Vocalization Behavior During the Autism Observation Scale for Infants in Siblings of Children with Autism Spectrum Disorders

Lindsay Williams

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science

University of Washington, Seattle

2013

Committee:

Annette Estes

Truman Coggins

John Thorne

Program Authorized to Offer Degree

Speech and Hearing Sciences

University of Washington

Abstract

Vocalization Behavior During the Autism Observation Scale for Infants in Siblings of Children with Autism Spectrum Disorders

Lindsay Williams

Chair of Supervisory Committee:

Research Associate Professor Annette Estes

Speech and Hearing Sciences

Due to the high heritability rate of autism, recent investigative efforts have focused on prospectively studying infant siblings of children with autism spectrum disorders (ASD) in order to map the developmental trajectory and potentially lower the age at which children may be diagnosed. Additionally, children with ASD typically exhibit language delays, therefore the purpose of this study was to evaluate pre-speech vocal productions of 6-month old infant siblings at high-risk (HR) and low-risk (LR) for ASD. Video recordings collected during standardized testing were analyzed and coded for babbling, consonant inventories, and atypical vocalizations. These data were then evaluated to determine if vocal behavior at 6 months was predictive of an autism diagnosis at 24 months. At 6 months, HR infants produced a higher percentage of canonical syllables than their LR peers. No other significant differences were found, and vocal behaviors at 6 months were not associated with higher scores on the Autism Diagnostic Observation Schedule (ADOS) at 24 months. Therefore, the results of this study provide evidence that there are few meaningful differences in vocal behavior between HR and LR infants at 6 months.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS

Page

LIST OF FIGURES

Figure Number **Page**

LIST OF TABLES

Table Number **Page**

ACKNOWLEDGMENT

To my parents and family, for their support and dedication to learning.

The author especially wishes to thank Nicole Kristek, for her contributions to early drafts of the "Introduction," completed Autumn-2011, in fulfillment of requirements for *SPHSC 506:Research Methods*.

Introduction

Autism spectrum disorders (ASD) are developmental disorders defined by qualitative impairments in social interaction and communication, and include restricted, repetitive and stereotyped patterns of behavior, interests and activities, with onset of symptoms typically before age three (4th ed., text rev.; *Diagnostic and statistical manual of mental disorders;* American Psychiatric Association, 2000). The prevalence of ASD for year 2008, the most recent year to be surveyed by the Centers for Disease Control and Prevention (CDC), is estimated to be 11.3 per 1000 children aged 8 years (2012). These latest data indicate an increase of 71% among this population during years 2002–2008 (from 6.4 to 11.3 per 1,000). The increase in estimated prevalence can partly be attributed to a heightened awareness of ASD in family health practitioners, educators, and the general public. However, a combination of genetic and environmental factors likely play a role as well (Lichtenstein, Carlstrom, Rastam, Gillberg, & Anckarsater, 2010; Engel & Daniels, 2011), and there is evidence to suggest underlying anatomical and physiological differences which begin pre- and neo-natally (Rodier, Ingram, Tisdale, Nelson, & Romano, 1996).

For example, the clinical onset of autism appears to be preceded by two phases of brain growth abnormality: a reduced head size at birth and a sudden and excessive increase in head size between 1 to 2 months and 6 to 14 month (Courchesne, Carper & Akshoomoff, 2003). By age 2- to 3-years, children with autism had greater cerebral white matter volume, and more cortical gray matter volume than their typically developing peers. Neurological differences continue to develop into adolescence, as children with autism were found to have a decrease in both white and gray matter volume compared to typically developing peers (Courchesne et al., 2001). Neonatal blood samples from children with ASD were found to have differences suggesting that the aberrant expression of certain proteins may play a role in the development of neurobehavioral disorders (Nelson et al., 2001).

Research investigating the neurodevelopmental trajectory and profile of autism is therefore, currently focusing on a number of possible indicators, including examining a general family phenotype, or “broader autism phenotype” (BAP) (Ben-Yizhak et al., 2011; Schmidt et al., 2008; Schwichtenberg, Young, Sigman, Hutman, & Ozonoff, 2010) and a search for biological markers (Carayol et al., 2010; Guerini et al., 2011; Dawson et al., 2007). At this time, however, the current standard for identification remains behavioral, with young children showing deficits or abnormalities in the areas of sensorimotor functioning, temperament, cognition, adaptive functioning and communication (Bryson, Zwaigenbaum, McDermott, Rombough, & Brian, 2008). Although characteristics are frequently reported to have been present by 12 months of age, typically measured through retrospective parent report or review of home videos (Zwaigenbaum et al., 2005), the average age of diagnosis remains closer to 24 months (Bryson et al., 2008).

With an increasing body of literature emphasizing the benefits of early intervention for children with ASD (for example: Dawson, 2008; Zwaigenbaum et al., 2009) developmental, behavioral, and neurobiologic research is attempting to refine the process of identification by establishing an early risk profile and mapping the developmental trajectory. Although this is not a new area of study, the broad spectrum of the disorder, early nature of the onset, and frequent retrospective reporting have contributed to limited quantifiable information regarding the first manifestations of autism in very young children.

Prospective research is currently investigating developmental and neurobiological characteristics in a sample of infants to help distinguish those children who will later be diagnosed with ASD (e.g., Wolff et al., 2012). This paper is part of a larger multisite prospective project, the Infant Brain Imaging Study (IBIS) that has been following more than three hundred children across the country in an effort to capture the earliest onset of certain key predictive characteristics. The study includes a “high-risk” (HR) group of infants who currently have an older sibling with a confirmed diagnosis of ASD and a control, “low risk” (LR) group, who do not have an older sibling with ASD. A number of studies have utilized the infant sibling model to increase the chances of prospectively including children who will later receive an ASD diagnosis. Autism has a heritability estimate of over 90% (Bailey et al., as cited in Landa & Garrett-Mayer, 2006) and a recurrence risk of 4.5% - 10% for families who already have one child with autism (Landa & Garrett-Mayer, 2006; Zwaigenbaum et al., 2005; Bryson et al., 2008). These studies have yielded valuable data about the early traits of children later diagnosed with ASD. Specifically, by 12 months of age, siblings who are later diagnosed with autism may be distinguished from other siblings and low-risk controls on the basis of several specific behavioral markers, including atypicalities in eye contact, visual tracking, disengagement of visual attention, orienting to name, imitation, social smiling, reactivity, social interest and affect, and sensory-oriented behaviors; prolonged latency to disengage visual attention; a characteristic pattern of early temperament, with marked passivity and decreased activity level at 6 months, followed by extreme distress reactions, a tendency to fixate on particular objects in the environment, and decreased expression of positive affect by 12 months; and delayed expressive and receptive language (Zwaigenbaum et al., 2005).

Similar early-age indicators have been found in other studies (Bryson et al., 2008), for example:

> Signs of autism emerged and/or were more striking earlier (by 12 vs. 18 months) in the subgroup with a decrease in measured IQ (hereafter, ‘‘early onset’’ cases). However, all of the children, in varying degrees, showed a combination of impaired social communicative development (lack of interest/pleasure in, and/or self-initiated contact with, others) and a behavior profile marked by visual fixation, and other atypical sensory and motor mannerisms and/or repetitive behaviors. In all of the children, the emergence of autism was associated, again in varying degrees, with what can be described as a distinct temperament profile characterized by marked irritability, intolerance of intrusions, proneness to distress/negative affect, and difficulties with self- or other-regulation of state. (p. 21-22)

Although many of these studies mention early communication, a general focus has been devoted to early indicators of temperament and visual attention, possibly because these features may be more readily categorized. Some research, however, has focused on the early speech and language characteristics of children with ASD, such as orienting to name, social referencing, joint attention, limited vocal imitation, fewer gestures, fewer comprehended phrases, delayed onset of speech, babbling characteristics and unusual vocalizations (Mitchell et al., 2006; Volkmar, Chawarska, & Klin, 2005). A commonly occurring theme is the presence of atypical vocalizations, that is, those occurring with an atypical vocal quality. Children in a HR category have been found to produce a greater number of non-speech-like vocalizations, such as high-pitched squealing, even when compared with language-matched peers (younger chronologically) (Sheinkopf, Mundy, Oller, & Steffens, 2000; Schoen, Paul & Chawarska, 2011; Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011). Some data suggest that children from the HR group produced fewer consonants than their peers and demonstrated fewer canonical syllable shapes at age 9 months (Paul et al., 2011). The presence of non-English consonant combinations has been observed in the early babbling of children later diagnosed with ASD, and it has been theorized that these children, "show… a failure to shape their production toward the sound parameters of the ambient language… a reduced tendency to hone sound production increasingly closely to models produced by others in the environment." (Schoen, et al., 2011).

Development of Vocalization and Babbling

By four to 6 months, infants undergo anatomical growth resulting in elongation of the pharynx, descent of laryngeal structures, and increased space in the oral cavity (Sapienza, Ruddy, & Baker, 2004). These changes allow for increased control and movement of speech articulators such as the tongue and soft palate, resulting in prelinguistic reflexive (e.g., cries, coughs) and non-reflexive vocalizations (e.g., cooing, babbling) (Morris & Klein, 2001). Vocal play may include a wide variety of productions including squeals, yells, bilabial trills, fricatives, and vowels. While some consonant-vowel (CV) sequences are produced, they tend to be more irregular and do not yet reach the level of true canonical babbling, which is characterized by having "well-formed syllables," "utterances that might be mistaken for words but have no meanings associated with them" (Oller, Neal, & Cobo-Lewis, 1998) and "obey timing restrictions of natural languages" (Oller, Eilers, Bull, & Carney, 1985).

Research on typical English-language acquisition of young children (Templin, 1957; Sander, 1972; Stoel-Gammon, 1985; Smit, 1990; Shriberg, 1993; Robb & Bleile, 1994) generally agree on a developmental pattern in which consonant inventories are built over time, with certain consonants emerging earlier than other consonants. The place of articulation for earlier developing sounds is predominantly bilabial, alveolar and glottal, and the manner of articulation is predominately stopping in the oral and nasal cavities (Robb & Bleile, 1994).

A number of studies demonstrate the acquisition of canonical babbling to be "relatively impervious to a number of potential risk factors" (Oller et al., 1998), including prematurity, low socio-economic status (SES), presence of Down syndrome or exposure to multiple languages. It is argued that because of the relatively robust nature of babbling development, a delay or disturbance may be a marker of a more serious disorder such as autism, pervasive developmental disorder, neurogenic disorders such as dysarthria and apraxia, and specific language impairment or dyslexia, and should therefore be monitored carefully.

A recent study describes early vocal behaviors in at-risk infants (Paul et al., 2011). The purpose of the study was to gain insight into pre-speech vocalization between 6 and 12 months, and the transition to speech and language in infants at risk for autism. It was theorized that a "direct and detailed analysis of vocal behaviors in infants at risk for ASD will provide richer information than scores on standard tests, such as Mullen, or than retrospective parent report". The study suggested three main advantages for a detailed analysis of vocal behavior beyond previously reported measures include the following:

1. Detailed analysis may identify prelinguistic behaviors such as consonant acquisition, syllable shapes, or prosodic contours that are not captured by standardized measures.
2. While parents may be sensitive to certain linguistic milestones such as first words and babbling, they are unlikely to recall specific details such as consonant or syllable development and distribution.
3. Such an analysis is likely to avoid errors of recall and bias common in retrospective reports.

At 6 months, they found that "only the *number of middle consonant types* produced by the HR infants at 6 months was significant in classifying participants with and without autistic symptoms at 24 months." (p. 594)

Purpose of the Study

In light of the possibility that early vocalizations may be important risk factors for developing ASD, the present study aims to analyze vocalizations recorded from clinical evaluations in a sample of 6-month-old infants.

Research Questions

The following hypotheses will be tested:

1. HR infant vocalizations will contain fewer consonants and canonical syllables, and more non-speech or atypical productions than LR peers at 6 months of age.
2. Less frequent and well-developed pre-speech vocal production in the first year will be predictive a diagnosis of autism during the second year of life. Specifically, at 6 months during the AOSI evaluation, (a) fewer speech-like vocalizations in total, and (b) fewer speech-like vocalizations per second will be associated with higher scores on the ADOS at 24 months.
3. A smaller middle consonant inventory at 6 months will be associated with higher scores on the ADOS at 24 months.

Method

Data Source

Data were obtained from the Infant Brain Imaging Study (IBIS), an ongoing, multisite longitudinal study investigating brain and behavioral development in ASD, and funded by the National Institutes of Health (grant number: RO1HD5574). Members of the IBIS network include University of North Carolina Chapel Hill; University of Washington, Seattle; the Children’s Hospital of Philadelphia; and Washington University, St. Louis. Additional data processing centers include McGill University, Montreal; and University of Utah, Salt Lake City.

Participants

Participants in the present report were selected from the larger IBIS study, and this subset consisted of 20 infants (13 male, 7 female) selected from the 6-month intake evaluation conducted at the University of Washington and Children's Hospital of Philadelphia. Specifically, the vocalizations studied in this report were recorded during the Autism Observation Scale for Infants (AOSI; Bryson, et al., 2008). Participants were selected randomly within three groups (HR autism/autism spectrum, HR non-autism, and LR non-autism) by the director of the UW IBIS site to ensure that the sample included a selection of HR infants with a diagnosis of autism/ASD, HR infants with no autism diagnosis, and LR infants with no diagnosis of autism. The coding team and author of this thesis were unaware of this selection process. The recordings were also pre-screened to ensure that the video quality was sufficient for vocalization coding. The author of this thesis and the coding group remained blind to risk status throughout the coding process. Table 1 provides a summary of child participants, including gender, age, risk status, and final diagnoses.

Table 1
Child Characteristics

Child ID #	Gender	Age in Months at Initial Assessment	Risk Status	Diagnosis
PHI0003	m	6.6	HR	Autism
PHI0071	m	6.0	HR	Autism
SEA0009	m	6.0	HR	Autism
SEA0015	f	6.3	HR	Autism
SEA0037	f	6.3	HR	Autism
SEA0001	m	5.9	HR	Autism Spectrum
SEA0034	m	6.1	HR	Autism Spectrum
SEA0069	f	6.4	HR	Autism Spectrum
SEA0099	f	6.0	HR	Autism Spectrum
SEA0107	m	6.9	HR	Autism Spectrum
SEA0004	m	6.1	HR	No Dx
SEA0007	m	6.2	HR	No Dx
SEA0018	m	6.0	HR	No Dx
SEA0030	f	6.3	HR	No Dx
SEA0068	m	6.0	HR	No Dx
SEA0050	f	6.2	LR	No Dx
SEA0060	m	6.4	LR	No Dx
SEA0078	f	6.5	LR	No Dx
SEA0102	m	6.8	LR	No Dx
SEA0103	m	6.9	LR	No Dx
Participants n = 20 m = 13 f = 7		Mean Age 6.295 mo.	High Risk n = 15 Low Risk n = 5	Diagnosis Autism = 5 ASD = 5 No Dx = 10

For the parent study, children were assessed at 6, 12, 24, and 36 months of age, and given a battery of tests, including MRI brain scans. Infants from two groups were recruited: a group at high risk (HR) for autism (younger siblings of children with autism) and a group at low risk (LR) for autism consisting of children with no family history of ASD. Participants were ineligible if they met any of the following criteria: birthday fell outside of a narrowly established age window (minus one week and plus 3 weeks of 6 months); a history of major sensory or motor impairment; perinatal brain injury or exposure to neurotoxins; significant physical anomalies (i.e., associated with a syndrome); prematurity or low birth weight; genetic disorders associated with ASD (e.g., Fragile X); neurological diseases, or adoption (Estes et al., 2013). Additionally, participants in the LR group were excluded if they had a first degree relative with psychosis, schizophrenia, or bipolar disorder (Wolff et al., 2012).

Procedures

Standard measures. A semi-structured phone interview with the primary caregiver was conducted prior to an in-person visit to obtain developmental and medical history, and assess for exclusionary criteria. Caregivers estimated the adaptive functioning level of older siblings using the Vineland Adaptive Behavior Scales, Second Edition (VABS-II; Sparrow, Balla, & Cicchetti, 2005), which assesses functional skills in five domains: communication, self-care, social, motor skills, and maladaptive behavior. The caregiver answered questions about ASD symptoms in the older siblings using the Autism Diagnostic Interview—Revised (ADI-R), a standardized semi-structured interview intended for differential diagnosis of pervasive developmental disorders (Lord et al., 1997). LR infants were included if older siblings did not meet criteria for ASD on the ADI-R, and did not receive standardized summary scores of less than 80 on the VABS-II.

Upon completion of the telephone interview, infant siblings were evaluated at a data collection site (UW, UNC, CHOP, WashU) by team members meeting reliability and training criteria. Such members included licensed clinical psychologists, doctoral students in clinical psychology, school psychologists, and masters-level psychometricians under the supervision of licensed clinical psychologists (Estes et al., 2013). Cognitive and motor testing was conducted using the Mullen Scales of Early Learning (MSEL; Mullen, 1995), a norm-referenced standardized developmental evaluation for children aged birth to 68 months. Adaptive functioning for infant participants was assessed using the VABS-II.

Examiners directly assessed autism risk markers using the Autism Observation Scale for Infants (AOSI; Bryson, et al., 2008), an observational measure developed to detect signs of autism in infants aged 6-18 months. The measure provides an interactive context for examiners to engage infants in semi-structured activities and systematically elicit specific behaviors such as visual tracking and attentional disengagement, coordination of eye gaze and action, imitation, affective responses, early social-communicative behaviors, behavioral reactivity, and sensory-motor development. It is approximately 20 minutes in length, although there is no strict time limit. Attention is evaluated by introducing a series of noise-makers (e.g., rattle, bell, squeak-toy), which are moved from the child's midline laterally to each side. Infants are rated on their ability to engage, track movements, cross midline, and disengage when competing stimuli are introduced. Social behaviors examined include eye-contact, smile reciprocation, attending to name, anticipation of social routines (i.e., peek-a-boo), social babbling, imitation, social interest, shared affect, and differential response to facial expressions (i.e., the child's response to a sudden change in the examiner's facial expression from smiling to a neutral expression). Temperament is examined yielding scores for behavioral reactivity, ability to transition, cuddliness, and soothability throughout the evaluation.

Vocalization sample collection. The vocalization samples examined in this study were obtained from videos collected during the AOSI examination as part of the original IBIS study. The original evaluation was conducted in a distraction-free testing room equipped with a two-way mirror and digital recording equipment. An examiner was seated across a small table from the parent and infant. The parent, who was present at all times, held the child in their lap or on the table. They were encouraged to soothe or interact with the child as necessary to maintain engagement with the various tasks, but to otherwise assume an observer role. A camera was positioned to record the examiner and capture the presentation of stimulus items to the infant, including facial expressions and body posture. A second camera was positioned so that the child's face could be seen in order to record temperament, eye-gaze behaviors, facial expressions, body movements, and reciprocation of social behaviors as previously outlined. No warm-up period was provided for the child and clinician interaction. Vocalization samples were recorded onto digital media using video recording equipment, typically allowing for "picture-in-picture" to observe the examiner and infant simultaneously.

Transcription. Transcription procedures follow those outlined in Paul et al. (2011) and Schoen, Paul & Chawarska, (2011). Vocalizations were separated into two categories: speech-like and non-speech-like. Utterances were considered speech-like if they resembled typical babble (e.g., speech-like resonance and/or presence of consonant vowel pairs). These were then transcribed using broad phonemic transcription represented by symbols of the International Phonetic Alphabet (IPA). Non-English phonemes were not coded (e.g., clicks, ingressives), and sounds appearing to be distortions of English phonemes were assigned to the nearest perceptual category. Non-speech-like transcription followed the conventions outlined by Scheinkopf et al., (2000), and included vocalizations such as squeals, grunts, growls, laughter, yells, and distress. Non-speech vocalizations were separated into utterances based on breath groups or pauses greater than one second.

The first 50 vocalizations produced by the child during the AOSI were transcribed, including speech-like and non speech-like. Vegetative sounds such as coughing, sneezing or burping were not transcribed.

Coding. Coders were blind to participant's risk group status and 24-month diagnosis.

Speech-like coding. The transcribed utterances were tallied and analyzed for the following information:

Stark assessment of early vocabulary development (SAEVD-R) and syllable structure complexity (SSL). The SAEVD-R (Nathani, Ertmer & Stark, 2006) is a perceptual and articulatory assessment that operationally defines and categorizes infant vocalization behavior into five levels, (a) Reflexive, (b) Control of Phonation, (c) Expansion, (d) Basic Canonical Syllables, and (d) Advanced Forms (see Appendix A for a full list of definitions). Syllable structure complexity was further evaluated by assigning each speech-like utterance to one of the following levels (Olswang, Stoel-Gammon, Coggins, & Carpenter, 1987; R. Paul, personal communication, June 4, 2012):

- Level 1: utterances composed of vowels or continuant single consonants (e.g., /mmm/).
- Level 2: utterances composed of a single consonant plus vowel, which might be reduplicated (e.g., /pa/ or /papa/).
- Level 3: utterances composed of two or more different consonants plus vowels (e.g., /pati/).

For the purposes of this study, these operational definitions and categories were used to help maintain consistency and reliability across participants and coders.

Consonant inventory. The transcribed speech-like utterances were analyzed and an inventory of consonants was built for each participant according to developmental order (i.e., early, middle, and late developing sounds), as classified by Shriberg (1993). The total number of consonant types and the number of consonant types in each of the three developmental categories were computed for each participant.

Table 2
"Shriberg's (1993) classification of developmental order and approximate age of emergence of consonant acquisition in English" (Paul et al., 2011, Table 1, p. 589)

Early 8:	/m/	/b/	/j/	/n/	/w/	/d/	/p/	/h/
Middle 8:	/t/	/ŋ/	/k/	/g/	/f/	/v/	/tʃ/	/dʒ/
Late 8:	/ʃ/	/θ/	/s/	/z/	/ð/	/l/	/ʒ/	/r/

Percent canonical syllable. The total number of syllables containing a true Consonant-Vowel (CV) structure (i.e., babbling; Oller et al., 1998) was counted for each participant and divided by the total number of speech-like vocalizations (Paul et al., 2011).

Non-speech coding. Utterances matching the following criteria established by Sheinkopf et al., (2000) were identified as non-speech-like, and assigned accordingly (Paul et al., 2011).

1. Delight: laughter
2. Atypical Utterances:
    a. Squealing: utterances that at some point enter into falsetto or highly tense maximal pitch register
    b. Growls: low-pitch, often creaky-voice vocalizations
    c. Yells: high-amplitude non-distress vocalizations
    d. Grunt: low-pitched, short, irregular vibration
3. Distress: noncry, nonreflexive utterances characterized as whines or fusses

The sum of non-speech vocalizations was divided by the total number of vocalizations (i.e., speech-like plus non-speech-like) to derive the percentage of non-speech vocalization for each participant.

Cognitive status. It is common for young children with ASD to exhibit uneven or disparate developmental skills (De Giacomo & Fombonne, 1998), and as previously discussed, the MSEL was administered to help define the developmental profile for LR and HR groups and observe potential differences. However, for the purpose of evaluating vocalization behavior, it was necessary to establish that any differences between the two groups were the result of risk status and not strictly cognitive or motor skills. Table 3 lists the means and standard deviations for LR and HR infants at the 6-month evaluation. A Welch Two Sample t-test was conducted to examine possible differences between the two groups with no statistically significant differences found at this age.

Table 3

Mean (and s.d.) MSEL Standard Scores and T-Scores at 6 months for high- vs. low-risk groups

	muagem		mucss		mugmts		muvrts		mufmts		Murlts		muelts	
HR	6.08	(0.26)	95.53	(5.26)	46.47	(6.91)	48.53	(5.28)	47.60	(5.30)	50.00	(8.27)	44.47	(6.45)
LR	6.27	(0.41)	95.20	(8.47)	50.00	(9.75)	47.40	(3.29)	48.20	(9.50)	47.60	(3.29)	47.00	(10.05)
Total	6.14	(0.32)	95.45	(5.96)	47.35	(7.59)	48.25	(4.80)	47.75	(6.31)	49.40	(7.34)	45.10	(7.29)

muagem = Mullen's Age in Months
mucss = Early Learning Composite
mugmts = Gross Motor T-Score
muvrts = Visual Reception T-Score
mufmts = Fine Motor T-Score
murlts - Receptive Language T-Score
muelts = Expressive Language T-Score

* $p < .05$

Further, in order to examine the relationship between cognitive skills, motor skills and vocal production, a pairwise correlation between MSEL scores and vocal production in HR infants was conducted (Table 4). The results indicated no statistically significant correlation between the MSEL scores and vocalization measures at 6 months. This is similar to the results documented in earlier studies, and provides evidence that "vocal production is somewhat independent of developmental level at this age" (Paul et al., 2011).

Table 4
Correlations between MSEL scores and vocal production in HR infants

	TNV	NSL	NC	NEC	NMC	NLC	%CS	%NS
mucss	-0.21	-0.28	-0.28	-0.05	-0.33	NA	-0.04	0.16
mugmts	-0.13	0.01	0.01	0.02	0.01	NA	0.11	-0.27
muvrts	-0.03	0.30	0.30	-0.04	-0.32	NA	0.36	0.38
mufmts	-0.34	0.19	-0.19	-0.19	0.03	NA	-0.14	-0.05
murlts	0.09	-0.01	-0.00	0.14	-0.29	NA	-0.34	0.09
muelts	-0.15	-0.09	-0.04	-0.00	-0.10	NA	0.21	-0.07

*p < .05

TNV = total number of vocalizations
NSL = number of non-speech-like vocalizations
NC = total number of consonants
NEC = total number of early consonants
NMC = total number of early consonants
NLC = total number of late consonants
%CS = percent canonical syllables (TNCS/SL)
%NS = percent non-speech vocalizations (NSL/TNV)
mucss = MSEL Early Learning Composite
mugmts = MSEL Gross Motor T-Score
muvrts = MSEL Visual Reception T-Score
mufmts = MSEL Fine Motor T-Score
murlts – MSEL Receptive Language T-Score
muelts = MSEL Expressive Language T-Score

Sample length. As the AOSI is an untimed test and the language samples were capped at 50 vocalizations, the overall length of each participant's sample varied. The shortest sample at 520 seconds was nearly one-third the length of the longest sample at 1416 seconds. Given this disparity, the possibility arises that differences observed in vocal measures (e.g., total number of utterances) may have been the result of sample length, and not risk status. In order to account for potential confounding factors in sample length, a Welch Two Sample t-test was conducted to examine differences in HR and LR groups (Table 5). The results of the t-test indicated that variations in the duration of the language samples were not statistically significant between the two groups, and therefore provided evidence that differences in vocalization measures were not simply the result of sample length.

Table 5
Mean and SD Length of AOSI Assessment for high- vs. low-risk groups &
T test Comparing Mean AOSI Assessment Length Between Groups

AOSI Length (sec)	Mean	SD	Max	Min	Mdn	*t* value	df	*p* value
HR	757.2	126.8	1005	567	750			
LR	811.2	357.6	1416	520	670			
Total	770.7	198.3	1416	520	749	-0.331	4.340	0.756

*p < .05

Reliability.

Training procedure. The author of this paper, a second year master's student in the Department of Speech and Hearing Sciences, served as the primary coder. Three post-baccalaureate students having experience with IPA transcription were recruited from that department to serve as reliability coders. Training of coders began by reading foundational literature and reviewing the AOSI testing protocol while watching pre-recorded AOSI sessions to gain familiarity with the assessment and assessment procedures. Coders then scored a random selection of practice videos together (see Appendix B for coding sheet), pausing after each vocalization to compare transcriptions and discuss assignment categories based on the SAEVD-R (Nathani, Ertmer & Stark, 2006) and SSL (Olswang et al., 1987) until consensus was reached. As the raters became more consistent and proficient, coding continued simultaneously, but individually, with discussion only at the end of each AOSI session. This process continued until point-to-point reliability exceeded 80% for three consecutive videos. The author of this paper then coded a 10% randomly selected sample of videos. The trained raters independently and separately scored the same selection of videos, achieving point-to-point reliability of 80% on all coding categories.

Data Analyses. Data analysis was conducted first through descriptive measures such as reporting means and standard deviations for each variable, and second through inferential statistics to compare performance across both groups.

Hypothesis 1.

The means and standard deviations for each of the eight coding categories were recorded: (1) total number of vocalizations, (2) total number of speech-like vocalizations, (3) total number of consonants, (4) total number of early consonants, (5) total number of middle consonants, (6) total number of late consonants, (7) percent canonical syllables, (8) percent non-speech vocalizations. Welch Two Sample t-tests were conducted to examine differences between risk groups in the eight coding categories.

Hypothesis 2. A linear regression analysis was used to test if fewer speech-like vocalizations in total (i.e., total number) and fewer speech-like vocalizations per second (i.e., frequency) during the AOSI at 6 months significantly predicted participants' severity scores on the ADOS at 24 months.

Hypothesis 3. A linear regression analysis was used to test if middle consonant inventory at 6 months significantly predicted participants' severity scores on the ADOS at 24 months.

Results

Hypothesis 1

The primary research hypothesis in this study is as follows: *HR infants will produce fewer consonants and canonical syllable shapes, and more non-speech vocal behavior than LR peers.*

Vocalization behavior. To address this hypothesis, the vocalizations of both groups were tallied and categorized according to speech-like or non speech-like criteria (Appendix C).

Total number of vocalizations. A summary of the total number of vocalizations produced by the study participants is shown in Table 6. The fewest number of vocalizations was 7, and the highest 50 (M = 26.50, SD = 14.89). The mode for the entire sample was also 50, with 3 infants reaching that cap. There was considerable spread for each group, with LR infants producing a minimum of 7 vocalizations, and a max of 50 (M = 29.40, SD = 20.18). Results for the HR group was similar, with 8 as the minimum and 50 as the maximum (M = 25.53, SD = 13.44). The modes for HR infants were 22 (2), and 50 (2).

Table 6
Total Number of Vocalizations for HR and LR groups at 6 months

Risk Group	Total # Vocalizations					
	Mean	*SD*	*Min*	*Max*	*Mode*	*Median*
HR	25.53	13.44	8	50	22, 50	25
LR	29.40	20.18	7	50	-	36
Total	26.50	14.89	7	50	50	26.5

A histogram of vocalizations is presented in Figure 1. Again, this figure highlights the range in total number of vocalizations produced at this age.

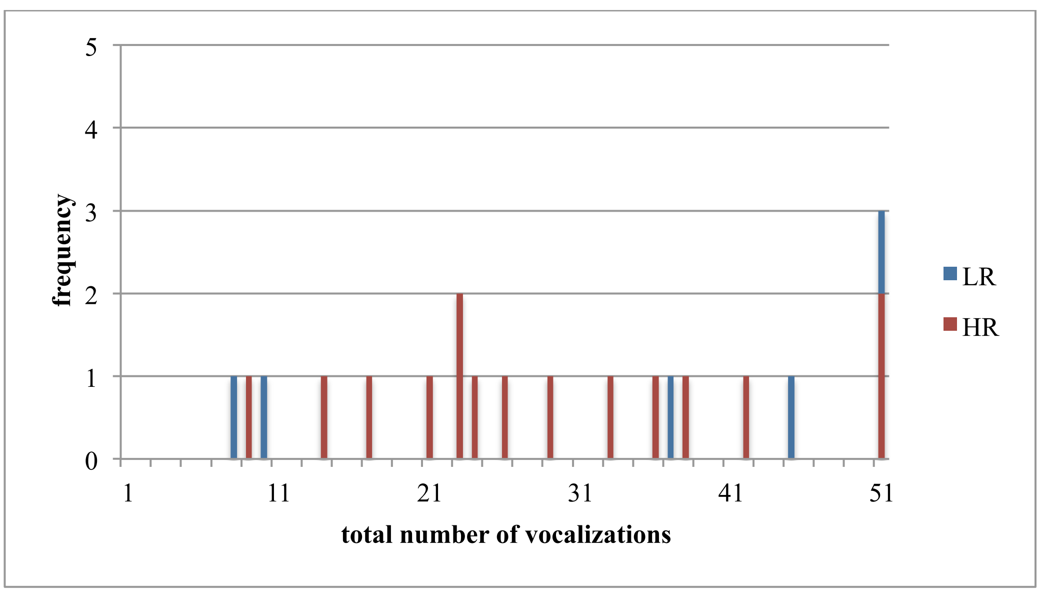

Figure 1. Histogram for Total Number of Vocalizations at 6 months

Number of consonants. The total number of consonants produced by both groups was relatively low (*M* = 1.90, *SD* = 1.12; Table 7), especially given the mean sample length of 770 seconds. The mean number of consonants produced by the HR group was 1.93 (*SD* = 1.10), and LR 1.80 (*SD* = 1.12). The results of the *t*-tests indicated that these differences were not statistically significant (*p* = 0.84). Therefore, HR infants did not produce significantly fewer consonants than their LR peers.

Table 7

T tests Comparing Mean (s.d.) Consonant Measures Between Groups

	Risk Status								
Domain	HR		LR		Total		*t* value	df	*p* value
#Consonants	1.93	(1.10)	1.80	(1.12)	1.90	(1.12)	0.21	6.03	0.84
#Early Consonants	1.60	(0.99)	1.60	(0.99)	1.60	(0.99)	0.00	6.13	1.00
#Middle Consonants	0.33	(0.49)	0.20	(0.47)	0.30	(0.47)	0.56	7.47	0.59
#Late Consonants	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)	-	-	-

*p < .05

Participants varied considerably in their individual responses, as detailed in Table 8. The minimum number of consonants produced was zero (LR = 1, HR = 1), the maximum was four (LR = 0, HR = 2), and the modal was two (LR = 1, HR 7). Five participants (25%) produced only one consonant that could be reasonable transcribed using IPA (LR = 1, HR 4). Several participants produced early developing consonants, with /m/ (*n* = 16) /j/ (*n* = 3) and /h/ (*n* = 11) occurring most frequently. Of those who produced middle-developing consonants, the sounds were restricted to velars, primarily /k/ (*n* = 2) and /ŋ/ (*n* = 3). Neither group produced later developing speech sounds. The most frequently occurring class of sounds were nasals (/m, n, ŋ/), stops (/b, k, g/), and fricatives (/j, h/).

Table 8

Consonant Inventory of HR and LR infants at 6 months

ID	Early Consonants								Middle Consonants								Late Consonants								Risk Status
	m	b	j	n	w	d	p	h	t	ŋ	k	g	f	v	ʧ	ʤ	ʃ	θ	s	z	ð	l	ʒ	ɹ	
PHI0003	X							X																	HR
PHI0071	X							X																	HR
SEA0009																									HR
SEA0015	X											X													HR
SEA0037								X																	HR
SEA0001	X		X								X														HR
SEA0034								X																	HR
SEA0069	X									X															HR
SEA0099	X			X				X		X															HR
SEA0107	X	X						X																	HR
SEA0004	X							X																	HR
SEA0007	X																								HR
SEA0018	X		X	X				X																	HR
SEA0030	X										X														HR
SEA0068	X																								HR
SEA0050																									LR
SEA0060	X							X																	LR
SEA0078	X																								LR
SEA0102	X							X		X															LR
SEA0103	X		X					X																	LR
TOTAL	16	1	3	2	0	0	0	11	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	

Canonical syllables. The percentage of canonical syllables (i.e., the number of CV syllables divided by the total number of speech-like vocalizations) was calculated for LR (*M* = 3.04, *S.D.* = 14.49) and HR (*M* = 14.17, *S.D.* = 15.69) groups, with results summarized in Table 8. The HR group did not vary significantly from LR peers in the vocalization measures of Total Number of Vocalizations ($p = 0.71$) and Total Number of Speech-Like Vocalizations ($p = 0.67$). However, HR infants produced a significantly higher percentage of canonical syllables ($p = 0.024$) than the LR group, which is in direct opposition to the hypothesized result. Post hoc analysis of the *total number of canonical syllables* produced by each group using Welch's two-sample *t*-test did not yield significant differences on this measure (Table 9).

Table 9

T tests Comparing Mean (s.d.) Number of Vocalizations and Percentage of Canonical Syllables Between Groups

	Risk Status								
Domain	HR		LR		Total		*t* value	df	*p* value
Total #Vocalizations	25.53	(13.44)	29.40	(14.89)	26.50	(14.89)	-0.39	5.24	0.71
#Speech-Like	11.93	(9.42)	14.40	(9.61)	12.55	(9.61)	-0.45	6.07	0.67
Total #Canonical Syll	1.87	(2.07)	0.80	(1.30)	1.6	(1.93)	1.35	11	0.20†
%Canonical Syllable	14.17	(15.69)	3.04	(14.49)	11.39	(14.49)	2.46	17.94	0.024*

*p < .05
†post hoc analysis

Table 10

Canonical Syllable Distribution for HR and LR infants at 6 months

ID	TNV	SL	TNCS	%CS	Risk Status	Dx
PHI0003	35	20	8	40	HR	Autism
PHI0071	32	8	2	25	HR	Autism
SEA0009	41	6	0	0	HR	Autism
SEA0015	22	13	1	7.7	HR	Autism
SEA0037	28	20	1	5	HR	Autism
SEA0001	50	36	3	8.3	HR	ASD
SEA0034	13	6	1	16.7	HR	ASD
SEA0069	23	11	0	0	HR	ASD
SEA0099	37	26	1	3.8	HR	ASD
SEA0107	20	6	3	50	HR	ASD
SEA0004	22	8	2	25	HR	No Dx
SEA0007	25	3	0	0	HR	No Dx
SEA0018	16	14	4	0	HR	No Dx
SEA0030	8	4	1	25	HR	No Dx
SEA0068	50	16	1	6.25	HR	No Dx
SEA0050	7	6	0	0	LR	No Dx
SEA0060	36	19	1	5.2	LR	No Dx
SEA0078	9	2	0	0	LR	No Dx
SEA0102	50	15	0	0	LR	No Dx
SEA0103	44	30	3	10	LR	No Dx

TNV = total number of vocalizations
SL = number of speech-like vocalizations
TNCS = total number of canonical syllables
%CS = percent canonical syllables (TNCS/SL)

Non-speech vocal behavior. The percentage of non speech-like vocal behavior (i.e., the total number of non speech-like vocalizations divided by the total number of vocalizations) was calculated for LR (*M* = 47.74%, *S.D.* = 25.11) and HR (*M* = 50.69%, *S.D.* = 25.49) groups, with results summarized in Table 10 and Table 11. The HR group did not vary significantly from LR peers in the vocalization measures of Total Number of Vocalizations ($p = 0.71$) and Total Number of Speech-Like Vocalizations ($p = 0.67$), or Total Percent Non-Speech ($p = 0.84$). Therefore, HR infants did not produce significantly more non speech-like behavior than their LR peers.

Table 11
T tests Comparing Mean (s.d.) Speech-like and Non Speech-like Measures Between Groups

	Risk Status								
Domain	HR		LR		Total		*t* value	df	*p* value
Total #Vocalizations	25.53	(13.44)	29.40	(14.89)	26.50	(14.89)	-0.39	5.24	0.71
#Speech-Like	11.93	(9.42)	14.40	(9.61)	12.55	(9.61)	-0.45	6.07	0.67
%Non-Speech	50.69	(25.49)	47.74	(25.11)	49.95	(25.11)	0.21	6.63	0.84

*p < .05

Participants varied considerably in their individual responses, as detailed in Table 12. The minimum number of non-speech-like vocalizations produced was one (LR = 1, HR = 2), the maximum was 35 (LR = 35, HR = 35), and the median was 13.5 (LR = 13, HR = 14). The most frequently occurring non-speech vocal behavior was grunting (U = 156), followed by delight (D = 48), distress (C = 44) and growling (G = 38). Squealing (S = 8) and yelling (Y = 4) were largely limited to single instances occurring across a few participants.

Table 12

Non Speech-like and Atypical Vocalizations in HR and LR infants at 6 months

ID	TNV	SL	NSL	%NS	S	G	Y	D	C	U	Risk Stat.	Dx
PHI0003	35	20	15	42.9	0	1	0	5	7	2	HR	Autism
PHI0071	32	8	24	75	0	8	0	6	3	7	HR	Autism
SEA0009	41	6	35	85	0	0	0	2	0	33	HR	Autism
SEA0015	22	13	9	40.9	3	0	0	0	0	6	HR	Autism
SEA0037	28	20	8	28.6	0	1	0	0	6	1	HR	Autism
SEA0001	50	36	14	28	0	0	0	3	9	2	HR	ASD
SEA0034	13	6	7	53.8	1	0	0	1	1	4	HR	ASD
SEA0069	23	11	12	52.2	1	0	0	9	0	2	HR	ASD
SEA0099	37	26	11	29.7	1	5	0	1	2	2	HR	ASD
SEA0107	20	6	14	70	0	0	1	6	0	7	HR	ASD
SEA0004	22	8	14	63.6	0	0	0	1	2	11	HR	No Dx
SEA0007	25	3	22	88	0	0	0	0	2	20	HR	No Dx
SEA0018	16	14	2	12.5	1	0	1	0	0	0	HR	No Dx
SEA0030	8	4	4	50	0	0	0	3	0	1	HR	No Dx
SEA0068	50	16	34	68	0	6	0	0	0	28	HR	No Dx
SEA0050	7	6	1	14.3	0	1	0	0	0	0	LR	No Dx
SEA0060	36	19	17	47.2	0	0	0	11	3	3	LR	No Dx
SEA0078	9	2	7	77.8	0	1	1	0	3	2	LR	No Dx
SEA0102	50	15	35	70	0	15	0	0	1	19	LR	No Dx
SEA0103	44	30	13	29.5	1	0	1	0	5	6	LR	No Dx
		Total Atypical Vocalizations			***8***	***38***	***4***	***48***	***44***	***156***		
					Means and (Standard Deviations)							
				HR	0.47 (0.83)	1.40 (2.64)	1.13 (0.35)	2.47 (2.83)	2.13 (2.92)	8.40 (10.36)		
				LR	0.20 (0.45)	3.40 (6.50)	0.40 (0.55)	2.20 (4.92)	2.40 (1.95)	6.00 (7.58)		
				Total	0.40 (0.75)	1.90 (3.85)	0.20 (0.41)	2.40 (3.32)	2.20 (2.67)	7.80 (9.61)		

TNV = total number of vocalizations *S = squeal* *D = delight*

SL = number of speech-like vocalizations *G = growl* *C = distress*

NSL = total number non speech-like vocalizations *Y = yell* *U = grunt*

%NS = percent non-speech vocalizations (NSL/TNV)

The means and standard deviations for the total number of atypical vocalizations were compared, and results of the *t*-test were not statistically significant (p = .9516; Table 13). Therefore, HR infants did not produce significantly more atypical vocalizations than their LR peers.

Table 13
Mean and SD Total Atypical Vocalizations for high- vs. low-risk groups
T tests Comparing Mean Atypical Vocalizations Between Groups

Risk Category	Mean	SD	Max	Min	Mdn	*t* value	df	*p* value
HR Atypical	15.000	9.849	35	2	14.00			
LR Atypical	14.600	12.920	35	1	13.00			
Total Atypical	14.900	10.330	35	1	13.500	0.0634	5.641	.9516

*p < .05

Hypothesis 2

The secondary hypothesis presented in this study is as follows: *Less frequent and well-developed pre-speech vocal production in the first year will be predictive a diagnosis of autism during the second year of life. Specifically, at 6 months during the AOSI evaluation, (a) fewer speech-like vocalizations in total, and (b) fewer speech-like vocalizations per second will be associated with higher scores on the ADOS at 24 months.*

Linear regression analysis. A linear regression analysis was used to test if fewer speech-like vocalizations in total and fewer speech-like vocalizations per second during the AOSI significantly predicted participants' severity scores on the ADOS at 24 months.

Total vocalizations. The results of the regression indicated that the total number of vocalizations explained .00018% of the variance (R^2 =0.000001819, F(1,18)=0.000033, p<.05) in ADOS scores. There is very little relationship between these two measures (Figure 2). Therefore, fewer speech-like vocalizations at 6 months during the AOSI was not predictive of ADOS scores at 24 months.

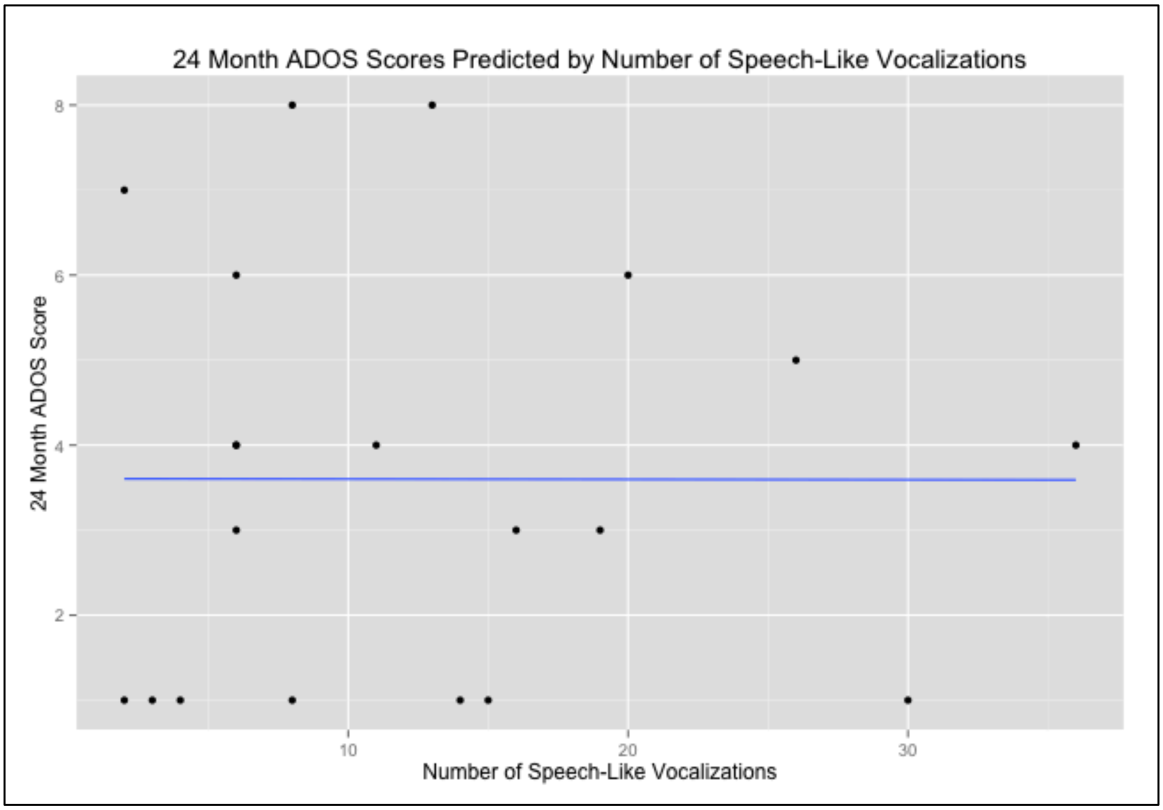

Figure 2. 24 Month ADOS scores predicted by number of speech-like vocalizations.

Frequency of vocalizations. The results of the regression indicated that the total number of vocalizations explained .4477% of the variance (R^2=0.004477, F(1,18)=0.08094, p<.05) in ADOS scores. There is very little relationship between these two measures (Figure 3). Therefore, fewer speech-like vocalizations per second at 6 months during the AOSI was not predictive of ADOS scores at 24 months.

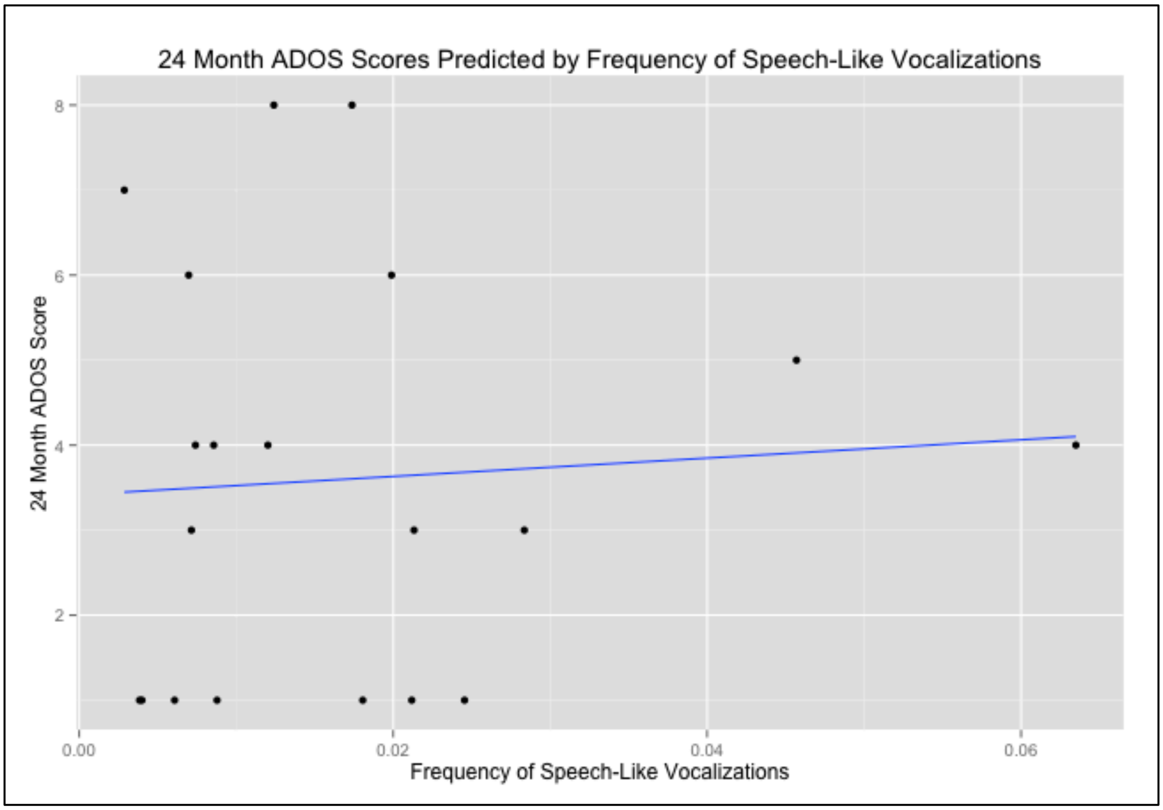

Figure 3. 24 Month ADOS scores predicted by frequency of speech-like vocalizations.

Hypothesis 3

The final hypothesis presented in this study is as follows: *A smaller middle consonant inventory at 6 months will be associated with higher scores on the ADOS at 24 months.*

Linear regression analysis. A linear regression analysis was used to test if the size of the middle consonant inventory significantly predicted participants' severity scores on the ADOS at 24 months. The results of the regression indicated that the total number of vocalizations explained .4137% of the variance (R^2=0.004137, F(1,18)=0.07478, p<.05) in ADOS scores. There is very little relationship between these two measures (Figure 3). Therefore, a smaller middle consonant inventory at 6 months during the AOSI was not predictive of ADOS scores at 24 months.

Discussion

The discussion that follows will first provide a summary and interpretation of findings, and an exploration of the differences between this study and earlier research. This will be followed by a discussion of the study limitations, and finally, future directions for investigation will be presented.

Research Questions

The primary purpose of this investigation was to examine the vocal behaviors of infants at high-and low-risk for autism. This study was prompted, in part, by previous research indicating that vocal behaviors such as babbling (Oller et al., 1985) may be important developmental markers for the identification of children with autism spectrum disorders (Landa & Garrett-Mayer, 2006), and that the development of atypical vocalizations may be quantitatively recorded in infants as early as 6 months (Iverson & Wozniak, 2006; Sheinkopf et al., 2000; Sheinkopf et al., 2012; Schoen et al., 2011; Paul et al., 2011). Video recordings were transcribed and coded according to operationally defined categories (Nathani et al., 2006; Olswang et al., 1987) in order to examine (a) the total number of vocalizations, (b) total number of speech-like vocalizations, (c) total number of consonants, (d) total number of early consonants, (e) total number of middle consonants, (f) total number of late consonants, (g) percent canonical syllables, (h) percent non-speech vocalizations; and to determine if the frequency and quantity of vocalizations were predictive of autism symptomotology at 24 months; and finally, to replicate in part, using participants from the IBIS cohort, previous findings indicating that the number of middle-developing consonants may be predictive of autism symptomotology at 24 months. The findings for these questions are considered below.

Main findings: an overview. The present study resulted in several key findings: (a) HR infants did not produce significantly fewer consonants than LR peers; (b) HR infants produced significantly more canonical syllable shapes than LR peers; (c) HR infants did not produce significantly more non-speech-like behavior than LR peers; (d) the total quantity and frequency of speech-like behavior was not predictive of ADOS severity scores at 24 months; and (e) the middle consonant inventory at 6 months was not predictive of ADOS severity scores at 24 months.

Consonant production. First, the present findings suggest that HR infants do not produce fewer consonants at 6 months than LR peers. This finding supports results reported by Paul and colleagues (2011), who did not find significant differences until infants reached 9 months.

Canonical syllables. The results of this study suggest that there is a significant difference between groups in the percentage of canonical syllables produced. The earlier study also reported differences as revealed through pair-wise comparisons, but only at only at 9 months (p = .04, Cohen's d = .79; Paul et al., 2011). In the present study HR infants produced a higher proportion of canonical babbling compared to their LR peers, however this finding can be largely attributed to the variability in the number of speech-like utterances produced by each participant (Table 9). For example, participants SEA0060 (LR) and SEA0034 (HR) both produced 1 canonical syllable during the AOSI. However, SEA0060 produced 19 speech-like utterances in 670 seconds compared to SEA0034's 6 in 700 seconds, which resulted in a considerable difference in percent canonical speech (SEA0060 = 5.2% vs. SEA0034 = 16.7%). When viewed in isolation, the percent canonical syllable measure does not provide a very meaningful representation of babbling differences at this young age. It may be more useful to compare the frequency of canonical syllables rather than the percentage. This is supported by the results of the post hoc analysis of total number of canonical syllables, which did not find significant differences between the two groups.

Additionally, it's important to note that total sample size for LR candidates was relatively small (LR = 5), which reduces the power for comparisons and increases the likelihood of random noise and outliers affecting results. While many threats to external validity were controlled during the interview and assessment process, it is difficult to categorically profile this group on the basis of five infants. For example, despite the directive to primarily take the role of observer during the AOSI, some parents were more talkative than others, which could have influenced the "talkativeness" of the infant. This difference would likely be minimized in a larger sample, but if only of child's behavior was changed due to parent interaction in this study, it potentially affected 20% of the sample.

Speech-like behavior. This study suggests that HR infants do not produce significantly more non-speech-like productions than LR peers. This is consistent with the earlier report that found that while the proportion non-speech productions was influenced by both age and risk status, it was not statistically significant until 12 months (Paul et al., 2011). On a broader scale, it is consistent with previous findings that there are few expressive language differences between low- and high-risk groups at 6 months (Ozonoff et al., 2010; Landa & Garrett-Mayer, 2006; Iverson & Wozniak, 2006).

Predicting autism outcomes. The findings in this report indicate that neither the quantity and frequency of speech-like behavior, nor the middle consonant inventory at 6 months, were predictive of ADOS severity scores at 24 months. This is similar to earlier findings that found few language measures at 6 months were predictive of later autism diagnosis. However, the earlier study by Paul et al., (2011), did find that "only the *number of middle consonant types* produced by the 17 HR children seen at both 6 months and 24 months was significant in classifying participants with and without autistic symptoms at 24 mo."

The lack of replication of this measure in the present study may be partially ascribed to the difference in sample size (Paul et al., HR: $n = 28$; LR: $n = 20$ vs. present study: HR: $n = 15$; LR: $n = 5$), with the earlier study having more than twice as many participants. Other factors possibly affecting the vocalization behavior may include the environment within which the vocal sample was collected. In the Paul study, vocal samples were collected during a low-structured parent-child interaction, compared to the present study where vocal samples were collected during a structured interaction consisting of an unfamiliar adult and child, with the parent present but less engaged. Additionally, the mean number of consonants produced for both groups in the Paul study was higher across nearly every category (e.g., early, middle, late developing consonants) compared to the present study, suggesting somewhat naturally, that the infants were overall more vocal during the parent-child interaction vs. the unfamiliar adult-child interaction.

It is important to note that the primary purpose of this replication study was to provide evidence that the results reported in the original investigation were reliable and valid. Given the outcomes presented here, it is possible that their initial findings were simply due to chance and are therefore, not truly representative of the general population. In other words, middle consonant inventory at 6 months may not in fact be predictive of later autism symptomotology.

Study Differences

This study was carried out in an effort to replicate previous findings regarding pre-speech vocalization behavior in infants at risk for autism (Paul et al., 2011). There are several differences between the two studies that warrant further discussion. First, as previously mentioned, the vocal samples were collected during very different social interactions (parent/child vs. unfamiliar adult/child). While a parent-child interaction may yield the most vocal behavior, there is also a possibility for greater variation in the interaction, which may interfere with later comparisons. For the present study, the vocal sample was collected during a standardized test administered by experienced and reliable clinicians. Under these conditions, vocalizations are less reliant on individual parent-child interaction style or relationship. The resulting samples and data from these interactions may be more generalizable for a given measure. In other words, one could state that infants participating in the AOSI have a speech profile of "XYZ," and regardless of the date or the individual study, the consistency of the administration potentially makes future research more reliable and replicatable.

Secondly, the data collected in this study were drawn from video recordings, while the original study was conducted using audio recordings. By using videos, there is greater ability to interpret vocalizations within the context of a given situation and increase the reliability of coding decisions. For example, a vocalization accompanied by a smile, regardless of the expected quality of an infant's laugh, may be construed as delight. Without visual support, coding efforts may be not capture the true nature of vocal responses.

Finally, the present report only evaluated vocalizations at the initial 6-month evaluation, rather than the 6, 9, and 12 months as reported by Paul et al., (2011). This is notable because several measures reported in the original finding were not significantly different for HR and LR groups until 9 months. For example, the total number of consonants, number of early consonants, middle consonants, late consonants, and percentage of canonical syllables were all significantly different at 9 months. In terms of replication, it would be interesting to see if the present study sample would yield similar results if data had been collected at 9 months.

Study Limitations

There are several limitations of the present study. First, the number of participants was relatively low, particularly with respect to the LR group. This makes the generalizability of the results somewhat difficult, especially since there are discrepancies between this study and the previous work of Paul and colleagues (2011), and reduces the ability for more sophisticated statistical analysis. Secondly, participants and subsequent data for this study were drawn primarily from the University of Washington collection site, rather than the entire IBIS network. By limiting the participants to one geographic location, the opportunity to generalize results was reduced. Finally, the transcription of speech samples was conducted solely on the basis of auditory and visual perception, and was not analyzed using formal audio/acoustic instruments (i.e., without the benefit of spectrograms, wave forms, etc.). A more precise measure of consonants, canonical babbling, and non-speech vocal behavior may have been acquired using such instrumentation.

Future Directions

Future studies could be conducted to address the limitations described above, and to extend the findings of the current study. Future studies should include more children to increase the sample size and including participants from the entire IBIS network. Further acoustical analysis using more sophisticated instrumentation would allow for greater fidelity to the vocalization categories defined in the SAEVD-R (Nathani, Ertmer & Stark, 2006).

Other areas of investigation that would extend the current study could include comparing vocalizations collected during other standardized measures such as the MSEL. In the current study, the AOSI was typically followed immediately by the MSEL, which allowed infants and clinicians time to interact and "warm-up." The resulting language samples may yield a richer vocalization profile. Additionally, the current report and comparison study included a cap of fifty vocalizations. However, given the controlled and standardized nature of the AOSI and/or MSEL, it may be an unnecessary limitation, and removing the cap may provide additional information. Finally, assuming that environmental factors such as noise and visual distractions could be controlled, it would be interesting to complete the AOSI or similar standardized testing in the home environment, thereby reducing the stress or wariness of participants interacting with unfamiliar adults. By working in the home, it may be possible to maximize the vocal output (as seen in unstructured parent-child interactions), while maintaining the consistency of standardized testing. The resulting data might allow researchers to create a truer developmental profile.

Conclusion

The present investigation provided information regarding vocalization behavior in 6-month old infants at low- and high-risk for autism spectrum disorders. The results indicated that few vocalization measures were reliable indicators of later diagnosis, or in fact, signified any meaningful differences in vocal behavior at this young age. In order to map the developmental profile and trajectory for individuals with autism and, therefore, aid in early diagnosis and intervention, continued research investigating all such measures is necessary

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC:Author.

Ben-Yizhak, N., Yirmiya, N., Seidman, I., Alon, R., Lord, C., & Sigman, M. (2011). Pragmatic language and school related linguistic abilities in siblings of children with autism. *Journal of Autism and Developmental Disorders, 41*, 750-760.

Bryson, S. E., Zwaigenbaum, L., McDermott, C., Rombough, V., & Brian, J. (2008). The autism observation scale for infants: scale development and reliability data. *Journal of Autism and Developmental Disorders, 38*, 731-738.

Carayol, J., Schellenberg, G. D., Tores, F., Hager, J., Ziegler, A., & Dawson, G. (2010). Assessing the impact of a combined analysis of four common low-risk genetic variants on autism risk. *Molecular Autism, 1*(4), 1-11.

Centers for Disease Control and Prevention. (2012). Autism spectrum disorders. Retrieved from http://www.cdc.gov/ncbddd/autism/data.html

Courchesne, E., Karns, C. M., Davis, H. R., Ziccardi, R., Carper, R. A., Tigue, Z. D., Chisum, H. J., Moses, P., Pierce, K., Lord, C., Lincoln, A. J., Pizzo, S., Schreibman, L., Haas, R. H., Akshoomoff, N. A., & Courchesne, R. Y. (2001). Unusual brain growth patterns in early life in patients with autistic disorder. *Neurology, 57,* 245-254.

Courchesne, E., Carper, R., & Akshoomoff, N. (2003). Evidence of brain overgrowth in the first year of life in autism. *Journal of the American Medical Association, 290*(3), 337-344.

Dawson, G., Munson, J., Webb, S. J., Nalty, T., Abbott, R., & Toth, K. (2007). Rate of head growth decelerates and symptoms worsen in the second year of life in autism. *Biological Psychiatry, 61*, 458-464.

Dawson, G. (2008). Early behavioral intervention, brain plasticity, and the prevention of autism spectrum disorder. *Development and Psychopathology, 20*, 775-803.

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

Engel, S. M., & Daniels, J. L. (2011). On the complex relationship between genes and environment in the etiology of autism. *Epidemiology 22*(4), 486-488.

Estes, A. M., Zwaigenbaum, L., Gu, H., Dager, S. R., Paterson, S., Hazlett, H., Botteron, K., Schultz, R., Kostopoulos, P., St. John, T., Evans, A., & Piven, J. (2013). *Development in infants at risk for autism spectrum disorders at 6 and 12 months of age.* Manuscript in preparation, University of Washington, Seattle, WA.

Guerini, F. R., Bolognesi, E., Chiappedi, M., De Silvestri, A., Ghezzo, A., Zanette, A., Rusconi, B., Manca, S., Sotgiu, S., Agliardi, C., & Clerici, M. (2011). HLA polymorphisms in Italian children with autism spectrum disorders: results of a family based linkage study. *Journal of Neuroimmunology, 230*, 125-142.

Iverson, J. M., & Wozniak, R. H. (2007). Variation in vocal-motor development in infant siblings of children with autism. *Journal of Autism and Developmental Disorders, 37*, 158-170.

Landa, R., & Garret-Mayer, E. (2006). Development in infants with autism spectrum disorders: a prospective study. *Journal of Child Psychology and Psychiatry*, 47, 629–638.

Lichtenstein, P., Carlstrom, E., Rastam, M., Gillberg, C., & Anckarsater, H. (2010). The genetics of autism spectrum disorders and related neuropsychiatric disorders in childhood. *American Journal of Psychiatry, 167*(11), 1357-1363.

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview-revised: a revised version of a diagnostic interview for caregivers of individual with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*(5), 659-685.

Lord, C., Rutter, M., DiLavore, P. C., & Risi, S. (2002). *Autism Diagnostic Observation Schedule (ADOS).* Los Angeles, CA: Western Psychological Services.

Mitchell, S., Brian, J., Zwaigenbaum, L., Roberts, W., Szatmari, P., Smith, I., & Bryson, S. (2006). Early language and communication development of infants later diagnosed with autism spectrum disorder. *Developmental and Behavioral Pediatrics, 27*(2), S69-S78.

Morris, S. E., & Klein, M. D. (2000). *Pre-feeding skills: a comprehensive resource for mealtime development* (2^{nd} ed). San Antonio, TX: Therapy Skill Builders.

Mullen, E. (1995). *Mullen Scales of Early Learning.* Circle Pines, MN: American Guidance Services, Inc.

Nathani, S., Ertmer, D. J., & Stark, R. E. (2006). Assessing vocal development in infants and toddlers. *Clinical Linguistics and Phonetics, 20*(5), 351-369.

Nelson, K. B., Grether, J. K., Croen, L. A., Dambrosia, J. M., Dickens, B. F., Jelliffe, L. L., Hansen, R. L., & Phillips, T. M. (2001). Neuropeptieds and neurotrophins in neonatal blood of children with autism or mental retardation. *Annals of Neurology, 49*(5), 597-606.

Oller, D. K., Eilers, R. E., Bull, D. H., & Earley-Carney, A. (1985). Prespeech vocalizations of a deaf infant: a comparison with normal metaphonological development. *Journal of Speech and Hearing Research, 28*, 47-63.

Oller, D. K., Eilers, R. E., Neal, A. R., & Cobo-Lewis, A. B. (1998). Late onset canonical babbling: a possible early marker of abnormal development. *American Journal of Mental Retardation, 103*(3), 249-263).

Olswang, L., Stoel-Gammon, C., Carpenter, R., Coggins, T. E. (1989). *Assessing Prelinguistic and Early Linguistic Behaviors in Developmentally Young Children.* Seattle:WA, University of Washington Press.

Ozonoff, S., Iosi, A., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., Rogers, S. J., Rozga, A., Sangha, S., Sigman, M. B., & Young, G. S. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child and Adolescent Psychiatry*, *49*, 256–266.

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. *Journal of Child Psychology and Psychiatry, 52*(5), 588-598. doi:10.1111/j.1469-7610.2010.02332.x

Robb, M. P., & Bleile, K. M. (1994). Consonant inventories of young children from 8 to 25 months. *Clinical Linguistics and Phonetics, 8*(4), 295-320.

Rodier, P. M., Ingram, J. L., Tisdale, B., Nelson, S., & Romano, J. (1996). Embryological origin for autism developmental anomalies of the cranial nerve motor nuclei. *The Journal of Comparative Neurology, 370*, 247-261.

Sander, E. K. (1972). When are speech sounds learned. *Journal of Speech and Hearing Disorders, 37*, 55-63.

Sapienza, C. M., Hoffman-Ruddy, B., & Baker, S. (2004). Laryngeal structure and function in the pediatric larynx: clinical applications. *Language, Speech, and Hearing Services in Schools, 35*, 299-307.

Schmidt, G. L., Kimel, L. K., Winterrowd, E., Pennington, B. F., Hepburn, S. L., & Rojas, D. C. (2008). Impairments in phonological processing and nonverbal intellectual function in parents of children with autism. *Journal of Clinical and Experimental Neuropsychology, 30*(5), 557-567.

Schoen, E., Paul, R., & Chawarska, K. (2011). Phonology and vocal behavior in toddlers with autism spectrum disorders. *Autism Research, 4*, 177-188.

Schwichtenberg, A. J., Young, G. S., Sigman, M., Hutman, T., & Ozonoff, S. (2010). Can family affectedness inform infant sibling outcomes of autism spectrum disorders? *Journal of Child Psychology and Psychiatry, 51*(9), 1021-1030.

Sheinkopf, S. J., Mundy, P., Oller, D. K., & Steffens, M. (2000). Vocal atypicalities of preverbal autistic children. *Journal of Autism and Developmental Disorders, 30*(4), 345-354.

Sheinkopf, S. J., Iverson, J. M., Rinaldi, M. L., & Lester, B. M. (2012). Atypical cry acoustics in 6-month-old infants at risk for autism spectrum disorders. *Autism Research, 5*(5), 331-339. doi:10.1002/aur.1244.

Shriberg, L. D. (1993). Four new speech and prosody-voice measures for genetics research and other studies in developmental phonological disorders. *Journal of Speech and Hearing Research, 36*, 105-140.

Smit, A. B., Hand, L., Freilinger, J. J., Bernthal, J. E., & Bird, A. (1990). Iowa articulation norms project and its Nebraska replication. *Journal of Speech and Hearing Disorders, 55*, 779-798.

Sparrow, S. S., Balla, D., & Ciccheti, D. V. (2005). *Vineland adaptive behavior scales, second edition (Second ed.)*. Shoreview, MN: American Guidance Service.

Stoel-Gammon, C., & Dunn, C. (1985). *Normal and disordered phonology in children.* Baltimore: University Park Press.

Templin, M. C. (1957). *Certain language skills in children: Their development and interrelationships.* Minneapolis, MN: University of Minnesota Press.

Volkmar, F., Chawarska, K., & Klin, A. (2005). Autism in infancy and early childhood. *Annual Review of Psychology, 35*, 315-336.

Zwaigenbaum, L., Bryson, S., Rogers, T., Roberts, W., Brian, J., & Szatmari, P. (2005). Behavioral manifestations of autism in the first year of life. *International Journal of Neuroscience,* 23, 143–152.

Zwaigenbaum, L., Bryson, S., Lord, C., Rogers, S., Carter, A., Carver, L., Chawarska, K., Constantino, J., Dawson, G., Dobkins, K., Fein, D., Iverson, J., Klin, A., Landa, R., Messinger, D., Ozonoff, S., Sigman, M., Stone, W., Tager-Flusberg, H., & Yirmiya, N. (2009). Clinical assessment and management of toddlers with suspected autism spectrum disorder: insights from studies of high-risk infants. *Pediatrics, 123*(5), 1383-1391.

Wolff, J. J., Gu, H., Gerig, G., Elison, J. T., Styner, M., Gouttard, S., Botteron, K. N., Dager, S. R., Dawson, G., Estes, A. M., Evans, A. C., Hazlett, H. C., Kostopoulos, P., McKinstry, R. C., Paterson, S. J., Schultz, R. T., Zwaigenbaum, L., & Piven, J. (2012). Differences in white matter fiber tract development present from 6 to 24 months in infants with autism. *American Journal of Psychiatry, 169*(6); 589-600. doi:10.1176/appi.ajp.2011.11091447

Appendix A

The Stark Assessment of Early Vocal Development-Revised (SAEVD-R) (Nathani et al., 2006)

Level 1. Reflexive (0–2 months)

- **VEG** Vegetative sounds, e.g. burp, cough, sneeze, etc.
- **CR** Sustained crying/fussing or series of brief discomfort sounds. Ingressive sounds, squeals, and vegetative sounds in cry are not classified as separate items. Cries that contain syllables (e.g. mamama) are classified as CR and the term ‘‘Fussy Syllables’’ is noted as a comment. Conversely, utterances that are fussy (not full-blown cries) or utterances that contain non-fussy elements + cry are assigned applicable vocalization types (e.g. CVCV, V) and ‘‘fussiness’’ and/or ‘‘cry’’ are noted.
- **Q** Quasi-Resonant Nuclei. Faint, low-pitched grunt-like sounds with muffled resonance. Characterized by a lack of energy above 2000Hz. If there is energy across mid and higher frequencies, the vocalization may be classified as Q if the sound is brief (,100 ms). Q sounds cannot be transcribed as an adult vowel.
- **Q2** Two or more Qs in a series or row.

Level 2. Control of Phonation (1–4 months)

- **F** Fully Resonant Nuclei. Vowel-like sounds that are longer than Qs but cannot be readily transcribed as adult vowels. These vocalizations have energy across a wide range of frequencies (i.e. not restricted to low frequencies like Q). They may have poor vocal quality (harshness, high pitch, etc.). If glottal stops or [h] interrupt a Q or F, they are counted as a single syllable and glottal stops are noted.
- **F2** Two or more Fs in a series or row. ___
- ~~**cv**~~ Vocalization in which a vocant (vowel-like segment) or an F are combined with a superimposed closant (consonant-like segment). Also includes an isolated closant (e.g. ‘‘raspberry’’, trill, click) or an isolated consonant (e.g. m, n, sh). Glottal stops and [h] are not considered closants.
- ~~**cv2**~~ Two closant-vocant combinations, or two or more closants in a series.
- **CH** At least two brief chuckles or sustained laughter. Frequently, a [h]-like closant is perceived before the vowel. Ingressive sounds during laughter are not classified separately.
-

Level 3: Expansion (3–8 months)

- **V** An isolated vowel. Vowels can be distinguished from Q/F because Vs are longer and more fully resonant than Qs and are of better quality and more easily recognized as vowels than Fs. They may contain some harshness, high pitch, etc. but are transcribable as adult vowels. Note any aberrant voice quality features.
- **V2** Two or more vowels in a series or row.
- **Vg** Vowel Glide. Vocant in which a change in vowel quality is present. No audible gap is
- present between the two segments. No closure can be identified, (e.g. [pa], [da]). The formant transition is characteristically slow: greater than 200ms. If formant transition duration is less than or equal to 200 ms, classify as CV if closure perceived (e.g. w, j), or judge as diphthong if no closure is perceived (e.g. oI, aI).

- **IN** Ingressive Sound. Single long (.200ms) ingressive sound or series of short ingressive sounds.
- **SQ** Squeal. High-pitched sound or series of squeals.
- **MB** Marginal babbling. Series of closant and vocant segments or series of Vgs. Irrespective of the nature of the closant/vocant, the key characteristic of MB is that formant transitions between the closant and vocant are prolonged. Therefore, even sequences of real consonants and vowels would be considered MB if they had long (.120 ms) formant transitions. Elements in the sequence need not always contain a closant and vocant; occasional isolated vocants and closants might also be present. Well-formed, rapid glide and other semivowel sequences (e.g. wa, ja) would not be included under MB; they would be included under CV.

Level 4: Basic Canonical Syllables (5–10 months)

- **CV** Single consonant-vowel syllable. Does not include syllables with /h/ or a glottal stop as a consonant.
- **CB** Canonical babbling. More than two CV syllables in sequence are required for this category. Because the consonants and vowels in the sequence can be same or different, this category includes reduplicated babbling (repeated productions of the same consonant-vowel sequence) and nonreduplicated babbling (sequence of different consonant-vowel combinations). If squeals, ingressive sounds, etc. occur during CB, corresponding vocalization types are merely noted.
- **WH** Whispered productions. V1, V2, Vg, MB, CB, or CV vocalizations produced without voice.
- **CV-C** A consonant-vowel combination followed by an isolated consonant. A silent gap between CV and C should be observed.
- **CVCV** Disyllables. Two adjacent CV syllables or series of two CV syllables with an audible gap separating the CVs.

Level 5: Advanced Forms (9–18 months)

- **CMPX** Complex syllables. (1) Single syllable types other than CV (e.g. VC, CCV, CCVC, etc.), or (2) Complex Disyllables (e.g. VCV, VCVC), or (3) Multisyllabic strings with complex syllables and without variable stress or intonation patterns (e.g. VCVCV, VCVCCV), or (4) Multisyllabic utterances with varied stress and/ or intonation patterns in which the consonants and vowels remains unchanging. The latter are designated as Canonical Jargon (CBJN).
- **JN** Jargon. A series of syllables with at least two different Cs and Vs with a changing stress and/or varied intonation pattern within the series. The series must contain more than two syllables.
- **DIP** Diphthongs, e.g. /oI/, /aI/, /au/, or other forms with rapid formant transitions. Diphthong is characterized by formant transition that is less than 200ms and overall syllable duration of less than 500 ms.

Appendix B

Infant Vocalization Coding Sheet, Page 1

1 **AOSI Infant Babbling Data Form**

Subject ID : ____________ Gender: ____________

A	B	C	D	E	F
#	**Time**	**+/- Canonical or S/G/Y/D/C/U**	**IPA Transc. or Non-Speech Description**	**Bab. Level** ***(I, II, III)***	**SAEVD-R Level**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					

****Do not code vegetative sounds (e.g., hiccup, burp, cough, sneeze)****

Infant Vocalization Coding Sheet, Page 2

2 **AOSI Infant Babbling Data Form**

Subject ID : ____________ Gender: ____________

A	B	C	D	E	F
#	**Video Time**	**+/- Canonical or S/G/Y/D/C/U**	**IPA Transc. or Non-Speech Description**	**Bab. Level** *(I, II, III)*	**SAEVD-R Level**
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					
41					
42					
43					
44					
45					
46					
47					
48					
49					
50					

**** Do not code vegetative sounds (e.g., hiccup, burp, cough, sneeze)****

Infant Vocalization Coding Sheet, Page 3

Subject ID : ______________ Gender: ______________

3 **AOSI Infant Babbling Data Form**

Measure 1 – Consonant Inventory

Consonant Inventory									Total	Total Cons.	Instructions
Early 8	m	b	j	n	w	d	p	h			1. Mark each consonant transcribed in Column D above. 2. Sum total for each type (e.g., Early, Middle, Late) 3. Sum total number of consonants
Middle 8	t	ŋ	k	g	f	v	tʃ	dʒ			
Late 8	ʃ	θ	s	z	ð	l	ʒ	r			

Measure 2 – Percent Canonical Syllables

Total Number of Speech-like Syllables		Instructions
Total Number of Speech-Like Syllables:	Box A	1. Sum all syllables transcribed using IPA
Total Number of CV Syllables :	Box B	2. Sum all syllables marked with '+' in Column C (SAEVD-R Level 4)
Percent Canonical Syllables:	Box C	3. Divide Box B by Box A to derive this metric (B / A = Number of CV Syllables / Number of Speech-Like Syllables)

Measure 3 – Non Speech-Like Vocalizations

Atypical Vocalization Type	Total	Atypical Vocalization Type	Total	Combined Total
S = Squeal		D = Delight		
G = Growl		C = Distress		
Y = Yell		U = Grunt		

Total Number of Speech-like Syllables		Instructions
Total Number of Non-Speech Vocalizations:	Box D	1. Sum all non-speech vocalizations (marked with S/G/Y/D/C/U)
Total Number of Vocalizations:	Box E	2. Sum all vocalizations, speech-like and non speech-like (Box A + Box D)
Proportion of Non Speech	Box F	3. Divide Box D by Box E to derive this metric (D / E = Number of Non-Speech / Total Number of Vocalizations)

Coder Name:		Date:	

Appendix C

Summary of Infant Vocalization Data

ID	TNV	SL	NSL	NC	NEC	NMC	NLC	TNCS	%CS	%NS	S	G	Y	D	C	U	Length (sec)	M/F	Risk Status	Dx
PHI0003	35	20	15	2	2	0	0	8	40	42.9	0	1	0	5	7	2	645	m	HR	Autism
PHI0071	32	8	24	2	2	0	0	2	25	75	0	8	0	6	3	7	695	m	HR	Autism
SEA0009	41	6	35	0	0	0	0	0	0	85	0	0	0	2	0	33	860	m	HR	Autism
SEA0015	22	13	9	2	1	1	0	1	7.7	40.9	3	0	0	0	0	6	748	f	HR	Autism
SEA0037	28	20	8	1	1	0	0	1	5	28.6	0	1	0	0	6	1	1005	f	HR	Autism
SEA0001	50	36	14	3	2	1	0	3	8.3	28	0	0	0	3	9	2	567	m	HR	ASD
SEA0034	13	6	7	1	1	0	0	1	16.7	53.8	1	0	0	1	1	4	700	m	HR	ASD
SEA0069	23	11	12	2	1	1	0	0	0	52.2	1	0	0	9	0	2	915	f	HR	ASD
SEA0099	37	26	11	4	3	1	0	1	3.8	29.7	1	5	0	1	2	2	569	f	HR	ASD
SEA0107	20	6	14	2	2	0	0	3	50	70	0	0	1	6	0	7	810	m	HR	ASD
SEA0004	22	8	14	2	2	0	0	2	25	63.6	0	0	0	1	2	11	911	m	HR	No Dx
SEA0007	25	3	22	1	1	0	0	0	0	88	0	0	0	0	2	20	750	m	HR	No Dx
SEA0018	16	14	2	4	4	0	0	4	0	12.5	1	0	1	0	0	0	775	m	HR	No Dx
SEA0030	8	4	4	2	1	1	0	1	25	50	0	0	0	3	0	1	658	f	HR	No Dx
SEA0068	50	16	34	1	1	0	0	1	6.25	68	0	6	0	0	0	28	750	m	HR	No Dx
SEA0050	7	6	1	0	0	0	0	0	0	14.3	0	1	0	0	0	0	839	f	LR	No Dx
SEA0060	36	19	17	2	2	0	0	1	5.2	47.2	0	0	0	11	3	3	670	m	LR	No Dx
SEA0078	9	2	7	1	1	0	0	0	0	77.8	0	1	1	0	3	2	520	f	LR	No Dx
SEA0102	50	15	35	3	2	1	0	0	0	70	0	15	0	0	1	19	611	m	LR	No Dx
SEA0103	44	30	13	3	3	0	0	3	10	29.5	1	0	1	0	5	6	1416	m	LR	No Dx

TNV = total number of vocalizations
SL = number of speech-like vocalizations
NSL = number of non-speech-like vocalizations
NC = total number of consonants
NEC = total number of early consonants
NMC = total number of early consonants
NLC = total number of late consonants
TNCS = total number of canonical syllables
%CS = percent canonical syllables (TNCS/SL)
%NS = percent non-speech vocalizations (NSL/TNV)

S = Squeal
G = Growl
Y = Yell
D = Delight
C = Distress
G = Grunt