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TRANSCRIBER, CAREGIVER, AND NAIVE LISTENER REPORT OF INFANT VOCALIZATIONS:

TOWARD IDENTIFICATION OF PRELINGUISTIC MARKERS FOR AUTISM

by

Leslie A. Clarke

A thesis

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Committee Approval

To the Graduate Faculty:

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RE: Your application dated 5/27/2014 regarding study number 4104: Transcriber, Caregiver, and Naturalistic Listener Report of Infant Vocalizations

Dear Ms. Clarke:

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 Tom Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

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Human Subjects Chair

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List of Abbreviations

ASD – Autism spectrum disorder

ASD-sib – Later-born sibling of a child diagnosed with an autism spectrum disorder

TD-sib – Later-born sibling of a typically developing child

Abstract

The purpose of this case study is to explore caregiver, naïve listener, and transcriber report of vocalizations produced by a later born sibling of a child with autism compared to an age- and gender-matched peer with a sibling who is typically developing. Specifically, will the quality and quantity of phonetic features in vocalizations judged vary dependent upon listeners and/or infants? Transcription is the traditional method of recording and tracking infant vocalizations, but current research is exploring the validity and functionality of caregiver and naive reports. All listener reports attributed more phonetic variability to the infant with a sibling who is typically developing than to the infant with a sibling who has autism. Further, the caregiver reports more efficiently identified discrepancies between the infant inventories, perhaps given the functional nature of this method.

Introduction

Autism spectrum disorders (ASD) are present in just over 1% of the population and are characterized by social and communication deficits (American Psychiatric Association, 2013), as well as a rigid dependency on routines, and restricted interest patterns (Ouellette-Kuntz *et al.*, 2013; Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011; Zwaigenbaum *et al.*, 2007). Currently, the average age for a child to be diagnosed with autism is 4 years (Centers for Disease Control and Prevention, 2010). Children may be diagnosed with ASD as young as 2 years of age, yet research has indicated that behavioral characteristics of ASD can be identified at a younger age (Watson, Baranek, Crais, Reznick, Dykstra, & Perryman, 2007; Zwaigenbaum *et al.*, 2007). Identifying children with ASD during the critical period of development between 6 and 18 months of age would be advantageous for the child and the family because prognosis for speech and language may improve with earlier intervention (Hebbeler *et al.*, 2007). Early identification of ASD is a current focus of research aiming to facilitate effective intervention tactics and family counseling during critical infant and toddler developmental periods (Hebbeler, 2009).

Prelinguistic Markers for Autism

Currently researchers are seeking to measure and credibly pinpoint prelinguistic behaviors of children with ASD in order to identify earlier predictors for diagnosis. Some researchers even propose that it is plausible to identify a child with ASD as young as 12 months of age by relying on a parent-based questionnaire as a screener (Watson *et al.*, 2007). Smith, Mirenda, and Zaidman-Zait (2007) conducted a study to explore future

vocabulary and language outcomes in children with ASD by examining their variability of expressive vocabulary development as a possible predictor while considering chronological age, developmental level, autism severity, and early language skills. The study included 35 children with autism ranging in age from 1; 8 to 5; 7 years. Prior to initiation of intervention, and then three more times over the course of 2 years, the developmental status and autism severity of these children were assessed in their homes. In each of the four assessments, early language development, imitation skills, and use of gestures were measured by parent report via the *MacArther-Bates Communicative Development Inventory* (Fenson *et al.*, 1991). After 2 years of data collection, the investigators separated the participants into four clusters based on their progress in expressive vocabulary: the first cluster had either no improvement in vocabulary or only a slight increase, the second cluster had a slow rate of vocabulary growth, the third cluster had a high steady increase in vocabulary, and the fourth cluster had a very steep increase of vocabulary growth. Smith and colleagues (2007) reported that verbal imitations, use of objects to pretend, and initiating joint attention significantly correlated with expressive vocabulary growth. These behaviors, then, are factors in the prognosis for later vocabulary development in children with ASD. This study supports the value of using caregiver report in tracking vocal development and also the importance of the caregiver's perceptions in interactions with their infants.

In the search for behavioral markers that may identify ASD at a younger age, prelinguistic behaviors of infants must be considered. Among the variety of characteristics associated with ASD, hypo- and hypersensitivities, reduced affective

expression, and delays in communication and social behaviors are some of the more salient symptoms. While other indicators play a role in arousing concern, a delay in speech and language is what most commonly prompts parents and caregivers to seek professional advice about their child (Chawarska *et al.*, 2007; De Giacomo & Fombonne, 1998). Just as speech and language delays in children with ASD are a salient prompt for concern in caregivers, irregular prelinguistic behaviors such as a lack of canonical babbling, or reduced babbling in general, and other irregular, non-speech like vocalizations should indicate a red flag for possible diagnosis of ASD (Paul *et al.*, 2011).

Oller and colleagues (2010) explored the use of automated analysis to measure early speech development in children with autism by collecting and analyzing 1,486 day-long recordings of 232 children in their homes to determine if an automated system could be constructed to identify autism from acoustic data. Speech-related child utterances (SCUs) were further divided into speech-related vocal islands (SVIs). SCUs were the child's utterances identified by the software excluding cries and vegetative sounds. SVIs were the salient syllables extracted from the SCUs. The software analyzed the SVIs on 12 acoustic features related to rhythm/syllabification, vocal quality characteristics, and syllable duration. The results indicated that the software reliably identified autism, with respect to the 12 acoustic features, as children with autism exhibited a poor correlation between SVI and SCU. These findings support assessment of prelinguistic vocalizations as a diagnostic feature for autism. The findings also demonstrate that preschoolers with ASD produce more atypical, non-speech-like vocalizations than their peers who are typically developing.

Additional studies that observe, record, and analyze the babbling and vocalizations of infants with ASD are needed in order to establish an expected progression of vocal development in infants with ASD. This information would enhance our understanding of the atypical patterns seen in infants with ASD when compared to typically developing peers. An enriched understanding of vocal development in infants with ASD may also improve prognosis of future speech and language development.

Infants with Siblings who have Autism

The fact that children are not typically diagnosed with ASD until 4 years of age encumbers our ability to observe the vocalizations of infants with ASD, and yet, such research is needed in order to credibly diagnose children at a younger age. Previous research has relied on retrospective accounts from caregivers, or analysis of home videos and recordings to track prelinguistic behaviors of infants with ASD (De Giacomo & Fombonne, 1998; Watson *et al.*, 2007; Zwaigenbaum *et al.*, 2007). While this has informed us on possible atypical behaviors and factors present at the time of recognition, there is a need for prospective studies that compare infants with ASD to infants who are typically developing in order to pin-point behaviors that can serve as biological markers to diagnose ASD at an earlier age (Zwaigenbaum *et al.*, 2007). Considering that ASD appears in about 1% of children, a sample of 100 infants may or may not include one, or maybe two infants who end up with a diagnosis of ASD. This is not an adequate sampling for determining the behavioral markers apparent in infants with ASD.

Studying infants who are at-risk for developing ASD, however, may be an effective method of sampling vocal behaviors in infants with ASD. Infants with siblings who have ASD (from here on referred to as ASD-sibs) are at least 20% more at risk for having ASD themselves than the general population because there is a genetic factor for ASD (Paul *et al.*, 2011; Zwaigenbaum *et al.*, 2007).

Not only are ASD-sibs at a higher risk for having ASD, but they are also at a higher risk for developmental, speech, and language delays. Other studies have found that ASD-sibs, when compared to infants who have typically developing siblings (from here on referred to as TD-sibs), smile less often, have less eye contact with their mothers, and respond less to joint attention (Yoder, Stone, Walden, & Malesa, 2009). They also make fewer requests, gestures, and initiations of joint attention (Yoder *et al.*, 2009). ASD-sibs are found to be at a much higher risk for, not only autism, but also mildly expressing symptoms of the disorder at a threshold below the diagnosis level.

Yoder and colleagues (2009) sought to predict the continuum of social impairment in ASD-sibs. Often times, family members of children with autism may not display the full triad of symptoms characteristic of ASD (repetitive behaviors/restricted interests, social impairments, and communicative impairments), but rather, just one. The researchers wanted to determine the prevalence and degree of ASD, as well as social impairments, in ASD-sibs. The study followed two groups of infants: one group of 43 ASD-sibs and one group of 24 TD-sibs. All of the infants were between the ages of 12 and 23 months at the beginning of the study, had no sensory impairments, and lived in homes where English was the primary language. Throughout a series of four

assessments occurring approximately every 4 months, the infants were measured on their response to joint attention and their weighted triadic communication skills (a measure that reflects language use and initiations of communication in non-verbal, single-word, and multi-word expressions). Approximately 6 months after the fourth assessment, the investigators assessed whether or not the children could be diagnosed with ASD. Yoder and colleagues (2009) found that 6 of the 43 ASD-sibs were diagnosed with ASD, with response to joint attention and weighted language measures predicting ASD. As a whole, the group of ASD-sibs was delayed with regard to responding to joint attention and other social measures, indicating that ASD-sibs are at higher risk for autism or milder social impairments.

Accordingly, recording the vocalizations of ASD-sibs will give us a sampling of a higher than typical concentration of infants who are later diagnosed with either ASD or social and language delays. Studies of infants who are later diagnosed with ASD can supply researchers with data regarding behavioral markers during this critical period of development to produce improved diagnostic tools for younger ages (Zwaigenbaum *et al.*, 2007).

Methodological Considerations

Methods used for analyzing both typical and atypical development *after* 18 months of age may not all be appropriate for analyzing development *prior* to 18 months of age, given that prelinguistic speech sounds (prior to 12 months of age) are not well-formed, and even many speech sounds in the early linguistic period (between 12 and 18 months of age) are still immature. Ramsdell and colleagues (2012) have begun to

explore new methods for tracking vocal development that may prove useful in highlighting differences between typical and atypical development. In their study, they used phonetic transcription to represent the traditional methodology, caregiver report to provide a more functional view of the infant's repertoire than transcription, and naive listener report to attempt to simulate caregiver report in the laboratory setting.

Transcription. The traditional method of tracking infant vocalizations by way of phonetic transcription has been shown to artificially inflate infant repertoires because infant vocalizations are varied and immature. As such, transcribers attribute a wider phonetic inventory to infants than they actually voluntarily and consistently control (Ramsdell, Oller, Buder, Ethington, & Chorna, 2012). This method is also problematic in that the International Phonetic Alphabet (IPA), used as the medium in transcription, was designed to represent mature speech sounds, and infants do not produce mature vocalizations (Ramsdell *et al.*, 2012). Ball and Rahilly (2002) suggest using a system of new symbols and diacritics that account for prosodic features such as pitch and tempo to more fully represent non-normal speech sounds. While this system may be an appropriate approach to display speech disorders, it still is not well suited for the pre-speech sounds and babbling of infants. Müller and Damico (2002) observe that because social interactions are complex and include more than just phonemes, the system of transcription needs to allow for more complex detail including contextual variables such as gaze, gestures, and facial expressions. When considering infants, who communicate through a system of developing, immature vocalizations, such contextual cues are vital to understanding what the infant is expressing. While adding such details may improve

the ability of the transcriber to capture infant vocalizations, it adds more complexity to the task, and the transcriber is still unaware of all the contextual cues. Regardless of procedure followed, reliability is low when transcribing infant vocalizations, both within and across transcribers, due to lack of canonicity, the often exotic nature of the immature sounds, and aberrant vocal quality (Ramsdell, Oller, & Ethington, 2007).

Caregivers. Caregiver report could provide us with a more reliable and valid method of exploring early vocalizations than transcription. Past research has shown that caregivers are a valid and reliable resource in reporting vocal, speech, and language development of children (Feldman *et al.*, 2005; Heilmann, Ellis Weismer, Evans, & Hollar, 2005; Korkman, Jaakkola, Ahlroth, Pesonen, & Turunen, 2004; Oller, Eilers, & Bassinger, 2001; Ramsdell *et al.*, 2012; Rescorla & Alley, 2001; Smith *et al.*, 2007; Watson *et al.*, 2007; Wetherby *et al.*, 2002). After Molemans, van den Berg, van Severn, and Gillis (2011) conducted a longitudinal study of infant vocalizations in order to determine how to reliably measure the onset of babbling, they conceded that a caregiver's "intuitive awareness" of the infant's vocal development should complement any quantitative measures.

Not only is dependence on caregiver report a reliable means in tracking speech and language development, it is more practical than transcription because the caregiver is with the infant most of the time and often the primary supplier of feedback to the infant. Report of caregiver perception is functional in two ways. First, the caregiver typically only recalls the vocalizations and babbling that are speech-like and novel for the infant. Second, what a caregiver perceives the child to communicate affects the

language input the child receives in response, therefore facilitating word learning and language development. It has been observed that caregiver response to both typical and atypical early communicative behaviors is predictive of the child's language development (Girolametto, Weitzman, Wiigs, & Pearce, 1999; Goldstein & Schwade, 2008; McDuffie & Yoder, 2010). Research indicates that adults modify their speech when they perceive that a child's production is inaccurate (Julien & Munson, 2012), and that mothers vary their responses to infant utterances based on the familiarity or non-familiarity of the early linguistic productions (Olson & Masur, 2012). Caregivers tend to respond to perceived inaccurate productions of sounds by phonetically enhancing the errors to facilitate correct productions from the child. They also provide additional examples and repetitions of novel words produced by the infant, reinforcing productions of novel words. Thus caregiver responses to infant utterances support language acquisition, and caregiver perception of infant utterances influences how they respond to their infant. When the words, word approximations, or consonant-vowel syllables, are familiar, meaning the infant has produced them previously, parents tend to expand on those productions, which supports the child's language development (Gros-Louis, West, Goldstein, & King, 2006; Olsen & Masur, 2012). Just as caregiver responses to early speech productions influence later speech and language development, it is natural to assume that caregiver responses to infant vocalizations influence, and may predict future speech and language acquisition. It also follows that just as the accuracy and familiarity of a child's productions influence how a caregiver

responds, it is natural to assume that the caregiver's perception of an infant's prelinguistic vocalizations influence how the caregiver responds as well.

Caregiver report and input is a critical aspect to early identification and therefore, intervention. Previous studies have included parents in exploring expressive language markers, such as vocabulary development and word combinations in language delay, in children between 18 and 32 months of age. Just as caregivers are reliable resources in tracking early speech and language development, we propose that they can be valuable in tracking the prelinguistic vocalizations and babbling of infants, prior to 18 months of age.

Research indicates that caregivers report a smaller number of sounds that may be more functional in guiding caregiver-infant interactions and word learning than transcription provides. The study by Ramsdell and colleagues (2012) showed that transcribers and caregivers report vastly different infant repertoire sizes with respect to vocalizations produced, with only marginal correlation between the phonological makeup of sounds reported.

Naive listeners. The findings of Ramsdell and colleagues (2012) also show that naive (i.e., naturalistic) listener report parallels, to a much greater extent than transcription, caregiver report of infant vocalizations, with respect to both quantity and phonological makeup of sounds reported. Naive listeners were described as non-maternal, and untrained (non-speech-language pathologists) volunteers who listened to vocalizations extracted from 20-minute recordings of caregivers and infants interacting (specifically, eight caregiver/infant dyads at 8, 10, and 12 months of infant age), and

then reported on what sounds they believed the infant could produce. The purpose of the naive listener was to simplify the research processes in the laboratory by eliminating the need to track caregiver report. These early results indicate that naive listeners appear to be an effective research tool in that they simulate caregiver report of infant vocalizations without parental bias.

Purpose

The purpose of this project is to sample and examine transcriber, caregiver, and naive listener report of vocalizations produced by an ASD-sib (infant with a sibling with Autism) compared to a TD-sib (infant with a sibling who is typically developing). Specifically, will the quality and quantity (phonological makeup) of vocalizations judged vary dependent upon listeners and/or infants? It was hypothesized that all listener reports would result in attribution of less phonetic variability to the ASD-sib than to the age- and gender-matched TD-sib. Further, it was hypothesized that caregiver and naive listener reports would more efficiently identify discrepancies between the infant inventories because of the functional nature of the task.

Method

Participants

This study includes data collected from a previous study at East Carolina University (ECU) by the investigator's mentor (approved by the University and Medical Center Institutional Review Board at ECU). In the previous study, 16 infants were followed longitudinally between the ages of 6 and 19 months. The present study will compare two infants from this data set: an ASD-sib and a TD-sib. The TD-sib was chosen because he matched the ASD-sib with respect to age, gender, and socio-economic status. Further the infants' siblings matched with respect to age and gender. Both of the infants were Caucasian males with no significant prenatal or perinatal problems, and no significant medical history at the time of the recordings for the study. The infants were matched on a variety of variables so as to increase the chance of differences in listener report resulting from developmental status alone. They both passed full hearing evaluations performed by a certified audiologist that included tympanometry, transient evoked otoacoustic emissions, and visual reinforced audiometry at 6 and 18 months of age. Both infants came from homes where English is the only language spoken and both the mother and father are present. The ASD-sib began receiving speech and play therapy services at 14 months of age due to delayed development.

Procedure

Prior to initiation of the study, exemption was obtained from the Human Subjects Committee at Idaho State University (ISU), as the study purpose was covered in the original consent.

Caregiver report. The caregivers in the study volunteered to participate and gave informed consent. The infant-caregiver dyads from the larger longitudinal study were followed for 14 months (from 6 to 19 months of age) through weekly interviews and monthly audio-video recorded hour-long sessions in the Infant Vocal Development Laboratory at ECU. The Infant Vocal Development Lab was designed to provide a natural setting with furniture and toys typically found in home nurseries. The weekly interviews were conducted either in person or over the telephone to document caregiver perception of infant vocal productions via a questionnaire administered by a laboratory staff member that asked, among other questions, "What sounds/words has your infant been producing since we last spoke?" The caregivers were not trained in how to recognize or produce infant sounds, as this was not the intent of the study. Rather, the intent was to gain a record of intuitive and natural responses from caregivers and compare that to current knowledge of infant vocal development. The data from these interviews was phonetically transcribed by the staff member administering the questionnaire and converted to numerical data to describe the phonetic features of the vocalizations reportedly produced by the infants.

Naive listener report. The naive listening task is in development and has been used to simulate caregiver listening in the laboratory setting (Killeen, 2014; Ramsdell *et al.*, 2012). The naive listeners were not trained in speech-language pathology; their task was to listen to recorded infant vocalizations and report what they heard. Much like the caregivers, they were not trained in how to recognize or produce infant-like sounds, but rather, they were expected to report an intuitive, natural response. The infant

vocalizations were presented as extractions from the audio of recorded sessions. Each recorded session had all of the extracted vocalizations arranged in random order and separated by 1.5 seconds, such that listeners heard the infant vocalizations void of extraneous sounds from other people in the recording room, or toys with which the infant may have been playing. Further, vegetative and reflexive sounds, as judged by the trained laboratory staff, were not presented to the listeners. Two naive listeners were presented with the infant vocalization audio files in a random order (of which there were 24, one for each infant at each age from 7 through 18 months), and then asked to answer the question, "What sounds/words did the infant produce?" Results across naïve listeners were averaged so only one value is reported for each phonetic feature. Thus, we gained a vocal repertoire of the infants as judged by the two naive listeners. The responses from the naive listeners were transcribed phonetically, converted into numerical data, and compared with the caregiver report.

Transcriber report. Since phonetic transcription has traditionally been the method used for tracking speech and language development, all of the recorded vocalizations from these infants were also transcribed by two separate transcribers. Each transcriber received ample training in transcription and analysis of infant vocalizations through undergraduate coursework in phonetic transcription and laboratory experience. The transcribers were trained in using the International Phonetic Alphabet (IPA). They listened directly to the recorded infant utterances (the same files presented to the naive listeners) no more than 6 times, and transcribed what they heard. In this way, the transcribed vocal repertoires of each infant were determined.

Results across transcribers were averaged resulting in one value for each phonetic feature. As with caregiver and naive listener report, transcriptions were converted into numerical data for comparison purposes.

Phonetic Features

Caregiver, naive listener, and transcriber reports were transcribed separately for each infant at each age, and compiled such that all reported vocalizations for each infant at 7 months of age were analyzed together, and so on and so forth

For each group of listeners, and for each infant at each age, tallies were calculated for the total number of utterances reported, along with the total number of consonants and vowels in reported utterances. Further, consonant sounds reported were examined 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 examined in terms of tongue position (number of high front, low front, central, low back, high back, rising diphthong, and rhotic diphthong vowels).

Design

The purpose of this project was to compare caregiver, naive listener, and transcriber report of vocalizations produced by an ASD-sib compared to a TD-sib, specifically with respect to the quality and quantity (phonetic makeup) of vocalizations judged. By exploring the distinctions between caregiver, naïve listener, and transcriber perception of infant vocalizations, we can begin to identify the utility of new methods

(caregiver and naïve listener report) for determining differences in speech production between infants with dissimilar developmental patterns. To fully analyze the ability to quantify differences in reports of vocal development for these two infants, we considered the following questions: what is the effect of listener (caregiver, naive listener, and transcriber), infant (ASD-sib and TD-sib), and age (early – 7 to 10 months of age, middle – 11 to 14 months of age, and late – 15 to 18 months of age) on report of vocalizations? Features of interest across variables included total number of utterances, consonants, and vowels; place of articulation, voicing, and manner of production for consonants; and tongue position for vowels.

Results

Features for the selected infants are displayed across age in table form for caregivers, naïve listeners, and transcribers. The tables demonstrate general features (e.g., number of utterances reported) as well as specific phonetic features (e.g., place of articulation and manner of production for consonants reported).

Caregiver Report

For general features in caregiver report (Table 1), the caregivers in this study reported differences in vocalizations between the two infants. In the early age group, the two infants had similar amounts of utterances, consonant tokens, and vowel tokens. However, the number of utterances reported by the ASD-sib caregiver did not increase from the early age group to the middle age group; yet there was an increase from the early age group to the late age group. In contrast, the TD-sib caregiver reported clear increases in the number of utterances produced 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 each of the general features across age groups, which is to be expected of a typically developing infant. Even though the number of consonants and vowels both increased for the TD-sib, there was a switch in the late age group where the number of consonants strongly outnumbered the vowel tokens, while the ASD-sib's caregiver reported a similar number of consonants and vowels across all age groups.

Table 1. General features in infant vocalizations reported by caregivers.

Infant	Infant Age (in Months)	# of Utterances Reported	# of Consonant Tokens	# of Vowel Tokens
ASD-sib	7 to 10	26.2	30.0	31.5
	11 to 14	21.0	31.5	28.0
	15 to 18	45.4	66.4	62.9
TD-sib	7 to 10	26.5	31.3	35.1
	11 to 14	54.7	85.0	82.1
	15 to 18	85.6	140.7	105.7

For place of articulation and voicing features in caregiver report (Table 2), the ASD-sib produced primarily voiced and labial sounds. Both infants were reported to produce more labial sounds than any other placement in the early age group, but again, there were some inconsistencies across infant age for the ASD-sib caregiver report. The only gradual increase reported was for labial consonants. 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. By the late age, the TD-sib was reported to produce more of each placement of consonants than the ASD-sib. The TD-sib caregiver also reported increases in both voiced and voiceless consonant productions across the age groups, while the ASD-sib's report displayed very few voiceless consonants in the early age group and none in the middle and late age groups.

Table 2. Place of articulation and voicing for consonant tokens in infant vocalizations reported by caregivers.

Infant	Infant Age (in Months)	Place of Articulation for Consonant Tokens				Voicing for Consonant Tokens	
		Labial	Coronal	Dorsal	Laryngeal	Voiced	Voiceless
ASD-sib	7 to 10	14.3	11.1	3.5	1.2	28.8	1.2
	11 to 14	22.7	8.7	0.0	0.0	31.5	0.0
	15 to 18	28.0	24.5	14.0	0.0	66.4	0.0
TD-sib	7 to 10	23.0	0.4	5.7	2.2	29.6	2.2
	11 to 14	27.7	32.6	17.2	7.6	47.5	37.6
	15 to 18	37.6	71.6	21.8	7.9	76.0	61.2

For manner of production features in caregiver report (Table 3), the infants produced more stops than other manners across age groups. Both caregivers also reported nasals and glides in the early months. However, the TD-sib's reported productions were more sophisticated than the ASD-sib's, 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 ages. Other consonant types were either not reported, or did not display a consistent increase as the ASD-sib developed.

Table 3. Manner of production for consonant tokens in infant vocalizations reported by caregivers.

Infant	Infant Age (in Months)	Stop	Fricative	Affricate	Nasal	Liquid	Glide	Click	Trill
ASD-sib	7 to 10	13.7	1.2	0.0	7.6	0.9	6.1	0.0	0.6
	11 to 14	21.0	0.0	0.0	8.7	0.0	0.0	0.0	1.7
	15 to 18	34.9	0.0	0.0	21.0	0.0	10.5	0.0	0.0
TD-sib	7 to 10	20.8	2.2	0.0	5.4	0.4	2.0	0.0	0.0
	11 to 14	54.7	13.7	0.0	11.4	1.7	3.5	0.0	0.0
	15 to 18	77.8	21.8	7.0	24.5	1.7	7.0	0.0	0.9

For vowel features in caregiver report (Table 4), while both infants produced mostly low back vowels, the TD-sib produced a variety of vowel types that the ASD-sib did not. 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. The ASD-sib's caregiver report did not display any consistent increase in vowel types as the infant matured, although low back vowels did increase with age. All other vowel positions, except for the low front, were minimally represented in the ASD-sib's caregiver report.

Table 4. Tongue position for vowel tokens in infant vocalizations reported by caregivers.

Infant	Infant Age (in Months)	High Front	Low Front	Central	Low Back	High Back	Rising Diphthong	Rhotic Diphthong
ASD-sib	7 to 10	1.2	6.1	7.9	14.0	2.3	0.0	0.0
	11 to 14	0.0	0.0	3.5	22.7	0.0	0.0	1.7
	15 to 18	3.5	17.5	3.5	38.4	0.0	0.0	0.0
TD-sib	7 to 10	2.0	1.5	6.8	18.9	0.0	5.4	0.0
	11 to 14	18.1	11.6	11.4	26.5	4.1	10.5	0.0
	15 to 18	19.2	13.1	17.5	20.1	7.9	26.2	1.7

Naïve Listener Report

For general features in naïve listener report (Table 5), differences in vocalizations across the two infants were also noted. The TD-sib displayed increases (although not always incremental) in production of utterances, consonants, and vowels across age. In contrast, the naive listener reports revealed decreases in the total number of utterances and number of vowel tokens and no incremental increase in the number of consonants for the ASD-sib. The TD-sib was reported to produce more consonants than vowels in each age group, while the ASD-sib was reported to produce more vowels than consonants in each age group. Overall, the TD-sib was reported to produce more utterances in each age group than the ASD-sib.

Table 5. General features in infant vocalizations reported by naïve listeners.

Infant	Infant Age (in Months)	# of Utterances Reported	# of Consonant Tokens	# of Vowel Tokens
ASD-sib	7 to 10	21.7	21.0	33.5
	11 to 14	20.8	30.2	34.3
	15 to 18	17.5	21.1	30.4
TD-sib	7 to 10	22.4	32.6	31.4
	11 to 14	35.5	56.0	45.3
	15 to 18	31.9	50.9	50.6

For place of articulation and voicing features in naïve listener report (Table 6), the TD-sib produced more labials in the early age group than any other placement, while the ASD-sib produced more laryngeals. As the TD-sib aged, the naïve listeners reported him to produce more coronals than labials, while the ASD-sib always produced more coronals than labials. Overall, the TD-sib was reported to produce several more coronal and labial consonants in each age group, while the ASD-sib appeared to prefer dorsal sounds in the middle and late age groups. The naive 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 with the number of voiced and voiceless consonants being almost equal in the late age group. The ASD-sib was reported to have a decrease in voiceless consonants.

Table 6. Place of articulation and voicing for consonant tokens in infant vocalizations reported by naïve listeners.

Infant	Infant Age (in Months)	Place of Articulation for Consonant Tokens				Voicing for Consonant Tokens	
		Labial	Coronal	Dorsal	Laryngeal	Voiced	Voiceless
ASD-sib	7 to 10	3.2	5.5	1.8	10.5	9.0	11.8
	11 to 14	4.5	8.8	11.2	5.5	24.0	6.0
	15 to 18	4.5	4.9	7.1	4.6	13.9	7.4
TD-sib	7 to 10	15.5	6.0	2.5	8.5	23.6	8.9
	11 to 14	12.5	21.5	19.2	2.5	35.8	20.0
	15 to 18	16.8	16.9	6.1	11.4	27.3	23.9

For manner of production features in naïve listener report (Table 7), few consistent increases were reported. The ASD-sib was reported to produce a gradual

increase in glides and liquids. The TD-sib reportedly produced gradual increases in fricatives, nasals, and glides. 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, followed by fricatives and nasals. Both infants had an increase in trills from the early to middle age group, and then a decrease from the middle to late age groups.

Table 7. Manner of production for consonant tokens in infant vocalizations reported by naïve listeners.

Infant	Infant Age (in Months)	Stop	Fricative	Affricate	Nasal	Liquid	Glide	Click	Trill
ASD-sib	7 to 10	7.3	10.3	0.0	2.7	0.2	0.5	0.0	0.2
	11 to 14	9.7	5.8	0.0	3.3	1.3	9.2	0.0	0.7
	15 to 18	4.5	7.4	0.0	0.4	1.6	7.0	0.0	0.3
TD-sib	7 to 10	14.0	7.3	0.0	4.0	4.9	1.8	0.1	0.6
	11 to 14	31.0	8.5	0.7	7.3	5.2	1.5	0.0	1.5
	15 to 18	20.9	12.9	0.1	8.8	2.5	4.4	0.0	1.4

For vowel features in naive listener report (Table 8), only a few consistent increases were noted. The ASD-sib only had non-incremental increases in high-front and high-back vowels, and decreases in all other vowel shapes (with the exception of rhotic diphthongs, which remained close to zero across age groups. The TD-sib reportedly increased productions in all vowel shapes, except for high-back as he matured. Overall, both infantsreportedly produced far more low-back vowels than any other shape. The TD-sib had more variety in vowel productions across age groups when compared to the ASD-sib.

Table 8. Tongue position for vowel tokens in infant vocalizations reported by naïve listeners.

Infant	Infant Age (in Months)	High Front	Low Front	Central	Low Back	High Back	Rising Diphthong	Rhotic Diphthong
ASD-sib	7 to 10	3.2	3.5	5.8	13.0	2.7	5.2	0.0
	11 to 14	0.8	3.2	8.5	17.0	0.8	3.8	0.2
	15 to 18	5.1	2.3	3.0	11.0	2.9	6.0	0.1
TD-sib	7 to 10	1.3	0.9	6.9	18.8	1.8	1.5	0.0
	11 to 14	8.8	2.7	8.0	11.5	5.0	9.0	0.0
	15 to 18	5.3	4.5	9.5	15.3	6.4	9.6	0.4

The data presented in Table 5-8 are collapsed across each of the two naïve listeners, and each of the four transcribers of the naïve listener reports. Paired samples *t* tests showed some variation between results across judgments made by each naïve listener and all transcribers. Across all features in the early age group, paired samples *t* tests that compared naïve listener reports showed minimal significant differences [listener one (M = 2.56, SD = 8.39) and listener two (M = 1.46, SD = 3.46), $t(80) = 2.24$, $p = 0.03$]. Across all features in the middle age group, paired samples *t* tests that compared naïve listener reports showed no significant differences [listener one (M = 3.52, SD = 15.11) and listener two (M = 2.30, SD = 8.95), $t(88) = 1.72$, $p = 0.09$]. Across all features in the late age group, paired samples *t* tests that compared naïve listener reports showed statistically significant differences [listener one (M = 3.76, SD = 18.00) and listener two (M = 1.45, SD = 3.55), $t(65) = 3.45$, $p < 0.01$].

Transcriber Report

For general features in transcriber report (Table 9), an increase in total number of utterances, consonant tokens, and vowel tokens was noted for the TD-sib, and a decrease was noted in all three for the ASD-sib. The TD-sib had more utterances,

consonants, and vowels in the middle and late age groups, with a continuous increase in each as he aged, while the ASD-sib had a higher number than the TD-sib in the early age group, with a decrease as he aged. The TD-sib had far more general features reported by transcribers in the late age group than the ASD-sib. The TD-sib also had a smaller gap between consonants and vowels in the middle and late ages indicating a higher ratio of consonant to vowel usage as he aged.

Table 9. General features in infant vocalizations reported by transcribers.

Infant	Infant Age (in Months)	# of Utterances Reported	# of Consonant Tokens	# of Vowel Tokens
ASD-sib	7 to 10	584.0	344.7	528.0
	11 to 14	474.7	371.3	600.7
	15 to 18	292.0	314.5	464.5
TD-sib	7 to 10	374.0	228.5	344.5
	11 to 14	533.3	606.7	661.3
	15 to 18	521.0	628.5	744.5

For place of articulation features in transcriber report (Table 10), the TD-sib produced more labial, coronal, and dorsal consonants than the ASD-sib in the middle and late ages. Both infants reportedly produced more laryngeal consonants than any other placement in the early ages. Interestingly, the ASD-sib reportedly produced a higher number of laryngeal consonants in the early age group with a sharp decrease as he aged—still remaining his most produced placement of articulation. The transcribers reported the ASD-sib to increase production of labial and coronal consonants with age, but not as much as the TD-sib. The transcriber reported a high number of labial consonants initially for the TD-sib. Overall, the TD-sib's transcriber report displayed an increase in each placement, with the TD-sib producing more of everything than the ASD-

sib in the late age group. The ASD-sib had slight increases in labial, coronal, and dorsal sounds.

Table 10. Place of articulation and voicing for consonant tokens in infant vocalizations reported by transcribers.

Infant	Infant Age (in Months)	Place of Articulation for Consonant Tokens				Voicing for Consonant Tokens	
		Labial	Coronal	Dorsal	Laryngeal	Voiced	Voiceless
ASD-sib	7 to 10	16.7	14.0	38.0	276.0	48.7	296.0
	11 to 14	46.7	93.3	53.3	178.0	175.3	196.0
	15 to 18	60.0	98.5	45.0	111.0	183.0	131.5
TD-sib	7 to 10	95.0	9.5	15.5	108.5	119.5	109.0
	11 to 14	134.0	191.3	125.3	156.0	313.3	293.3
	15 to 18	227.5	153.5	78.5	169.0	323.0	305.5

For voicing features in transcriber report (Table 10), the ASD-sib produced several more voiceless consonants than voiced in the early age group, but these decreased with age. In the middle age group, the ASD-sib produced almost equal amounts of voiced and voiceless consonants, and then more voiced in the late age group. The TD-sib, however produced an increased amount of both voiced and voiceless consonants with age. The TD-sib also produced more voiced consonants than the ASD-sib at all ages.

For manner of production features in transcriber report (Table 11), both infants produced more stops and fricatives than any other manner. The ASD-sib reportedly decreased in his production of stops and fricatives with age, while the TD-sib increased in his production of stops, fricatives, nasals, and glides with age. In the early age group, the ASD-sib was reported to produce more stops and fricatives than the TD-sib, but fewer in the middle and late age groups. The ASD-sib reportedly produced few affricates and trills altogether, with decreases in each as well. Interestingly, the transcribers reported the highest number of trills in the middle age group. The TD-sib's transcriber

report appears to contain more variety across manner types in each age group when compared to the ASD-sib's.

Table 11. Manner of production for consonant tokens in infant vocalizations reported by transcribers.

Infant	Infant Age (in Months)	Stop	Fricative	Affricate	Nasal	Liquid	Glide	Click	Trill
ASD-sib	7 to 10	153.3	170.0	0.7	8.0	0.7	10.7	0.0	1.3
	11 to 14	152.7	130.7	0.7	20.7	6.0	52.7	2.0	5.3
	15 to 18	102.0	147.0	0.0	25.5	6.0	33.0	0.0	1.0
TD-sib	7 to 10	62.0	104.0	0.0	39.5	3.5	17.0	0.0	2.5
	11 to 14	234.0	244.0	8.0	36.0	8.7	48.7	0.0	27.3
	15 to 18	292.0	169.5	2.5	93.0	3.5	55.5	0.5	11.5

For vowel features in transcriber report (Table 12), similar results were noted for the production of high-front vowels in both infants, with an increase as they aged, but more produced in the middle age group than the late age group. In the late age group, the TD-sib produced more central, low-back, high-back, and rising diphthongs than the ASD-sib. The ASD-sib produced a high number of central vowels in the early age group, which decreased with age. The transcribers did not report any rhotic diphthongs for either infant. Overall, the TD-sib reportedly produced a higher variety of vowels than the ASD-sib in the middle and late age groups, with increases in each vowel type as he aged.

Table 12. Tongue position for vowel tokens in infant vocalizations reported by transcribers.

Infant	Infant Age (in Months)	High Front	Low Front	Central	Low Back	High Back	Rising Diphthong	Rhotic Diphthong
ASD-sib	7 to 10	98.7	112.0	260.0	7.3	33.3	14.0	0.0
	11 to 14	187.3	160.0	160.7	10.7	36.0	43.3	0.0
	15 to 18	146.0	96.0	101.5	9.0	56.5	54.5	0.0
TD-sib	7 to 10	99.0	52.5	109.5	3.5	47.0	20.5	0.0
	11 to 14	246.0	96.7	128.0	8.7	116.0	62.0	0.0
	15 to 18	152.0	68.5	216.5	48.0	126.0	133.0	0.0

In general, the transcriber report demonstrated an increase of phonological variability with age for the TD-sib and a decrease in the ASD-sib.

The data presented in Table 9-12 are collapsed across each of the two transcribers. Paired samples *t* tests showed no variation between results across judgments made by each transcriber. Across all features in the early age group, paired samples *t* tests that compared transcriber reports showed no significant differences [transcriber one (M = 22.29, SD = 942.34) and transcriber two (M = 25.69, SD = 987.54), $t(90) = -0.53$, $p = 0.60$]. Across all features in the middle age group, paired samples *t* tests that compared transcriber reports showed no significant differences [transcriber one (M = 30.17, SD = 1277.89) and transcriber two (M = 34.23, SD = 1443.94), $t(90) = -0.53$, $p = 0.59$]. Across all features in the late age group, paired samples *t* tests that compared transcriber reports showed no significant differences [transcriber one (M = 31.99, SD = 1513.32) and transcriber two (M = 35.27, SD = 1674.29), $t(90) = -0.39$, $p = 0.69$].

Cross-Listener Comparison

Comparing the caregiver, naïve listener, and transcriber reports is necessary in order to consider the validity of caregiver report for tracking infant vocalizations. When comparing the transcriptions to the caregiver and naïve listener reports, however, one must keep in mind that the latter two reported things only from memory, while the transcriber reported on each vocalization heard. As a result, the transcribers reported many more utterances than the caregivers. With that being said, there were many

interesting similarities between the three reports, supporting the notion that caregiver report may be a valid method for tracking infant vocalizations.

General features. For general features reported across listeners, a higher total number, and a consistent increase of utterances, consonants, and vowels were noted for the TD-sib across age groups than the ASD-sib (with the exception of the transcriber report in the early age group, which noted a higher number of utterances, consonants, and vowels for the ASD-sib). The caregiver and naïve listeners reported only a slight, non-incremental increase in the three previously mentioned general features for the ASD-sib, and the transcriber reported a decrease (including a more than 50% decrease in number of utterances) in all three with age.

Place of articulation for consonant tokens. For place of articulation features reported across listeners, an increase in labial, coronal, and dorsal consonants was noted for the ASD-sib with age, but a larger increase was noted for the TD-sib. The naïve listener reports, however, demonstrated a less incremental increase for each infant across age groups, and a slight decrease in the late age group in coronals for the ASD-sib. The ASD-sib was reported to have a decrease in laryngeal consonants with age, and the TD-sib an increase. The caregivers reported the ASD-sib to produce primarily labial consonants across ages, while the transcribers reported him to produce primarily laryngeal sounds, and the naïve listener varied with each age group.

Voicing for consonant tokens. For voicing features reported across listeners, all listeners noted a decrease in voiceless consonants with age for the ASD-sib and an increase with age for the TD-sib. All listeners reported the ASD-sib and TD-sib to have an

increase in voiced consonants with age, but the increase was larger for the TD-sib. Each listener varied on the relative numbers of voiceless consonants across ages for the ASD-sib.

Manner of production for consonant tokens. For manner of production features reported across listeners, all reports were similar for the TD-sib, but displayed differences for the ASD-sib. All listeners reported a decrease in fricatives for the ASD-sib with age, as well as few liquids, glides, and affricates. Caregivers and transcribers reported an increase in nasals with age in both infants, but naïve listeners reported a decrease in nasals with age for the ASD-sib. The caregivers reported both infants to produce mostly stops at all ages, while the naïve listeners reported only the TD-sib to produce mostly stops, and the transcriber reported more fricatives than stops for both infants in the early age group. For the ASD-sib, the caregivers reported an increase in nasals, the transcribers reported an increase in nasals and glides, and the naïve listeners only reported a slight increase in liquids and glides.

All three reports demonstrate more sophistication in manner of production features for the TD-sib than the ASD-sib by noting more variety in sound types produced. This variety was most apparent in the caregiver report.

Tongue position for vowel tokens. For vowel features reported across listeners, variability was present. All listeners reported at least a slight increase in high front vowels in both infants with age, and a decrease in central vowels in the ASD-sib. They all reported an increase across all vowel shapes with age for the TD-sib (with the exception of rhotic diphthongs). Both the caregivers and naïve listeners reported each infant to

produce mostly low-back vowels, while the transcribers reported fewer low back vowels than any other vowel shape. Also, the transcribers reported several more central vowels for both infants than caregivers and naïve listeners did. All listeners reported the TD-sib to produce more of a variety of vowel shapes than the ASD-sib by the late age group, although the naïve listener report is not as clear on this regard.

Discussion

The purpose of this case study was to explore caregiver, naïve listener, and transcriber report of infant vocalizations from an ASD-sib and a gender- and age-matched TD-sib. Specifically, this study was designed to explore the extent to which caregiver, naïve listener, and transcriber reports identify similar differences across infants. Research has demonstrated that caregiver report provides a unique perspective of vocal development when compared to traditional transcription methodologies. Research shows that speech and language development can be altered or delayed in ASD-sibs (Yoder *et al.*, 2009; Zwaigenbaum *et al.*, 2007). Therefore, given new methodology, it was hypothesized that caregivers, naïve listeners, and transcribers would report fewer phonetic features when listening to an ASD-sib than to a TD-sib.

Differences were identified in the vocal development between the two infant participants. Reports indicated that the TD-sib was developing appropriately, as his increases in features follow an expected developmental trajectory, and the ASD-sib was producing fewer sounds than the TD-sib in all instances (with the exception of the transcriber report of the early age group).

Given the small scale of this case study, continued research in prelinguistic vocalizations using these new methodologies is warranted. Caregiver and naïve listener perspective may lead to new methods for identifying early behavioral markers for infants at risk of future speech and language delays/disorders in a more efficient manner than phonetic transcription, therefore facilitating clinical practice.

Caregiver Report

The caregivers reported several patterns for the TD-sib that are expected for typical development, and some atypical patterns for the ASD-sib. The most obvious difference between the two infants is the fewer number of utterances for the ASD-sib across age groups than for the TD-sib. This pattern was reported from all three listeners and causes concern regarding the ASD-sib's vocal and linguistic development. In addition, the TD-sib's general features gradually increased in production across each age group. The ASD-sib, however, had some decreases and limited increases across age groups, suggesting that his vocal development is delayed.

Another pattern that the caregivers reported is the interplay between the vowels and consonants as the infants aged. It is developmentally expected that initially, more vowels will be produced than consonants. However, given that adults produce more consonants than vowels, as an infant's utterances become more speech-like, it is expected that more consonants will be produced than vowels (Stoel-Gammon, 1985). The TD-sib's caregiver reported this pattern clearly, while the ASD-sib's caregiver did not.

The relationship between labial and coronal consonants across age groups was also a developmental pattern of note in the caregiver report. Initially, infants begin to produce labial sounds because they are less marked given that they can be both seen and heard. Coronal sounds, however, are more commonly produced in General American English, so as infants mature, they transition from producing more labial

sounds to producing more and more coronal sounds (Stoel-Gammon, 1985). The caregivers reported this pattern very clearly in the TD-sib, but not for the ASD-sib.

As far as consonant voicing, again the TD-sib's caregiver reported a developmentally expected pattern. In the early age group, he produced several more voiced than voiceless consonants. With age, the TD-sib was reported to produce more similar numbers of voiced and voiceless consonants. We would expect this because the voiced consonants are earlier to develop as they are less marked, and are more frequently produced in General American English (Oller, 2000). The ASD-sib's caregiver did not report a similar increase in voiceless consonants.

As for manner of production, caregivers reported both of the infants to produce mostly stops, nasals, and glides in the early and late age groups, which is expected as these are earlier developing features (Stoel-Gammon, 1985). The TD-sib was reported to produce growing numbers of fricatives and affricates in the late age group, whereas, the ASD-sib was not. This suggests that as the infants developed, the TD-sib's productions were more sophisticated; he reportedly began to use more later developing sounds in addition to the nasals, stops, and glides.

When considering vowels, the caregivers' reports once again demonstrated a more sophisticated repertoire for the TD-sib when compared to the ASD-sib, especially in the later age group, indicating a delay in the ASD-sib. The most obvious pattern demonstrated by the caregivers for vowels is the dramatic increase of rising diphthongs for the TD-sib. Rising diphthongs require tongue transition during production, and thus are later-developing (Oller, 2000), so the TD-sib's productions follow the developmental

expectation according to caregiver report, while the ASD-sib was not reported to produce any rising diphthongs.

Naïve Listener Report

Like caregivers, the naïve listeners also reported an increase across age groups in the number of utterances for the TD-sib, and a decrease across age groups in the total number of utterances and consonant tokens for the ASD-sib. This flags concern for the ASD-sib. When considering voicing, the naïve listeners reported the TD-sib to produce more voiced and voiceless productions across age groups. They also reported increases in both for the ASD-sib, but the increases were not incremental. When considering place of articulation, manner of production, and tongue position for vowels however, naïve listener report failed to display any obvious developmental patterns. For manner features, they did report the TD-sib to produce more stops than any other manner in all age groups, which is typical for his age. Oddly, however, the ASD-sib was reported to produce more fricatives than any other manner in the early and late age groups. This high number of fricatives correlates with the high number of laryngeal consonants in the early age group, so perhaps there were many /h/ phonemes reported, a voiceless glottal fricative. Further, for vowel features, both infants were reported to produce mostly low-back vowels across all age groups and the TD-sib appeared to follow developmental norms more than the ASD-sib.

Transcriber Report

The transcribers included several vowels and consonants that are not considered part of the phonetic inventory of General American English to account for the different

sounds that the infants produced, thus adding variability to their report. The increased phonetic variability observed in transcriber report is likely the result of the increased level of detail with which transcriptions are conducted.

Transcriber report clearly displayed an increase in the number of consonants compared to vowels as the TD-sib aged. In contrast, the ASD-sib was reported to produce more vowels than consonants across ages. Once again, an increase in the ratio of consonants to vowels is expected with age, and thus, the TD-sib is reported to follow a more typical developmental pattern in this regard.

As for place of articulation, the transcribers reported a contrast in the laryngeal consonants for the infants. The ASD-sib produced a high number of laryngeal consonants in the early age group, with a steady decline as he aged, while the TD-sib had far fewer laryngeal consonants in the early age group, with a steady increase as he aged. An increase in all places of articulation is expected with age, and as such, the ASD-sib's report displayed an irregular pattern of development. As for voicing, the ASD-sib was reported to produce a high number of voiceless consonants in the early age group, and very few voiced consonants. This is developmentally abnormal, as well as the fact that the ASD-sib's productions of voiceless consonants reportedly decreased with age. The TD-sib's reported voiced and voiceless productions were more developmentally appropriate. As for manner of production, the transcribers reported a high number of fricatives for both infants in the early age group. Typically fricatives are a later developing class of sounds (Locke, 1983), so this is unexpected. The high number of

voiceless laryngeal fricatives reported suggests that transcribers may have identified many /h/ phonemes (a voiceless glottal fricative) in the infants' vocal samples.

Further, with respect to manner of production, both infants were also reported to produce many stops and glides, which are earlier developing sounds (Stoel-Gammon, 1985). The transcriber report for the ASD-sib, however, demonstrated a decrease in stops, which is atypical, while the TD-sib produced more stops, fricatives, and nasals with age, in alignment with typical development.

With respect to vowel features, the TD-sib was reported to produce a more variable repertoire of vowels by the late age group when compared to the ASD-sib. The transcribers reported an increase in rising diphthongs in the TD-sib across age groups, indicating an increase in tongue control for vowel production. The transcribers also reported an increase in production of rising diphthongs for the ASD-sib, but only slightly. Few low-back vowels compared to other vowels were reported, in contrast with caregiver and naïve listener report of more low-back vowels. The transcribers instead reported more central, high-front, and low-front vowels for both infants. This may be explained by differences across listener tasks. Perhaps the caregivers and naïve listeners were inclined to collapse across vowel differences given that they were responding about sound types from memory. They would not collapse across consonants, however, because consonants are more salient in production. Transcribers were responding about sound types with each presentation of an utterance, almost online, and therefore had more opportunity to list all of the phonetic detail present in the productions.

Conclusions

All three reports displayed a more developmentally appropriate pattern of features for the TD-sib than the ASD-sib. The naïve listener report was the least clear in displaying differences between infants, while caregiver and transcriber reports clearly displayed differences. There were also some instances, such as with the manner of production, and the labial and coronal positioning interplay, where the patterns were most visible from the caregiver report.

Observation of the similarities and differences between the caregiver and transcriber reports indicates that the method of caregiver report may be a valid tool in identifying developmental patterns in an infant's vocal repertoire. Follow-up speech and language testing was conducted with each child at 3 ½ years of age. Results supported speech and language development within normal limits for the TD-sib, and atypical development for the ASD-sib. More specifically, the ASD-sib demonstrated expressive language and hearing abilities within normal limits for his age, and total language abilities below expected for his age, with significant deficits in receptive language. Additionally, the ASD-sib exhibited delays in speech sound production, likely as a result of articulation, rather than phonology (with the exception of gliding).This finding indicates that caregiver and naïve listener report had accurate portrayals of the infants' prelinguistic speech and language developmental trends.

Limitations

Several possible limitations have been set forth that may resolve differences in listener reports. The amount of vocalizations heard by each listener could have

influenced the number of vocalizations reported. Caregivers simply had more opportunity to hear sounds produced by the infants. If naïve listeners had more opportunity to hear sounds, such as presentation of each recording twice instead of a single instance, it is anticipated that a higher number of different vocalization types would have been reported. The transcribers also heard far fewer vocalizations than the caregivers, yet were able to analyze and document each sound to which they listened.

It is further believed that because of closer contact with the infants, caregivers have a greater inherent understanding of the infant's repertoire. It is possible that because there was no direct contact with the infants, no viewing of video recordings even, the naïve listeners were at a disadvantage from reporting more similar findings to caregivers and transcribers.

The transcribers were aware of the age and infant for which they were transcribing, allowing for potential bias in transcriptions. The utterances were listened to in chronological order.

There is also concern that caregivers may have been biased toward over- or under-representation of their child's vocalizations. For example, a parent with an older child that has autism may compare her second infant to her first and assume that he is typically developing (and perhaps over-represent the sounds he/she is making), or be in denial that her second child also has delays (if that is indeed the case). Either scenario may change the kind of responses the parent gives about questions regarding the development of his/her child.

This is simply a comparison of two infants. A larger sample would be needed to make more solid conclusions. It is recognized that in order to report statistical significance, a much larger group of participants needs to be studied.

Clinical Implications

It is anticipated that through this new methodology of relying on caregiver report to track infant vocalizations, the gap between research and clinical practice can be eliminated. For example, a clinician working with infants can easily ask caregivers (whether that be grandparents, parents, neighbors, or even daycare specialists) what sounds the infant is making. The same clinician is not likely to have time to invest in recording and phonetically transcribing the infant's vocalizations. Caregiver report is natural and does not require special training. In this case study, the caregivers appear to have given us accurate information regarding the development of their children. It appears that with caregiver report, if there is a discrepancy in the reported sounds and what would be expected in typical development, further testing and therapy can begin immediately, instead of waiting for a larger deficit to appear.

Further, with additional consideration and refinement of methodology, naïve listeners are potentially the link between caregivers and laboratory measures, creating less need to take caregiver's limited time.

Future Directions

Based on the results and limitations of this study, it is suggested that future research be conducted on larger, more representative samples. This would increase the ability to generalize the data and broaden the scope of understanding for this

methodology. Additionally, phonetic transcription needs to be included to compare across methods and present a more solid picture of the best practice for documenting infant vocalizations.

It is further suggested that more specific training for naïve listeners needs to take place; perhaps utilizing a sample file to listen and compare with laboratory staff before performing the task. The naïve listeners of this study did not have children, and it would be useful to determine if caregivers have greater acuity to infant vocalizations than the non-caregiver counterpart. Potentially caregivers listening to other infants would report different vocalizations than naïve listeners who do not have their own children.

Overall, the results and clinical implications of this study warrant further investigation of these methods for tracking vocal development. The potential to translate this research into accessible means for speech-language pathologist and pediatricians creates a need to continue to investigate these methodologies.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* 5th ed.). Arlington, VA: American Psychiatric Publishing.

Ball, M. J., & Rahilly, J. (2002). Transcribing disordered speech: The segmental and prosodic layers. *Clinical Linguistics & Phonetics 16*(5)*,* 329-344.

Centers for Disease Control and Prevention (2010). Prevalence of autism spectrum disorder among children aged 8 years – Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2010. Retrieved from http://www.cdc.gov/ncbddd/autism/data.html

Chawarska, K., Paul, R., Klin, A., Hannigen, S., Dichtel, L. E., & Volkmar, F. (2007). Parental recognition of developmental problems in toddlers with autism spectrum disorders. *Journal of Autism & Developmental Disorders*, *37*, 62-72. doi: 10.1007/s10803-006-0330-8

De Giacomo, A., & Fombonne, E. (1998). Parental recognition of developmental abnormalities in autism. *European Child & Adolescent Psychiatry, 7*(3), 131-136.

Feldman, H. M., Dale, P. S., Campbell, T. F., Colborn, D. K., Kurs-Lasky, M., Rockette, H. E., & Paradise, J. L. (2005). Concurrent and predictive validity of parent reports of child language at ages 2 and 3 years. *Child Development*, *76*, 856–868.

Fenson, L., Dale, P., Reznick, S., Thal, D., Bates, E., Hartung, J., et al. (1991). *The MacArthur communicative development inventories*. San Diego, CA: San Diego State University.

French, A. (1988). What shall we do with "medial" sounds? *British Journal of Disorders of Communication, 23,* 41-50.

Girolametto, L., Weitzman, E., Wiigs, M., & Pearce, P.S. (1999). The relationship between maternal language measures and language development in toddlers with expressive vocabulary delays. *American Journal of Speech-Language Pathology, 8,* 364-374.

Goldstein, M.H., & Schwade, J.A. (2008). Social interaction to infants' babbling facilitates rapid phonological learning. *Psychological Science, 19,* 515-523.

Gros-Louis, J., West, M.J., Goldstein, M.H., & King, A.P. (2006). Mothers provide differential feedback to infants' prelinguistic sounds. *International Journal of Behavioral Development, 30,* 112-119.

Grunwell, P. (1986). Aspects of phonological development in later childhood. In K. Durkin (Ed.), *Language development in the school years* (pp. 34-56). London, England: Croom Helm.

Hebbeler, K. (2009). *First five years find briefing. Presentation given at a Congressional briefing on June 11, 2009, to discuss Education that works: The impact of early childhood intervention on reducing the need for special education services.* Retrieved from http://www.sri.com/neils/pdfs/FFYF_Briefing_Hebbeler_June2009_test.pdf

Hebbeler, K. Spiker, D., Bailey, D., Scarborough, A., Mallik, S., Simeonsson, R., & Singer, M. (2007). *Early intervention for infants & toddlers with disabilities and their families: Participants, services, and outcomes. Final report of the National Early*

Intervention longitudinal Study (NEILS). Retrieved from http://www.sri.com/neils/pdfs/NEILS_Report_02_07_Final2.pdf

Heilmann, J., Ellis Weismer, S., Evans, J., & Hollar, C. (2005). Utility of the MacArthur-Bates Communicative Development Inventory in identifying language abilities of late-talking and typically developing toddlers. *American Journal of Speech-Language Pathology, 14,* 40-51.

Julien, H.M., & Munson, B. (2012). Modifying speech to children based on their perceived phonetic accuracy. *Journal of Speech, Language, and Hearing Research, 55,* 1836-1848.

Killeen, R. J. (2014). *Caregiver and naive listener report of infant vocalizations: Toward identification of prelinguistic markers for autism* (Master's thesis). Idaho State University, Pocatello, ID.

Korkman, M., Jaakkola, M., Ahlroth, A., Pesonen, A.-E., & Turunen, M.-M. (2004). Screening of developmental disorders in five-year-olds using the FTF (Five to Fifteen) questionnaire: A validation study. *European Child and Adolescent Psychiatry, 13*(Suppl. 3), 31-38.

Locke, J. L. (1983). Phonological acquisition and change. New York, NY: Academic Press.

McDuffie, A., & Yoder, P. (2010). Types of parent verbal responsiveness that predicts language in young children with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research, 53,* 1026-1039.

Molemans, I., van den Berg, R., van Severen, L., & Gillis, S. (2012). How to measure the onset of babbling reliably? *Journal of Child Language, 39*(3), 523-552.

Müller, N., & Damico, J. S. (2002). A transcription toolkit: Theoretical and clinical considerations. *Clinical Linguistics & Phonetics, 16*(5), 299-316.

Oller, D.K. (2000). *The emergence of the speech capacity.* Mahwah, NJ: Erlbaum.

Oller, D.K., Eilers, R.E., & Basinger, D. (2001). Intuitive identification of infant vocal sounds by parents. *Developmental Science, 4,* 49-60.

Oller, D. K., Niyogi, P., Gray, S., Richards, J. A., Gilderson, J., Xu, D.,…Warren, S. F. (2010). Automated vocal analysis of naive recording from children with autism, language delay, and typical development. *Proceedings of the National Academy of Sciences, 107*(3), 13354-13359. doi:10.1073/pnas.1003882107

Olson, J., & Masur, E.F. (2012). Mothers respond differently to infants' familiar versus non-familiar verbal imitations. *Journal of Child Language, 39,* 731-752.

Ouellette-Kuntz, H., Coo, H., Miu, L., Breitenbach, M. M., Hennessey, P. E., Jackman, P. D.,…Chung, A. M. (2013). The changing prevalence of autism in three regions of Canada. *Journal of Autism Developmental Disorders, 44,* 120-136.

Paul, R., Fuerst, Y., Ramsay, G., Chawarska, K., & Klin, A. (2011). Out of the mouth of babes: Vocal production in infant siblings of children with ASD. *The Journal of Child Psychology and Psychiatry, 52*(5), 588-598. Doi: 10.1111/j.1469-7610.2010.02332.x

Ramsdell, H. L., Oller, D. K., Buder, E. H., Ethington, C. A., & Chorna, L. (2012). Identification of prelinguistic phonological categories. *Journal of Speech, Language, and Hearing Research, 55*, 1626-1639.

Ramsdell, H.L., Oller, D.K., & Ethington, C.A. (2007). Predicting phonetic transcription agreement: Insights from research in infant vocalizations. *Journal of Clinical Linguistics and Phonetics*, *21*, 793-831.

Rescorla, L., & Alley, A. (2001). Validation of the Language Development Survey (LDS): A parent report tool for identifying language delay in toddlers. *Journal of Speech, Language, and Hearing Research, 44,* 434-445.

Smith, V., Mirenda, P., & Zaidman-Zait, A. (2007). Predictors of expressive vocabulary growth in children with autism. *Journal of Speech, Language, and Hearing Research, 50*, 149-160.

Stoel-Gammon, C. (1985). Phonetic inventories, 15-24 months: A longitudinal study. *Journal of Speech and Hearing Research*, *28*, 505-512.

Watson, L.R., Baranek, G.T., Crais, E.R., Reznick J. S., Dykstra, J., & Perryman, T. (2007). The first year inventory: Retrospective parent responses to a questionnaire designed to identify one-year-olds at risk for autism. *Journal of Autism & Developmental Disorders, 37*, 49-61. doi: 10.1007/s10803-006-0334-4.

Wetherby, A.M., Allen, L., Cleary, J., Kublin, K., & Goldstein, H. (2002). Validity and reliability of the Communication and Symbolic Behavior Scales Developmental

Profile with very young children. *Journal of Speech, Language, and Hearing Research, 45,* 1202-1218.

Yavaş, M. (1998). *Phonology: Development and disorders.* San Diego, CA: Singular.

Yoder, P., Stone, W. L., Walden, T., Malesa, E., (2009). Predicting social impairment and ASD diagnosis in younger siblings of children with autism spectrum disorder. *Journal of Autism & Developmental Disorders, 39,* 1381-1391.

Zwaigenbaum, L., Thurm, A., Stone, W., Baranek, G., Bryson, S., Iverson, J.,…Sigman, M. (2007). Studying the emergence of autism spectrum disorders in high-risk infants: Methodological and practical issues. *Journal of Autism and Developmental Disorders, 37*, 466-480. DOI: 10.1007/s10803-006-0179-x