**Symposium Title:** Vocal Development in Children with Autism Spectrum Disorder and Children with Fragile X Syndrome

**Chair:** Jena McDaniel

**Discussant:** Tiffany Woynaroski

**Overview:** Vocal development, the process through which a child produces increasingly speech-like sounds [1], is critical for spoken language. The continuity of babbling and spoken words, correlations between vocalizations and expressive language, and interactions between child vocalizations and caregiver behaviors suggest that facilitating vocal development could improve spoken language outcomes for children with developmental disabilities [2-5]. Deficits in vocal development have been observed in several populations of children including children with autism spectrum disorder (ASD) and Fragile X syndrome (FXS) [6-7]. Further investigation is needed regarding the details of these deficits, variations in vocal development across children with different disabilities, and how intervention, including parent-mediated interventions [8-10], can facilitate vocal development. Collaborating with families to provide targeted, effective intervention at the prelinguistic stage of vocal development is an underdeveloped area of potential clinical utility for enhancing language trajectories of children with ASD, FXS, and potentially other developmental disabilities. This cross-institutional symposium addresses vocal development in children with ASD and children with FXS from varied, yet complementary viewpoints. The symposium addresses the multifaceted nature of vocal development by discussing volubility, complexity, and reciprocity of vocalizations in children with ASD and FXS. Because family members play critical roles in language interventions, particularly for young children, the symposium discusses how families and professionals can collaborate to support the development of vocalizations and language of their children with disabilities.

The first presentation addresses critical questions regarding the nature of early vocal development in children with ASD and children with FXS, focusing on volubility and use of canonical syllables. Findings inform our understanding of differences across populations, influence decisions for when to start intervention, and provide evidence toward understanding the origins of language impairment in neurodevelopmental disorders. Such information is essential to partnering with families to support children with ASD and FXS. The second presentation addresses vocal reciprocity – another aspect of vocal development expected to be especially important for children with ASD. The authors directly compare the evidence of convergent construct validity for two automated measures of vocal reciprocity that claim to represent a dyadic process between the child and adults. Because these measures use the Language ENvironment Analysis (LENA) system [11], they offer the opportunity to evaluate a child’s vocalizations within naturalistic settings with familiar individuals, including family members, to inform intervention planning and monitoring progress. The third presentation focuses more directly on intervention for young children with ASD. The authors present evidence from a randomized control trial for toddlers with an older sibling with ASD that compares a 12-week parent-mediated intervention (Improving Parents as Communication Teachers [ImPACT]) with business as usual (BAU) services. They compare the frequency of communication acts that vary in complexity (e.g., gestures, non-words, canonical syllables, and words) produced by toddlers in the ImPACT condition versus those in the BAU condition and investigate correlations between vocal communication and later expressive vocabulary skills. Findings identify types of communication acts expected to be most malleable with intervention for children at high familial risk for ASD. Combined, these presentations offer a framework for assessing vocal development of young children with disabilities and for applying findings to developing interventions that target vocal development for the purpose of improving language outcomes.

**References/Citations:**


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Paper 1 of 3

Paper Title: Differentiating Vocalizations in Autism Spectrum Disorder and Fragile X Syndrome at 9-12 months

Authors: Katie Belardi3, Linda Watson4, Kimbrough Oller5, Betsy Crais4, & Grace Baranek6

Introduction: Fragile X syndrome (FXS) and autism spectrum disorder (ASD) are neurodevelopmental disorders associated with communication impairment. The impairment may be revealed by examining the timing and nature of early vocal development differences in neurodevelopmental disorders compared to typical development (TD) [1]. One significant stage of vocal development, canonical babbling (around 9-10 months), signals a child’s use of the timing and syllable shape characteristics of adult-speech, prior to lexical learning. Children are considered to be in the canonical babbling stage when 15% of a child’s total babbles are canonical babbles [2]. A canonical babble includes a consonant-like sound with a vowel-like sound produced with a short transition between them [3]. Previous research suggests that the development of canonical babbling is robust, such that substantial delays in the onset of canonical babbling have been documented only among children with profound hearing impairment and Williams syndrome. These findings suggest that delays in reaching the canonical babbling stage are associated with later spoken language disorders.

Another important aspect of vocal development is volubility. Volubility is the rate of vocalizations, measured in terms of frequency of syllables. Previous research indicates that individuals with severe to profound hearing loss and infants with Down syndrome produce a similar number of syllables compared to typically developing infants. However, individuals from low socioeconomic backgrounds produce fewer syllables suggesting that volubility may be related to language input from the environment.

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The purpose of this project is to compare data from two retrospective video studies to examine the differences in canonical babbling and volubility in ASD and FXS compared to typical development [4,5]. These two studies previously documented that infants with ASD and infants with FXS have lower canonical babbling ratios and lower volubility than infants with TD, but did not compare the two clinical groups to one another. This information can inform our understanding of the timing and nature of the communication impairment. The goal of this work is to find more precise risk indicators based on vocal development and to bring down the age at which indicators can be detected.

**Methods:** Participants included 10 9- to 12-month-old infants with full-mutation FXS (but not later diagnosed with ASD), 23 infants with ASD (but not FXS), and 14 infants with TD from two different studies [4,5]. Children were recruited at age two years and older as part of a larger project comparing development of infants with neurodevelopmental disorders to those with typical development through retrospective video analysis. Parents provided video footage of their child from 9-12 months. Videos were compiled and edited using the coding system described by Baranek [6]. Two five-minute video clips were coded for each participant for this study. Researchers used the Naturalistic Listening Technique [7], listening to the video in real time and coding canonical and non-canonical vocalizations. Two coders who were blind to diagnostic group coded the videos, overlapping on 20% of the videos for reliability purposes. The resulting intraclass correlation coefficients were .89 for frequency of canonical babbles and .94 for volubility.

**Results:** None of the 10 infants with FXS, 4 of the 23 with ASD, and 8 of the 14 with TD met the .15 criterion (canonical babbles/total babbles) for being in the canonical babbling stage [3]. The mean canonical babbling ratio for the FXS group was .04 (SD = .05) and .12 (SD = .21) for the ASD group. A Mann-Whitney U test indicated the canonical babbling ratio is nonsignificantly different in the ASD and FXS group (U = 89, p = .98). The average syllables in 10-minutes of video were 31.5 (SD = 15.60) for FXS and 45.5 (SD = 28.09) for ASD. A Mann-Whitney U test indicated the average volubility is nonsignificantly different in the ASD and FXS groups (U = 81, p = .10).

**Discussion:** Both of these clinical groups of infants are known to be at high risk for poor expressive language outcomes. Infants with FXS had nonsignificantly lower canonical babbling ratios than those with ASD. While the differences in volubility were also nonsignificant, it is important to note that the individuals with FXS had the greatest variability in volubility, and also tended to show even lower volubility than infants with ASD. Canonical babbling may set the foundation for language learning, especially in light of evidence that a child’s canonical babbling elicits more complex language input from parents [8]. Although neither canonical babbling nor volubility appears to strongly differentiate infants with FXS from those with ASD, these measures are useful early markers for language impairment versus typical language development, and inform our understanding of the origins of language impairment in neurodevelopmental disorders and possible areas of treatment.

**References/Citations:**

Paper 2 of 3

Paper Title: Investigating the Dyadic Nature of Vocalizations in Children with Autism Spectrum Disorder: A Comparison of Two Automated Vocal Reciprocity Measures

Authors: Jena McDaniel¹, Joshua Wade¹, Annette Estes⁷, Sally Rogers⁸, and Paul Yoder¹

Introduction: Vocal development, the process through which a child produces increasingly speech-like sounds [1], is critical for spoken language. Children with autism spectrum disorder (ASD) exhibit deficits in vocal development [2-7]. Addressing early vocalizations could alter the language trajectories of children with ASD positively and improve social, adaptive, and vocational outcomes [8,9]. Vocal reciprocity, one aspect of vocal development, may be particularly important for children with ASD. We define vocal reciprocity as sequences of a child vocalization (CV) followed immediately by an adult vocalization (AV) followed immediately by another CV (i.e., CV → AV → CV). Such exchanges may support vocal development for children with ASD by increasing the probability that the children attend to, process, and emulate the adult’s vocal models that promote speech-likeness of vocal communication [10-12].

For vocal reciprocity measures to claim they represent a dyadic process, not only a child behavioral tendency, they must correlate with later expressive language skills [13] when controlling for (a) the probability of CVs and (b) the chance sequencing of the sequence of interest (i.e., CV → AV → CV) [14]. The purpose of this presentation is to compare the evidence for construct validity of two automated vocal analysis measures of vocal reciprocity: (a) frequency of CV→AV→CV sequences and (b) reciprocal vocal contingency (RVC) [14]. Both measures use three-event sequences rather than the two-event sequences available through standard automated vocal analysis software [15]. These two-event sequences have been shown to be overly influenced by the frequency of CVs. Only RVC mathematically considers events other than the sequence of interest in an exhaustive manner. Therefore, the validity of the RVC is hypothesized to be less influenced by the probability of CVs and chance sequencing than the frequency of CV→AV→CV sequences.

Methods: Thirty-one children (7 female; 24 male) with ASD from a larger study are included. Participants had a mean chronological age of 35.45 months (SD = 4.60 months), mean receptive language age equivalent of 29.40 months (SD = 11.97 months) [16], expressive language age equivalent of 27.19 months (SD = 11.52 months) [16], and used a mean of 245 words (SD = 190; range = 0 - 581) on the MacArthur-Bates Communicative Development Inventories expressive vocabulary compilation form (MB-CDI) [17] at the initiation of the current study, which was 12 months after the onset of the larger study.

Participants’ families collected one daylong audio recording with the Language ENvironment Analysis (LENA) system [15]. From the LENA recordings, we calculated (a) the frequency of CV→AV→CV sequences and (b) RVC. The frequency of CV→AV→CV sequences is simply the number of times this sequence occurs within the recording. Using a specially designed computer program, we calculated RVC using event lag with contiguous pauses sequential analysis [18]. This method maintains the event sequence and temporal proximity. It was found to be more accurate and less correlated with chance occurrence of the events of interest than other sequential analysis methods in a simulation study [18]. RVC is the operant contingency value (OCV; i.e., a/[a+b] - c/[c+d]) for a 2x2 contingency table of the recording’s key acoustic events and time (see Figure 1). The three-event CV→AV→CV sequence is divided into CV→AV and CV for the 2x2 table. Positive RVC scores provide correlational evidence that

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immediately preceding adult vocal responses influence the child’s vocal response. Caregivers completed the MB-CDI compilation form for expressive vocabulary 12 months later by marking words they observed their child saying in the past two weeks.

Figure 1. 2×2 contingency table used to tally three-event sequences of child and adult vocalizations. CV = child vocalization. AV = adult vocalization. → = followed by. Highlighted cells comprise the 2 x 2 table. Cell labels (a, b, c, and d) are italicized in the top center of each cell.

**Results:** The frequency of CV→AV→CV sequences and RVC correlate with expressive language 12 months later (r = .47, p = .007, and r = .51, p = .003, respectively). When controlling for the probability of CVs (i.e., number of CVs divided by total number of events), RVC continues to correlate with expressive language 12 months later (part \( r = .41; p = .006 \)), but the frequency of CV→AV→CV sequences does not (part \( r = .11; p = .48 \)). Similarly, when controlling for the probability of chance sequencing of CV→AV→CV, RVC continues to correlate with expressive language 12 months later (part \( r = .46; p = .004 \)), but the frequency of CV→AV→CV sequences does not (part \( r = .25; p = .14 \)).

**Discussion:** RVC exhibits stronger evidence of convergent construct validity than the frequency of CV→AV→CV sequences. The continued association of RVC with later expressive language skills of children with ASD even when controlling for the probability of CVs and the chance sequencing of CV→AV→CV sequences indicates that RVC is more than a result of the base probabilities of AV, CV, or their combination. Incremental prediction of language when controlling for the probability of CVs and chance sequencing is essential for a dyadic variable of vocal reciprocity. Otherwise, the frequency with which the child vocalizes “drives” the vocal reciprocity value, even though such vocalizations are not necessarily reciprocal. Indeed, the reduced, non-significant correlation between the frequency of CV→AV→CV sequences and expressive language when controlling for the probability of CVs suggests that the three-event sequence count is mostly a reflection of how frequently a child vocalizes. Results suggest that the frequency of CV→AV→CV sequences is more simply interpreted as representing a child variable than a dyadic variable.

RVC provided evidence of independence from the probability of CVs and chance sequencing and warrants continued development for use in research and clinical practices. Benefits for use of RVC include its automated nature that limits the active time required for data collection and analysis, its use within the child’s natural environment with familiar adults, including family members, and its ability to predict expressive language 12 months later above and beyond how often a child vocalizes and chance sequencing. Measuring vocal reciprocity between adults and children with ASD could provide meaningful information for planning intervention, including predicting for whom an intervention is expected to be beneficial, measuring progress, and supporting caregiver training for language facilitation strategies.

**References/Citations:**


**Paper 3 of 3**

**Paper Title:** Early Intervention Increases Types of Communication Acts in Toddlers at High Familial Risk for Autism Spectrum Disorder

**Authors:** Sarah R. Edmunds⁷, Catherine Dick⁷, Paul Yoder¹, & Wendy Stone⁷

**Introduction:** Up to 40% of later-born siblings of children with autism spectrum disorder (ASD) are diagnosed with: (a) ASD (7-19%) [1,2] or (b) other language and/or cognitive delays (14-20%) [3] by age three. The diverse language outcomes of these high-
risk (HR) toddlers and the ability to observe them prior to overt symptom emergence make them an ideal sample from which to learn about the effectiveness of early communication-based intervention. Vocal complexity, a measure of the developmental maturity of vocal communication, seems to be a strong predictor of later language outcomes in many populations [4-11]. Vocal complexity is conceptualized in many ways; it is often operationalized as the frequency of vocal communicative acts that include canonical syllables. Low vocal complexity may signal early language difficulties and a need for intervention in HR toddlers [7-11].

Vocal complexity may be malleable with intervention. Improving Parents as Communication Teachers (ImPACT) is a 12-week, naturalistic developmental behavioral intervention (NDBI) designed to improve social communication and language skills in toddlers with ASD [12]. ImPACT teaches parents to respond contingently to toddlers’ more complex vocalizations. Because parent responsiveness to child vocalizations has been found to predict increased vocal complexity and better expressive language in children with typical development and children with ASD [13-15], it is plausible that ImPACT will also increase HR toddlers’ vocal complexity.

This project examines communicative acts within a longitudinal randomized controlled trial (RCT) of the ImPACT intervention (compared to a business as usual [BAU] condition) in HR toddlers funded by the National Institute on Deafness and Other Communication Disorders. Specifically, it is hypothesized that compared to toddlers in the BAU condition, toddlers who have participated in the ImPACT intervention will produce more frequent communication acts that contain words and canonical syllables, and toddlers’ more complex vocal communication will relate to their later expressive language ability.

**Methods:** The final sample for this presentation will contain 56 15- to 21-month-old toddlers (M = 17.46 months; SD = 2.09 months) at high risk for ASD who have completed the RCT in the ImPACT condition (n = 23) or the BAU condition (n = 23). Videos and language data have been collected for this sample, and coding of the data is ongoing. Currently, child communication data for 21 toddlers (M = 17.01 months; SD = 2.05 months) will be presented, 8 in the ImPACT condition and 13 in the BAU condition.

For all toddlers, communication acts were coded directly after completion of the 12-week intervention for toddlers in the ImPACT condition (i.e., post-intervention) from videos of the Communication and Symbolic Behavior Scales (CSBS) [16], a 20- to 30-minute semi-structured interaction in which examiners presented toddlers with open-ended presses designed to elicit requests for objects, joint attention, and play. Child communicative acts consisted of: (a) a non-imitative sign or word, (b) a conventional gesture plus attention to an adult, or (c) a non-word vocalization or nonconventional gesture with coordinated attention to an adult and object. Canonical syllables were coded within communicative acts when a vocalization had a consonantal sound, vowel, and rapid transition between the consonant and vowel [13]. Pre- and 6-month-post-intervention expressive vocabulary were measured using the MacArthur-Bates Communicative Development Inventories (MCDI) [17].

**Results:** Preliminary analyses indicate that toddlers in the ImPACT condition produced more total communication acts post-intervention than did toddlers in the BAU condition, t(19) = -2.12, p = .048. Specifically, compared to BAU toddlers, ImPACT toddlers produced more communicative gestures, t(19) = -2.11, p = .048, and marginally more communicative non-word vocalizations, t(19) = -2.04, p = .055. Given the large effect size (see Table 1), this finding may become significant with the larger planned sample size [18]. ImPACT toddlers did not significantly differ from BAU toddlers in the number of word communication acts, t(19) = -1.38, p = .184, or communication acts with canonical syllables they produced, t(19) = -1.61, p = .123.

There were no significant group differences in pre-intervention t(18) = 1.19, p = .250 or 6-month-post-intervention expressive vocabulary, t(15) = 0.65, p = .52. For both groups of toddlers, the number of immediately post-intervention word communication acts they produced related to their expressive vocabulary at 6 months post intervention, (ImPACT: r = .74, p = .04; BAU: r = .72, p = .03). However, immediately post-intervention communication acts with canonical syllables were only significantly correlated with 6-month-post-intervention expressive vocabulary for ImPACT toddlers (ImPACT: r = .72, p = .03; BAU: r = -.36, p = .34). Currently, low power prevents us from determining whether the relation between canonical syllabic communication and later expressive vocabulary statistically differed by treatment condition.
Table 1: Frequency of Toddler Communication Acts by Treatment Condition

<table>
<thead>
<tr>
<th>Communication Act Consists of:</th>
<th>ImPACT M (SD)</th>
<th>BAU M (SD)</th>
<th>Group differences t(df), p</th>
<th>Effect Size Cohen’s d (descriptor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any behavior below 42.00 (27.21)</td>
<td>42.00 (27.21)</td>
<td>24.31 (10.75)</td>
<td>t(19) = -2.12, p = .048</td>
<td>0.95 (large)</td>
</tr>
<tr>
<td>Gestures 22.88 (10.08)</td>
<td>22.88 (10.08)</td>
<td>14.62 (7.79)</td>
<td>t(19) = -2.11, p = .048</td>
<td>0.95 (large)</td>
</tr>
<tr>
<td>Non-words 31.88 (29.32)</td>
<td>31.88 (29.32)</td>
<td>13.92 (10.22)</td>
<td>t(19) = -2.04, p = .055</td>
<td>0.92 (large)</td>
</tr>
<tr>
<td>Canonical syllables 15.50 (22.83)</td>
<td>15.50 (22.83)</td>
<td>5.15 (4.24)</td>
<td>t(19) = -1.61, p = .123</td>
<td>0.73 (medium-to-large)</td>
</tr>
<tr>
<td>Words 1.50 (1.73)</td>
<td>1.50 (1.73)</td>
<td>0.46 (0.78)</td>
<td>t(19) = -1.38, p = .184</td>
<td>0.62 (medium)</td>
</tr>
</tbody>
</table>

Note. Communication act types are not mutually exclusive.

Discussion: From these preliminary findings, it may be that less complex types of communication such as gestures and non-words are more malleable with intervention than vocally complex communication because of the relatively brief intervention period or given the children’s young age and developmental level. It may also be that gestures and non-words are simply the first types of communication to increase after intervention, potentially followed by increases in more complex vocal communication. Indeed, canonical syllabic communication acts were found to be significantly related to later expressive vocabulary for toddlers who participated in ImPACT but not for toddlers in the BAU condition; this may suggest that the ImPACT intervention’s focus on expanding on toddlers’ current communication and language skills may influence parents to treat their children’s canonical syllabic communication as a direct stepping stone to language ability, which may promote more consistent growth from canonical syllabic communication to language ability for this group. However, given the current lack of power to assess whether treatment influences the association between canonical communication and later expressive language, these findings should be interpreted with caution. This dissertation work is in progress: ultimately, group differences in both pre- and post-intervention vocal communication and relations to later language ability will be presented, and elements of the ImPACT intervention that may facilitate toddlers’ vocally complex communication (e.g., parents’ responsiveness to children’s vocal communication acts, targeting of gestural and vocal social communication skills) will be discussed.

References/Citations:


