefore, perhaps more functional) in that the sounds were repeated more consistently and were more well formed, or "speech like" (Ramsdell et al., 2012).

Early results have revealed that both caregivers and naturalistic listeners can provide relevant details to assist researchers in determining the prelinguistic phonetic repertoire of infants (Ramsdell et al., 2012). Naturalistic listeners provide methodical

observations of infant communicative behaviors in situations similar to those experienced by caregivers (Pence & Justice, 2008). The naturalistic listening procedure is a simple task, which can be conducted fairly quickly (Ramsdell et al., 2012). As found in the Ramsdell et al. study (2012), naturalistic listeners reported similar results, in terms of repertoire size and prelinguistic phonetic categories, to those reports offered by caregivers. In this study, the listeners were able to recall phonetic details when their judgments were gathered immediately after presentation of audio only files. While this methodology has yet to be performed on a large scale, preliminary studies suggest it may be an appropriate method to assess the babbling repertoire of infants (Ramsdell et al., 2012).

Proposed Study and Research Questions

In summary, this study focuses on the perception of caregivers and naturalistic listeners, rather than standard laboratory measures, including phonetic transcription and acoustic analysis (Warlaumont et al., 2010), when analyzing the vocalizations from both an ASD-sib and an age- and gender-matched TD-sib. Vocalizations from these two infants will be analyzed from 7- through 18-months-of-age in three age groups; early (7 to 10 months), middle (11 to 14 months), and late (15 to 18 months) age groups. The early age group is the time frame in which infants are prelinguistic, or their vocalizations are not yet word like. The late age group is also known as the linguistic stage, or the point in development when infants begin to produce first words. Finally, the middle age group, for the purpose of this study, is considered an "inbetween" stage, where both prelingustic sounds and first words will exist. These age groups are important as they fall into pertinent developmental stages.

Further, we will compare caregiver to naturalistic listener report of infant vocalizations. Accordingly, the following question is posed; from the perspective of caregivers and naturalistic listeners, is there a difference in the vocal characteristics of an ASD-sib and a TD-sib? It is hypothesized that caregiver and naturalistic listener reports will result in attribution of less phonetic variability to the ASD-sib than to the age- and gender-matched TD-sib. If the results support this hypothesis, further research exploring caregiver and naturalistic listener report of ASD-sibs and TD-sibs is warranted. In addition, results of this study may provide pilot data to guide future studies, and ultimately lead to better outcomes for early identification and treatment of atypical patterns in vocal development.

Chapter II: Methodology

Participants

This study includes data collected from a previous study directed by the investigator's faculty mentor, Dr. Heather L. Ramsdell-Hudock. As a way to generate pilot data for future research, participants include two infant/caregiver pairs selected from this previously conducted longitudinal study at East Carolina University (ECU). The archived study included 16 caregiver/infant dyads. The ASD-sib was selected out of convenience, given that he had a sibling with autism. Further, he was the only infant at risk for developing a speech and/or language disorder from the pool of 16 infant participants. Additionally, the TD-sib was selected as an age- and gender-matched peer who had a typically developing older sibling who was also age- and gender-matched with the ASD-sib's older sibling. Each infant had only one older sibling.

Each pair was seen during monthly visits to the ECU Infant Vocal Development Laboratory from 6- to 18-months-of-age, at which time the pair was audio- video-recorded. The selected infants were both Caucasian males with normal births and no significant medical history at the time of the recordings. Each infant was from a middle socioeconomic, English speaking household, with both parents present. The two infants passed full hearing evaluations performed by a licensed audiologist at 6- and 18-months-of-age, including tympanometry, transient evoked otoacoustic emissions, and visual reinforced audiometry.

Procedures and Materials

Caregiver report. Caregivers of both infants provided voluntary informed consent (previously approved through the University and Medical Center Institutional

Review Board at ECU) for their participation in the study. Exemption was sought from the Human Subjects Committee at Idaho State University, as the study purpose was covered in the original consent. Exemption was granted. As part of the larger longitudinal study, interactions between these infant/caregiver pairs were recorded at ECU in monthly intervals in a naturalistic environment, which resembled a nursery. Caregivers completed weekly interviews throughout the duration of the study, over the phone or during recordings at the lab. Caregivers, without any training, were asked questions about the specific sounds and syllable patterns their infants produced. Caregivers were not asked to reproduce infant sounds, rather, they were simply asked, "What sounds/words has your infant been producing since we last spoke?" The intention of this study was to acquire an unbiased, untrained, natural, intuitive response from caregivers in order to measure whether or not those responses relate with our current knowledge of vocal development. Also, the responses from caregivers were compared to sounds that correspond to later speech and language development.

The results of these interviews were documented and translated into numerical data, disclosing the different number of sound types and tokens each infant produced from 7- to 18-months-of-age as perceived by the caregiver. Each caregiver completed a different number of interviews with laboratory staff. As a result, the average number of interviews conducted across all infant age groups was calculated (27.083), and all of the data presented in this study for these two infants has been normalized to account for this average. Graduate and undergraduate students employed in the Infant Vocal Development Lab, trained and under the guidance of Dr. Ramsdell-Hudock, tallied the number of phonetic features reported by caregivers.

Naturalistic listener report. Infant vocalizations were located and individually extracted from 21 of the archived audio files, from each infant at each age range between 7- and 18-months-of-age (minus 3 months where data was not gathered). The extracted utterances were then randomized within their session and merged together into 21 new audio files containing only the infant vocalizations. Each audio file contained randomized utterances from one 20-minute session, with each utterance separated by 1.5 seconds. In doing so, all extraneous audio (e.g. noise from toys, caregivers, and lab staff vocalizations, etc.) was eliminated. Further, vegetative sounds (coughing, burping, hiccups, etc.) were not extracted from the original files and were not played to the naturalistic listeners. After all of the extraneous audio was removed, the new audio files ranged in length from 2 minutes to just over 7 minutes and averaged just over 4 minutes in length. The new audio files contained anywhere from 39 to 215 infant utterances (depending upon infant volubility at the time of the recording), with an average of 172 utterances per session. Overall, naturalistic listeners heard a total of 2,379 infant utterances from the ASD-sib and TD-sib. More specifically, the ASD-sib's utterances ranged from 39 to 215 in the audio files (x = 108.5), with 1,085 total utterances presented. The TD-sib's utterances ranged from 52 to 182 in the audio files (x = 117.6), with 1,294 total utterances presented.

Naturalistic listeners in this study are characterized as naïve listeners, not trained in speech-language pathology, music, or education, who listened to and judged the infant vocalizations from audio- recorded files. Each of the infant-only audio files was presented randomly to two naturalistic listeners (as there were two caregivers), such that the listeners heard a random order of infants and infant ages during the task. After

listening to each session of utterances, the naturalistic listeners responded to the question, "What sounds/words did the infant produce?" The responses from each listener were recorded into an audio recorder.

The length of each listening task depended on the listener's ability to attend to, and make judgments about the vocalizations from each infant. Factors such as listener fatigue, length of recordings, etc. determined how long each listening task ran. Overall, each listener spent approximately 4 hours completing the listening activity. Four laboratory staff members then listened to and transcribed the reports from both naturalistic listeners in order to assess reliability. The transcribed data was then translated into numerical data using the same method performed with caregiver data, implementing the use of graduate and undergraduate students employed in the Infant Vocal Development Laboratory. In doing so, we were able to identify the different number of sound types and tokens each infant produced from 7- to 18-months-of-age as perceived by the naturalistic listeners.

Phonetic Features

- Caregiver and naturalistic listener reports were transcribed separately for each infant at each age. Those results were then compiled such that all reported vocalizations for each infant at each age were analyzed together by both caregiver, and naturalistic listener. In order to accurately classify phonetic features and syllable shapes, each reported multisyllabic vocalization was broken up into syllables based on guidelines for spoken syllabification (French, 1988; Grunwell, 1986; Yavaş, 1998); Single consonant sounds within utterances were considered part of the second syllable

    - With the exception of /ŋ/, which will be grouped with the first syllable;
- A sequence of two consonant sounds within utterances will be divided consonant-syllable break-consonant (C.C),
    - Unless they form an acceptable cluster in American English, in which case they will be considered part of the second syllable; and
- A sequence of three consonant sounds within utterances will be divided C.CC,
    - Unless they form an acceptable cluster in American English, in which case they will be considered part of the second syllable, or
    - Unless the result is an unacceptable combination of sounds in American English, in which case they will be divided CC.C.

For each group of listeners (caregivers and naturalistic listeners), for each infant (the ASD-sib and TD-sib), and for each infant age (early, middle, and late age group), tallies were calculated for the total number of utterances reported, the total number of consonants and vowels in reported utterances, and the number of different syllable shapes. Further, consonant sounds reported were explored in terms of place of articulation (number of labial, coronal, dorsal, and laryngeal consonants), voicing (number of voiced and voiceless consonants), and manner of production (number of stop, fricative, affricate, nasal, liquid, glide, click, and trill consonants). Vowel sounds reported were explored in terms of tongue position (number of high front, low front, central, low back, high back, rising diphthong, and rhotic diphthong vowels). Syllable shapes reported were also explored in further detail.

Research Design

Given the purpose of this project, to explore caregiver and naturalistic listener report of vocalizations produced by an ASD-sib compared to an TD-sib, specifically with respect to the quality and quantity (phonetic makeup) of vocalizations judged, the following questions will be asked. For total number of consonants and vowels, what is the effect of listener (caregiver and naturalistic listener), infant (ASD-sib and TD-sib), and age (early, middle, and late age group)? For total number of syllable shapes, what is the effect of listener, infant, and age? For each level of place (labial, coronal, dorsal, and laryngeal), what is the effect of listener, infant, and age? For each level of voicing (voiced and voiceless), what is the effect of listener, infant, and age? For each level of manner (stop, fricative, affricate, nasal, liquid, glide, click, and trill), what is the effect of listener, infant, and age? For each level of tongue position for vowels (high front, low front, central, low back, high back, rising diphthong, and rhotic diphthong), what is the effect of listener, infant, and age? Therefore, the dependent variable is the number of different phonetic features reported and the independent variables are listener, infant, infant age, and phonetic category.

Chapter III: Results

By exploring the distinctions between caregiver and naturalistic listener perception of infant vocalizations, we can begin to identify the utility of these methods for determining differences in speech production between ASD-sibs and TD-sibs. Results are reported below to review the differences in the phonetic features of each infant's vocalizations. As expected, based on reports from caregivers and naturalistic listeners, the ASD-sib in this study was overall less vocal than the TD-sib in both type and token of sounds produced. The caregivers reported vast differences between the two infants with many of the same differences being identified by naturalistic listeners. While naturalistic listeners did not simulate caregiver judgments across all areas of inspection, there were consistent differences in several phonetic features across infants. The differences found were observed across each age grouping.

Caregiver Report

Both caregivers in this study reported differences in vocalizations between the two infants. First, as seen in Table 1a, when considering the number of utterances reported, the ASD-sib caregiver reported fewer utterances when compared to the TD-sib caregiver. Further, the number of utterances reported by the caregiver for the ASD-sib did not increase from the early age group to the middle age group; however, there was an increase from the early age group to the late age group. In contrast, the TD-sib displayed clear increases in the number of utterances produced as he transitioned from the early prelinguistic age group (7 to 10 months) to the later linguistic age groups (11 to 14 months and 15 to 18 months). The TD-sib's caregiver reported a consistent increase in the number of utterances, number of consonants, number of vowels, and number of

syllable shapes reported across age groups, which is to be expected of a typically developing infant.

Table 1a. Phonetic features of caregiver report.

Infant	Infant Age (in Months)	# of Utterances Reported	# of Consonant Tokens	# of Vowel Tokens	# of Syllable Shapes
TD-sib	7 to 10	24.826	29.340	30.845	21.817
	11 to 14	20.313	30.469	27.083	15.234
	15 to 18	44.010	64.323	60.938	33.854
ASD-sib	7 to 10	24.006	27.083	30.777	21.544
	11 to 14	43.164	67.708	66.862	37.240
	15 to 18	85.764	136.545	103.819	83.507

When considering place of articulation and voicing for consonant tokens (see Table 1b), the ASD-sib was found to produce primarily voiced labial sounds, as reported by the caregiver. Again, there were some inconsistencies across infant age for the ASD-sib reports. The only gradual increase reported was for labial consonants. Furthermore, the ASD-sib caregiver reported few, if any voiceless consonants across all age groups. The TD-sib caregiver, on the other hand, reported consistent increases across infant age for labial, coronal, dorsal, and laryngeal consonants. For the TD-sib, labial sounds were reported most often in the early age group, labial and coronal sounds were reported equally in the middle age group, and coronal sounds predominated place of articulation in the late age group. The TD-sib caregiver also reported more voiced productions overall, and increases in both voiced and voiceless consonant productions across the age groups.

Table 1b. Phonetic features of caregiver report.

Infant	Infant Age (in Months)	Place of Articulation for Consonant Tokens				Voicing for Consonant Tokens	
		Labial	Coronal	Dorsal	Laryngeal	Voiced	Voiceless
TD-sib	7 to 10	12.789	11.285	3.762	1.505	27.836	1.505
	11 to 14	22.005	8.464	0.000	0.000	30.469	0.000
	15 to 18	27.083	23.698	13.542	0.000	64.323	0.000
ASD-sib	7 to 10	19.081	0.616	5.540	1.847	25.852	1.847
	11 to 14	23.698	22.005	15.234	6.771	38.932	28.776
	15 to 18	38.368	68.837	20.313	7.899	71.094	62.066

Next, when examining results from caregiver reports regarding manner of production for consonant tokens (see Table 1c), both infants appeared to produce

primarily stops, especially in the early age category. However, the TD-sib's productions appeared to be more sophisticated than the ASD-sib, as the TD-sib was reported to produce fricatives, affricates, nasals, liquids, and glides with consistent increases across all age groups. Aside from stops, the ASD-sib was reported to produce nasal sounds with a gradual increase across age. Other consonant types were either not reported, or did not display a consistent increase as the infant developed.

Table 1c. Phonetic features of caregiver report.

Infant	Infant Age (in Months)	Manner of Production for Consonant Tokens							
		Stop	Fricative	Affricate	Nasal	Liquid	Glide	Click	Trill
TD-sib	7 to 10	12.789	1.505	0.000	7.523	0.752	6.019	0.000	0.752
	11 to 14	20.313	0.000	0.000	8.464	0.000	0.000	0.000	1.693
	15 to 18	33.854	0.000	0.000	20.313	0.000	10.156	0.000	0.000
ASD-sib	7 to 10	17.235	1.847	0.000	4.309	0.616	2.462	0.000	0.000
	11 to 14	44.010	10.156	0.000	9.310	0.846	3.385	0.000	0.000
	15 to 18	74.479	22.569	6.771	22.569	1.128	7.899	0.000	1.128

Caregiver report continued to reveal differences between the two infants when examining reported vowel productions (see Table 1d). While both infants were reported to produce mostly low back vowels, the TD-sib was reported to produce a variety of vowel types that the ASD-sib was not reported to use. For instance, the TD-sib was reported to produce rising diphthongs, which increased in production as the infant progressed from one age group to the next. However, the ASD-sib was not reported to produce any rising diphthongs, and high back vowels were only reported in the early age group. High front, low front, central, high back, and rhotic diphthong vowels did not

Table 1d. Phonetic features of caregiver report.

Infant	Infant Age (in Months)	Tongue Position for Vowel Tokens						
		High Front	Low Front	Central	Low Back	High Back	Rising Diphthong	Rhotic Diphthong
TD-sib	7 to 10	1.505	6.771	8.275	12.037	2.257	0.000	0.000
	11 to 14	0.000	0.000	3.385	22.005	0.000	0.000	1.693
	15 to 18	3.385	16.927	3.385	37.240	0.000	0.000	0.000
ASD-sib	7 to 10	1.847	1.231	6.155	16.619	0.000	4.309	0.000
	11 to 14	15.234	8.464	8.464	22.852	2.539	9.310	0.000
	15 to 18	18.056	10.156	14.670	21.441	9.028	29.340	1.128

display any consistent increases across all three age groups (only in the late age group) as the ASD-sib matured although low back did increase with age.

With respect to reported syllable shapes (see Table 1e), results were similar to other phonetic features. The TD-sib was reported to produce a variety of syllable shapes with clear increases across age groups for most syllable shapes. The vowel only syllable shapes gradually decreased for the TD-sib, which is to be expected as the infant matures and begins to produce more complex syllable shapes. The majority of the TD-sib's syllable shapes were consonant-vowel-consonant (CVC) in form. Typically developing infants are expected to increase the production of CVC shapes as they mature. The ASD-sib, on the other hand, was not reported to produce any CVC, vowel-consonant (VC), or vowel-consonant-vowel (VCV) syllable shapes. The majority of syllable shapes reported for the ASD-sib were consonant-vowel-consonant-vowel (CVCV) in shape. There was a consistent increase in production across age for CVCV shapes.

Table 1e. Phonetic features of caregiver report.

Infant	Infant Age (in Months)	Syllable Shapes							
		V	CV	VC	CVC	VCV	CVCV	CVCVCV	Other
TD-sib	7 to 10	4.514	11.285	0.000	0.000	0.000	3.009	3.009	0.000
	11 to 14	1.693	1.693	0.000	0.000	0.000	11.849	0.000	0.000
	15 to 18	6.771	6.771	0.000	0.000	0.000	13.542	6.771	0.000
ASD-sib	7 to 10	6.155	8.617	0.000	0.000	0.000	4.924	1.231	0.616
	11 to 14	4.232	11.003	1.693	4.232	2.539	7.617	3.385	2.539
	15 to 18	3.385	21.441	5.642	30.469	3.385	10.156	0.000	9.028

Caregiver report is normalized according to number of interviews conducted.

Naturalistic Listener Report

The naturalistic listeners in this study also reported differences in vocalizations across the two infants. When considering the phonetic features reported by naturalistic listeners, again the TD-sib displayed clear increases in production of utterances, consonants, vowels, and syllable shapes across age (see Table 2a). In contrast, the naturalistic listener reports did not reveal sequentially incremental increases across all

three age groups in the number of utterances, consonants, or syllable shapes produced by the ASD-sib (with the exception of a slight increase in the number of vowels produced across age for the ASD-sib).

Table 2a. Phonetic features of naturalistic listener report.

Infant	Infant Age (in Months)	# of Utterances Reported	# of Consonant Tokens	# of Vowel Tokens	# of Syllable Shapes
TD-sib	7 to 10	16.250	15.750	25.125	10.500
	11 to 14	15.625	22.625	25.750	11.500
	15 to 18	17.500	21.125	30.375	10.625
ASD-sib	7 to 10	22.375	32.625	31.375	11.875
	11 to 14	26.625	42.000	34.000	14.000
	15 to 18	31.875	50.875	50.625	20.625

Next, the place of articulation and voicing for consonant tokens was compared for each infant across age groups (see Table 2b). The naturalistic listeners did not report consistent increases for either infant, with the exception of voicing. The TD-sib was reported to produce increases in both voiced and voiceless consonant productions. The ASD-sib was reported to produce increases in voiced and voiceless consonant productions; however, unlike the TD-sib, the increases were not sequentially incremental.

Table 2b. Phonetic features of naturalistic listener report.

Infant	Infant Age (in Months)	Place of Articulation for Consonant Tokens				Voicing for Consonant Tokens	
		Labial	Coronal	Dorsal	Laryngeal	Voiced	Voiceless
TD-sib	7 to 10	2.375	4.125	1.375	7.875	6.750	8.875
	11 to 14	3.375	6.625	8.375	4.125	18.000	4.500
	15 to 18	4.500	4.875	7.125	4.625	13.875	7.375
ASD-sib	7 to 10	15.500	6.000	2.500	8.500	23.625	8.875
	11 to 14	9.375	16.125	14.375	1.875	26.875	15.000
	15 to 18	16.750	16.875	6.125	11.375	27.250	23.875

When examining the manner of production for consonant tokens across each infant, very few consistent increases were reported (see Table 2c). The ASD-sib was reported to produce a gradual increase in glides. The TD-sib reportedly produced gradual increases in nasals, glides, and trills. Further, the ASD-sib produced mostly fricatives in the early age group, stops and glides in the middle age group, and fricatives and glides in

the late age group. The TD-sib consistently produced mostly stops across all age groups, which is to be expected of a child his age.

Table 2c. Phonetic features of naturalistic listener report.

Infant	Infant Age (in Months)	Manner of Production for Consonant Tokens							
		Stop	Fricative	Affricate	Nasal	Liquid	Glide	Click	Trill
TD-sib	7 to 10	5.500	7.750	0.000	2.000	0.125	0.375	0.000	0.125
	11 to 14	7.250	4.375	0.000	2.500	1.000	6.875	0.000	0.500
	15 to 18	4.500	7.375	0.000	0.375	1.625	7.000	0.000	0.250
ASD-sib	7 to 10	14.000	7.250	0.000	4.000	4.875	1.750	0.125	0.625
	11 to 14	23.250	6.375	0.500	5.500	3.875	1.125	0.000	1.125
	15 to 18	20.875	12.875	0.125	8.750	2.500	4.375	0.000	1.375

Similar to manner of production for consonant tokens, tongue position for vowel token productions reported by naturalistic listeners yielded very few consistent increases (see Table 2d). The ASD-sib was not found to produce any increases in vowel productions across age groups, while the TD-sib reportedly increased low front and high back vowel productions as he matured. Overall, the ASD-sib and TD-sib were reported to produce mostly low back vowels across all age groups.

Table 2d. Phonetic features of naturalistic listener report.

Infant	Infant Age (in Months)	Tongue Position for Vowel Tokens						
		High Front	Low Front	Central	Low Back	High Back	Rising Diphthong	Rhotic Diphthong
TD-sib	7 to 10	2.375	2.625	4.375	9.750	2.000	3.875	0.000
	11 to 14	0.625	2.375	6.375	12.750	0.625	2.875	0.125
	15 to 18	5.125	2.250	3.000	11.000	2.875	6.000	0.125
ASD-sib	7 to 10	1.250	0.875	6.875	18.750	1.750	1.500	0.000
	11 to 14	6.625	2.000	6.000	8.625	3.750	6.750	0.000
	15 to 18	5.250	4.500	9.500	15.250	6.375	9.625	0.375

In regard to syllable shape (see Table 2e), consistent increases in the quantity of CVs produced by the ASD-sib and of CVCs produced by the TD-sib were seen across age groups.

Table 2e. Phonetic features of naturalistic listener report.

Infant	Infant Age (in Months)	Syllable Shapes							
		V	CV	VC	CVC	VCV	CVCV	CVCVCV	Other
TD-sib	7 to 10	7.125	1.750	1.125	0.500	0.875	0.625	1.000	2.375
	11 to 14	3.375	3.375	0.375	0.125	0.875	0.750	1.125	3.500
	15 to 18	6.750	3.875	0.625	0.000	0.500	0.250	0.500	3.375
ASD-sib	7 to 10	2.250	6.625	0.500	0.250	1.625	2.625	1.250	3.250
	11 to 14	2.250	8.125	0.750	3.875	0.250	3.750	0.500	5.000
	15 to 18	4.875	7.125	0.750	4.250	1.375	2.625	0.375	8.625

The ASD-sib was reported to produce mostly Vs in the early age group, Vs and CVs in the middle age group, and Vs again in the late age group. Conversely, the TD-sib was reported to produce mostly CVs across all age groups.

The data presented in Table 2a-2e are collapsed across each of the two naturalistic listeners, and each of the four transcribers of the naturalistic listener reports. Paired samples *t* tests showed that similar results were found across judgments made by each naturalistic listener and all transcribers. For example, paired samples *t* tests that compared naturalistic listener reports for the total number of utterances judged across age groups showed no significant differences in the early age group [listener one (*M*=6.375, SD=9.188) and listener two (*M*=5.469, SD=1.879), *t*(3)=0.905, p = 0.432]; minimal differences in the middle age group [listener one (M=8.313, SD=12.099) and listener two (*M*=6.594, SD=7.973), *t*(3)=4.654, *p* = 0.019]; and no differences in the late age group [listener one (*M*=6.844, *SD*=4.296) and listener two (*M*=5.500, *SD*=0.177), *t*(3)=1.575, *p* = 0.213]. Paired samples *t* tests that compared transcribers 1 and 2 on the total number of utterances transcribed for listener report showed no significant differences in the early age group [transcriber one (*M*=5.500, *SD*=3.667) and transcriber two (*M*=5.688, *SD*=2.474), *t*(3)=-0.792, *p* = 0.486]; the middle age group [transcriber one (*M*=7.563, *SD*=10.682) and transcriber two (*M*=7.438, *SD*=11.016), *t*(3)=0.522, *p* = 0.638]; and the late age group [transcriber one (*M*=6.250, *SD*=1.667) and transcriber two (*M*=6.438, *SD*=1.932), *t*(3)=-0.878, *p* = 0.444].

Cross-study Comparison

Caregivers in this study were asked to report on all sounds they heard their infants produce in the infants' natural environment, while naturalistic listeners were asked to

report on only sounds we played to them without the ability to visualize the infants as they interacted with their caregivers, which was a much smaller data set. While a statistical analysis could not be performed across these data sets due to the listeners being exposed to different sounds, we did explore the similarities and differences of descriptive statistics between caregiver and naturalistic listener report across both infants. As expected, naturalistic listeners and caregivers reported similar changes in the vocal characteristics of both infants. The reports were similar in that both listeners reported the TD-sib to produce more types and tokens than the ASD-sib. Both sets of listeners reported the TD-sib to produce more utterances, consonants, vowels, and syllable shapes than the ASD-sib. Furthermore, both sets of listeners reported the TD-sib to produce more voiced and voiceless consonants, as well as more labial, coronal, and laryngeal consonants than the ASD-sib across most age groups. The ASD-sib was also reported to produce fewer stops, fricatives, affricates, nasals, and liquids than the TD-sib, especially in the later age group.

The naturalistic listeners typically reported fewer tokens then caregivers across all categories, which is to be expected given this set of listeners was reporting on a smaller data set. However, there were instances when caregivers reported few to no tokens in certain categories and naturalistic listeners did report tokens. When examining reports of syllable shapes from both listeners, interestingly, both caregiver and naturalistic listeners reported no CVC productions for the ASD-sib in the late age group. This is especially critical considering research in normal vocal development suggests infants begin producing “word-like” utterances between 15- and 18-months-of-age.

Chapter IV: Conclusions

As mentioned in the review of literature, when compared to typically developing infants, ASD-sibs are at a significantly higher risk for developing ASD or other developmental delays (Iverson & Wozniak, 2007; McDuffie & Yoder, 2010; Paul et al., 2011; Yoder et al., 2009; Zwaigenbaum et al., 2005). The study of prelinguistic vocalizations is important for the purpose of identifying atypical vocal characteristics in at-risk populations, such as ASD-sibs. The traditional method of analyzing infant vocal development is phonetic transcription (Ramsdell et al., 2012). The International Phonetic Alphabet was not designed for use with prelinguistic utterances, but rather for mature, well-developed sounds and words. Caregivers, and more recently naturalistic listeners, have been used in research to help track the earliest vocal repertoires typically developing infants (Ramsdell et al., 2012). The use of caregivers and naturalistic listeners may be a more functional, valid tool to analyzing infant vocal development than traditional methodology, but more research needs to be conducted.

The primary purpose of this research was to examine the similarities and differences between caregiver and naturalistic reports in the study of prelinguistic vocal development in two infants, one who was at risk for developing ASD. In doing so, researchers may begin to shift away from more traditional approaches to analyzing vocal development, to more functional and representative methods, implementing the perspectives of caregivers and naturalistic listeners. The new methodology used in this pilot study was able to identify differences in the vocal development between the two infant participants. Both the caregiver and naturalistic listener report demonstrated clear differences between the ASD-sib and the TD-sib across all age groups. The TD-sib

reports indicated the infant's repertoire was developing appropriately, while the ASD-sib reports indicated fewer utterances produced as well as an underdeveloped repertoire compared to the TD-sib. In follow-up interviews with caregivers, researchers discovered that the ASD-sib had not yet produced any words at age 2 and was receiving language and play therapy. A more detailed study of his data and current status, with cooperation of the parents, is ongoing.

The findings suggest important implications for future research in prelinguistic vocalizations; caregiver and naturalistic listener perspective may lead to new methods for identifying early behavioral markers for infants at risk for ASD to be used in clinical practice.

Caregiver Report

As the results from this study indicate, caregivers appear to be capable of reporting infant vocal characteristics, suggesting caregiver report is perhaps a more valid tool than phonetic transcription when comparing the perceptions offered by caregivers to guidelines of typical infant vocal development. Reports from the TD-sib caregiver appear to form a link with what we would expect given results from Stoel-Gammon (1985). First of all, stops, nasals, and glides appeared in development earlier than fricatives and liquids. In addition, labial and coronal sounds appeared earlier than dorsal and laryngeal sounds. Further, voiced sounds appeared predominantly before voiceless sounds. For vowel sounds, it has been found that front and central, as opposed to high and back vowel-like sounds are produce earlier in development (Chen & Irwin, 1946; Davis & MacNeilage, 1990; Irwin, 1945, 1946, 1947a, 1947b, 1948, 1951; Irwin & Chen, 1946; Kent & Bauer, 1985; Winitz & Irwin, 1958), and caregivers reported accordingly

for the TD-sib. With respect to syllable shapes, especially during the later babbling periods, open syllables are the most common (Kent & Bauer, 1985), and again this was present in caregiver report of the TD-sib's vocalizations.

Paul and colleagues (2007) argued a valid point; caregivers are often not attuned to the vocal features that their infants produce, like specific consonants or syllable types. Most caregivers are not trained to recognize or differentiate between speech sounds. While we are aware of this potential confound, we do not need caregivers to be able to identify and distinguish between the intricacies of phonetic features. Instead, we rely on intuitive reports from caregivers and naturalistic listeners of sounds they perceive the infant to produce, and from their report we are able to extract phonetic details ourselves.

Of course caregiver report, like many other assessment methods, is subject to errors of recall and bias. Both caregivers and naturalistic listeners were asked to report on specific sounds and words from memory. Responding to the question, 'what sounds or words is your infant producing' requires caregivers to rely on recall and knowledge of the possible variety of sounds that could be made, or that something they hear from the infants is even considered a sound. Further, caregivers naturally want to report positively, which may result in bias, or artificially inflated repertoires. However, even with potential for errors in recall and bias, caregivers are likely to report information that is more salient because they are not able to remember every detail. Presumably it is the salient infant vocalizations that guide caregiver/infant interaction and shape language development and word learning.

Naturalistic Listener Report

While the use of naturalistic listeners for this specific purpose has only been carried out in one prior study (Ramsdell et al., 2012), results from this pilot study suggest naturalistic listeners are able to replicate the reports of caregivers to some extent. Similar to caregivers, naturalistic listeners were asked to respond to the question, 'what sounds or words did the infant produce' which relies on immediate recall without visual input or cues about the type of context in which the interactions took place. Anecdotally, naturalistic listeners found the task to be quite challenging; yet, they were able to report specific details about the sounds each infant produced, even after listening to sessions up to 7-minutes in length. However, it is possible that adaptations could be made to further enhance the effectiveness of this method, because the procedure is new.

For the TD-sib, the naturalistic listeners reported a natural progression in language development similar to what we would expect when compared to results from Stoel-Gammon (1985). For example, the TD-sib produced stops prior to production of fricatives. Additionally, the TD-sib produced labials prior to laryngeal sounds. Further, voiced sounds appeared predominantly before voiceless sounds. The TD-sib was reported to produce primarily low back and central vowels prior to rising diphthongs. With respect to syllable shapes, especially during the later babbling periods, open syllables are the most common (Kent & Bauer, 1985), and again this was present in naturalistic listener report of the TD-sib with the infant progressing from CV to CVC and other syllable shapes.

On the other hand, naturalistic listeners reported much different productions for the ASD-sib. For instance, the ASD-sib reportedly produced far more fricatives than

stops, and more laryngeal and coronal sounds than labials. The ASD-sib produced similar vowel productions when compared to the TD-sib. However, syllable shapes were mostly limited to vowel only sounds.

Similar to caregiver report, naturalistic listener report is subject to errors of recall. However, errors of bias are reduced in this task. Responding to the question, 'what sounds or words did the infant produce' requires listeners to rely on immediate recall. This can be a difficult task, especially for longer files. Just as caregivers are likely to report information that is more salient, naturalistic listeners are likely to do the same because they are not able to remember every detail from each session. Rather, the listeners, using only auditory input, are more likely to remember sounds or words that were repeated, sound more word-like, and convey some type of meaning.

ASD-sib versus TD-sib vocalizations

When comparing the productions between the ASD-sib and the TD-sib, both caregivers and naturalistic listeners reported differences for this dataset. Overall, the ASD-sib produced fewer consonants and vowels than the TD-sib. Further, the number of productions did not consistently increase as the ASD-sib matured, which is atypical. The TD-sib's productions increased on a consistent basis between age groupings, suggesting normal vocal development. The ASD-sib also produced fewer syllable shapes, which were mostly limited to CV and vowel only productions. When comparing the reports the vowel productions of the ASD-sib and the TD-sib between the caregivers and naturalistic listeners, there were notable differences. The caregiver reported many CV productions, while the naturalistic listeners reported twice as many vowel only syllable shapes than CV syllables. This difference may be attributed to caregiver bias error, or over reporting.

Conversely, both the caregiver and naturalistic listeners reported the TD-sib to produce a variety of syllable shapes, with twice as many CV productions than vowel only productions. Additionally, the TD-sib's syllable shapes increased both in number and complexity as he transitioned between age groups, while the ASD-sib did not display a clear increase. It is also important to address the differences we discovered between the two caregiver reports may be attributed to individual differences. For instance, perhaps the TD-sib caregiver is more attentive than the ASD-sib caregiver. However, this is unlikely given what we know about the continued development of these two infants. The ASD-sib is currently receiving speech and language intervention, which leads us to believe, the differences we found in the intuitive reports rendered by caregivers were clearly evident.

When considering place of articulation, the ASD-sib's productions were unusual in that the caregiver reported nearly equal productions for labial and coronal sounds. Further, the caregiver reported laryngeal sounds in the early stage, but none in the middle or late stages. Reports of voicing from the caregiver were also unusual in that there were no voiceless sounds in the mid and late age groups. The naturalistic listener report was very different than the caregivers, in that naturalistic listeners consistently underreported. However, since caregivers are reporting on a much larger data set and are more familiar with their own infant's productions, we expect their reports to be much larger than those offered by naturalistic listeners. Additionally, the naturalistic listeners reported the ASD-sib to produced fewer labials than any other sound (laryngeal, dorsal, and coronal) and more voiceless than voiced productions in the early age group with no clear increases. On the other hand, the caregiver and naturalistic listener reports for the TD-sib were

comparable, both reporting mostly labial productions with clear increases, which is developmentally appropriate. As the TD-sib transitioned to the mid to late age groups, his coronal productions increased, and his voiced productions continued to be greater than voiceless productions.

When considering manner of production, the differences between the ASD-sib and the TD-sib were notable. First, the TD-sib produced more than 3 times the amount of stops as the ASD-sib across both age and listener. While the caregiver reported very few fricatives for the ASD-sib, the naturalistic listeners reported fricatives as the most frequently produced sound.

Finally, when considering tongue position for vowel productions, both infants reportedly produced mostly low back and central vowels across age and listener.

Further Limitations

One possible limitation to this study is that we did not explore phonetic transcription of the vocalizations, the traditional methodology used when analyzing infant vocal development. In other words, transcribers were not asked to listen to and transcribe all of the audio files presented to the naturalistic listeners. If phonetic transcriptions from both infants were available, we would have been able to compare, utterance for utterance, the similarities and differences between the two infants. We would also have been able to consider the validity of caregiver reports. Given the nonfunctional nature of the transcription task with respect to tracking vocal development, we expect the repertoires would have been much larger and less representative than those offered by caregivers and naturalistic listeners.

Another limitation is that the caregivers and naturalistic listeners reported on two separate datasets. Caregivers referred to their total knowledge of what vocalizations their infant was producing based on hundreds or thousands of hours of interaction and listening, while naturalistic listeners in the laboratory reported on a smaller sample of the infants' vocalizations taken from only 20 minute recording sessions across the 7- to 18-month age range. Despite this difference, the naturalistic listening task appears to simulate caregiver report to some degree. In other words, both caregivers and naturalistic listeners are reporting somewhat similar information about infant vocalizations across infants and infant ages. However, the rationale for presenting randomized audio files to the naturalistic listeners in this study may not be valid. The audio files were randomized to prevent the naturalistic listeners from becoming too familiar with the vocalizations of the two infants. This concern is not valid given the fact that caregivers become familiar with the sounds their own infants produce. Since the goal of the naturalistic listening task is to simulate caregiver report, we want the tasks to be as similar as possible. Therefore, the decision to randomize the audio files is a limitation in this study and should be addressed accordingly in future research.

Another consideration is the small sample size used in this study. A larger sample size would yield more valid, reliable results. For the purpose of this case study, the sample size of 2 was sufficient to observe differences in the phonetic makeup of the sounds reported. Given that the results from this case study support the hypothesis that caregiver and naturalistic listener reports result in attribution of similar types of phonetic variability to the ASD-sib than to the age- and gender-matched TD-sib, further research exploring caregiver and naturalistic listener report of ASD-sibs and TD-sibs is warranted.

In addition, results of this study provide pilot data to guide future studies, and ultimately may lead to better outcomes for early identification and treatment of atypical patterns in vocal development.

Future research should focus on a larger, more representative sample size, include phonetic transcription as a means of comparing new and traditional methodologies, and reconfigure the naturalistic listening task to enhance the comfort level of listeners. Additionally, given the results of Plumb and Wetherby's recent study (2013), children with ASD produce significantly more distress vocalizations than typically developing peers. These results may reflect the difficulties children with ASD experience with emotional regulation. As a result, future research should also consider investigation of specific distinguishing features between ASD-sibs and TD-sibs, such as eye gaze direction, vocal quality (e.g., noting distressed vocalizations as indicated by increased intensity or pitch), and facial affect.

Perhaps the most noteworthy consideration that needs to be made is the naturalistic listening/caregiver paradigm. Given the fact that these two sets of listeners reported on two very different data sets, it is hard to validate the effectiveness of this methodology. However, this study was meant to simply explore the use of these new methodologies. While we cannot generalize these results to the population, we can explore possible ways to improve the tasks and offer those considerations to future researchers. A few changes could be made to improve the paradigm used in this study.

First, future researchers could consider including video interactions of the caregiver/infant interactions. Although, this change would still present problems since the listeners would still be reporting on different, more limited data sets. Also, the

naturalistic listening task would become even more tedious, which is one reason we proposed to eliminate the phonetic transcription task.

Secondly, it might be useful to provide phonetic training to caregivers and naturalistic listeners. By training the listeners, researchers would change the types of questions from intuitive report questions to asking questions about specific phonetic features. However, it is unlikely that caregivers and naturalistic listeners would be willing to undergo adequate training in phonetics sufficient enough for research review.

Lastly, it may be interesting for future researchers to consider allowing the caregivers to also be naturalistic listeners. In other words, caregivers would agree to come into the lab and perform recorded interactions with their infants, but also perform the naturalistic listening task on extracted utterances from their own infant, or from a number of other infant participants. Implementing this change may save researchers valuable time and resources while also ensuring that the two listening tasks are similar enough to establish concurrent validity.

Clinical Implications

Results of the current investigation of early vocalizations produced by an ASD-sib and a typically developing age-matched peer between ages 7- and 18-months offer potential clinical implications for earlier identification of speech and language concerns, as well as earlier intervention services. Both caregivers and naturalistic listeners reported differences in the vocal development of the ASD-sib and the TD-sib, allowing us to draw conclusions about the difference we observed from their reports. When comparing the reports of both caregivers, and naturalistic listeners, the ASD-sib was found to produce fewer utterances then the TD-sib. These findings suggest ASD-sibs are less likely to

engage in vocal exploration. Vocal play allows for social exchanges between infants and caregivers and also facilitates language and development. In other words, these at-risk infants are less likely to practice producing a variety of age appropriate sounds. Inevitably, less vocal practice may lead to less social interaction and delayed vocal development.

More importantly, the purpose of this study was to, ideally, explore the use of new methodology in analyzing infant vocal development. Rather than exploring the vocal development of these two infants employing traditional phonetic transcription, we focused on validating the effectiveness of caregivers and naturalistic listeners. If future studies can apply these methodologies to a larger sample size, employing the recommendations we have made to improve the naturalistic listening/caregiver paradigm, we believe the use of these listeners will replace the tedious nature of analyzing infant vocal development. If researchers are afforded a more functional, representative report of infant vocal behavior, they will potentially be able to identify potential behavioral markers of at risk populations. The ability of caregivers and naturalistic listeners to correctly report details about the vocal productions of ASD-sibs is incredibly important for clinical application. These types of listeners offer insightful information about the vocal characteristics of at-risk populations, which may lead to earlier identification of speech and language concerns.

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