

Atypical Vocalizations as Potential Early Identification Markers in Children with Autism: An Etiological Analysis

Authors: Liu Min, Hu Yang, Liu Qiaoyun, Liu Qiaoyun

Date: 2021-10-14T00:00:00+00:00

Abstract

Early identification and early intervention for children with Autism Spectrum Disorder (ASD) are crucial for their developmental outcomes. Vocalizations refer to sounds produced by children before they learn to speak. Existing research has demonstrated that atypical non-speech-like and speech-like vocalizations are potential identification markers for children with ASD before age two. Theoretical explanations for vocalization abnormalities in children with ASD primarily include motivation-oriented, neuromotor-oriented, perceptual-oriented, and social feedback-oriented theories. Future research may consider exploring the possibility of vocalization abnormalities as unique early identification markers for children with ASD, strengthening investigations into crying in early screening of ASD children, exploring automated learning classification models based on the most predictive acoustic parameter sets, examining the influence of intrinsic and social motivation on speech-like vocalizations in children with ASD, and further investigating the neural mechanisms underlying speech-like vocalization abnormalities in children with ASD. This would thereby provide more objective theoretical foundations for the early identification and early intervention of children with ASD.

Full Text

Common Analysis Indicators in Vocalization Research

The following terminology is used throughout vocalization studies in autism spectrum disorder (ASD) research:

Non-Speech-Like Vocalizations: Vocal sounds that are not speech-like, divided into fixed signal sounds and vegetative sounds (the latter being reflexive sounds like coughing, hiccups, and sneezing that are typically excluded from analysis).

- **Pleasure/Delight Sounds:** Sounds expressing positive emotions, such as laughter.
- **Atypical Vocalizations:** Non-typical sounds primarily including high-pitched screams, low-pitched roars, and high-intensity cries.
- **Distress Sounds:** Vocalizations associated with negative emotional states, mainly including intense crying and wailing.

Acoustic Parameters: - **Fundamental Frequency (f0):** The number of vocal fold vibrations per second, reflecting voice pitch. - **Pause Length:** The duration of pauses between cry episodes. - **Cry Duration:** The length of individual crying episodes.

Speech-Like Vocalizations: Sounds with phonetic structure but without linguistic meaning.

- **Quasivowel:** Weak, low-pitched sounds sometimes with nasal quality, produced with closed glottis, minimal respiratory support, short duration (typically <100ms), and insufficient energy above 2000Hz, making them difficult to transcribe as vowels.
- **Vowel:** Produced with open glottis and clear formant structure.
- **Vocal Complexity:** The frequency, consistency, and diversity of speech-like vocalizations, including non-canonical syllable frequency (quasivowels, single vowels, single consonants, marginal syllables), canonical syllable proportion/frequency, and consonant types.
- **Marginal Syllable:** Also called marginal babbling, slow CV sequences with long transition time (>250ms) between consonant (C) and vowel (V).
- **Canonical Syllable:** Includes single CV syllables and canonical babbling composed of two or more CV sequences with rapid transitions (<250ms). Canonical babbling includes reduplicated syllables (identical CV combinations) and non-reduplicated syllables (varied CV combinations).
- **Complex Syllable:** Includes single syllables other than CV (VC, CCV), complex disyllables (VCV, VCVC), and multisyllabic strings with or without stress and intonation (VCVCV, VCVCCV).
- **Communicative Vocalization:** Vocalizations clearly intended to communicate with others through eye contact and gestures, such as the proportion of vocalizations used for communication and the number of communicative vocalization behaviors.

Nonspeech-Like Vocalizations in ASD

Fundamental Frequency Characteristics

Research on nonspeech-like vocalizations in ASD children primarily examines three aspects: frequency/rate of nonspeech vocalizations, and acoustic features of cries including fundamental frequency, pause length, and duration. While findings on vocalization frequency and proportion remain inconsistent (e.g., Plumb & Wetherby, 2013; Schoen et al., 2011), conclusions regarding atypical cry acoustic features are relatively consistent: children with ASD show higher

fundamental frequency and shorter pause lengths and durations compared to typically developing (TD) children (e.g., Bornstein et al., 2016; Esposito et al., 2014; Esposito et al., 2015).

Fundamental frequency serves as the most informative parameter for characterizing cry acoustics (Lester & Gasse, 2020) and has been widely used in ASD research. Cry samples have been collected from both non-distress contexts (familiar or novel situations) and naturalistic distress contexts. Studies consistently show that children with ASD exhibit higher cry fundamental frequency than TD peers. Retrospective home video analyses of infants later diagnosed with ASD reveal that between 5-18 months, ASD infants produce higher fundamental frequency in non-distress cries compared to TD infants (Bornstein et al., 2016; Esposito et al., 2012, 2013; Esposito et al., 2015; Esposito & Venuti, 2010a, 2010b). These findings are supported by studies of 15-month-old high-risk infants and older toddlers (36-52 months) in novel situations (Esposito et al., 2014; Ozturk et al., 2018). Prospective research further indicates that 6-month-old high-risk infants show higher fundamental frequency in distress cries compared to low-risk infants, with infants later diagnosed with ASD showing the highest fundamental frequency across both cry types (Sheinkopf et al., 2012). This evidence suggests that elevated cry fundamental frequency may serve as an early identification marker for ASD, with higher distress cry fundamental frequency potentially representing a more sensitive indicator.

Pause Length and Duration Characteristics

Pause length and cry duration reflect respiratory control capabilities (LaGasse et al., 2005) and have been extensively investigated in ASD infant cry research. Studies consistently demonstrate that children with ASD exhibit shorter pause lengths and cry durations than TD peers. Research shows that 12-13-month-old infants with ASD have significantly shorter pause lengths than TD infants (Esposito et al., 2012, 2013; Esposito et al., 2015; Esposito & Venuti, 2009; Venuti et al., 2012). Prospective studies reveal that high-risk infants show shorter cry durations at 12 and 15 months, with infants later diagnosed with ASD showing the shortest durations (Esposito et al., 2014; Unwin et al., 2017). These findings indicate that reduced pause length and cry duration may constitute early identification markers for ASD.

Speech-Like Vocalizations in ASD

Vocal Complexity

Numerous studies have examined vocal complexity in ASD children. While two studies found no significant differences between ASD or high-risk children and TD children (Chericoni et al., 2016; Talbott et al., 2016), substantial evidence indicates atypical patterns, with vocal complexity being either significantly lower or higher than TD peers (e.g., Garrido et al., 2017; Heymann et al., 2018; Werner & Dawson, 2005).

First, most research confirms that children with ASD demonstrate lower vocal complexity than TD children. Prospective and retrospective studies show that before age 2, ASD infants exhibit significantly reduced frequency and proportion of speech-like vocalizations including vowels, marginal syllables, and canonical syllables, with delayed onset (Garrido et al., 2017; Patten et al., 2014; Plumb & Wetherby, 2013; Wetherby et al., 2004), and produce fewer consonant types (Schoen et al., 2011; Wetherby et al., 2007). High-risk infants similarly show reduced frequency and proportion of vowels, reduplicated syllables, and complex syllables (Heymann et al., 2018; Paul et al., 2011; Winder et al., 2013) and fewer consonant types (Chenausky et al., 2017; Paul et al., 2011). Furthermore, vocal complexity demonstrates strong predictive validity for ASD diagnosis. Patten et al. (2014) found that canonical syllable ratio and syllable frequency at 9-12 months predicted ASD diagnosis with 82% accuracy. Paul et al. (2011) showed that consonant variety at 9 and 12 months predicted ASD symptoms at 24 months with 77% and 65% accuracy, respectively. This evidence suggests that reduced vocal complexity may serve as an early identification marker for ASD.

Second, a subset of children with regressive ASD show higher vocal complexity than TD children, exhibiting hypervocalization. Retrospective research found that 12-month-old infants with regressive ASD (n=15) produced significantly more complex babbling than TD infants, while early-onset ASD infants (n=21) produced less. Specifically, 46% of regressive ASD infants showed complex babbling frequencies above the TD mean, compared to only 6% of early-onset ASD infants (Werner & Dawson, 2005). This study also revealed that regressive ASD children's complex babbling declined over time, becoming similarly delayed as early-onset ASD by 24 months. A recent prospective study found that 9-month-old high-risk ASD infants produced more speech-like vocalizations than low-risk infants, primarily driven by hypervocalization in 12 infants (31%) (Swanson et al., 2018). These results suggest that elevated vocal complexity may characterize regressive ASD in early development.

Communicative Vocalizations

Communicative vocalizations assess the social function of vocal behavior in ASD children (McDaniel et al., 2020). Research consistently shows that children with ASD produce fewer communicative vocalizations than TD children, with ASD infants before age 2 demonstrating significantly fewer intentional communicative acts (Bacon et al., 2018; Dow et al., 2020; Dow et al., 2017; Plumb & Wetherby, 2013; Shumway & Wetherby, 2009). Studies of high-risk infants support these findings, showing reduced socially-directed vocalizations, with infants later diagnosed with ASD showing the lowest communicative vocalization capacity (Garrido et al., 2017; Sacrey et al., 2021; Winder et al., 2013). Even hypervocal high-risk infants produce less social babbling than low-risk infants (Swanson et al., 2018). Research further indicates that combining communicative vocalizations with overall vocalization rate improves ASD prediction beyond vocal complexity alone (Garrido et al., 2017). This evidence suggests that the

interaction between communicative vocalizations and vocal complexity may provide a more effective predictive marker for ASD.

Theoretical Explanations for Unusual Vocalizations

Motivation-Oriented Theories

Intrinsic Motivation: Strong intrinsic motivation for special interests may explain atypical vocal complexity in ASD. Intrinsic motivation refers to spontaneous curiosity and interest, the tendency to actively practice skills and acquire knowledge, supported by the dopaminergic system and associated with neural networks for attention control and self-referential cognition (Di Domenico & Ryan, 2017). Computational modeling demonstrates that intrinsic motivation is a general mechanism for infant vocal development (Acevedo-Valle et al., 2018; Moulin-Frier et al., 2014), with self-generation and goal selection as key principles. This mechanism enables infants to autonomously construct vocal experiments and learning plans, explaining the automatic transition from self-exploratory vocalizations that initially ignore the surrounding speech environment to imitation influenced by adult speech, progressing from nonspeech vocalizations to unclear quasivowels and finally to clear complex canonical syllables. The role of intrinsic motivation in TD infant vocalizations is validated by behavioral research showing that most speech-like vocalizations occur during solitary exploratory play (Oller et al., 2019). When adults seek social interaction, most infant vocalizations (approximately 60%) are not directed toward them; when adults are present but not actively engaging, this proportion increases to approximately 80% (Long et al., 2020). Individuals with ASD demonstrate stronger intrinsic motivation for stereotyped special interests than typical populations (Grove et al., 2016), evident even before 12 months (Bacon et al., 2018). ASD infants may prefer repetitive syllable play, whereas TD infants explore phonetic nuances (Long et al., 2021). This suggests that strong intrinsic motivation for special interests may impact the acquisition of vocal complexity, particularly consonant diversity, and may also contribute to excessive vocal complexity in regressive ASD. Notably, empirical research on intrinsic motivation's impact on ASD vocalizations remains limited. A recent study by Long et al. (2021) investigating intrinsic motivation's effect on canonical babbling in high- and low-risk infants found no differential impact, though future research with diagnosed ASD infants may provide new evidence.

Social Motivation: Deficits in social motivation may contribute to reduced communicative vocalizations in ASD. Social motivation encompasses psychological tendencies and biological mechanisms that prioritize social adaptation, seek and enjoy social interaction, and cultivate social bonds (Chevallier et al., 2012). Chevallier et al. (2012) propose that disruption of social motivation mechanisms may constitute a primary deficit in ASD, associated with dysfunctional social reward brain regions including reduced caudate nucleus and anterior cingulate activity, and decreased structural and functional connectivity between the ventral tegmental area and nucleus accumbens (Clements et al., 2018; Supekar et

al., 2018). Reduced face attention and diminished parent-child joint attention provide strong support for the social motivation deficit hypothesis (Adamson et al., 2019; Reid et al., 2017). Within this framework, children with ASD rarely initiate speech-like vocalizations to communicate. Additionally, since speech-like vocal development involves bidirectional child-adult interaction (Elmlinger et al., 2019; Oller et al., 2016), social motivation deficits may impair the formation of effective social interactions that support vocal development. However, empirical research on social motivation's impact on ASD vocal development remains extremely limited, necessitating future investigation.

Neuromotor-Oriented Theories

Immature or disordered neuromotor mechanisms may specifically impact vocal complexity in ASD. Speech-like vocalizations (or quasispeech) possess phonetic structure without linguistic meaning (Kent, 2015), and numerous studies have used meaningless vowels or canonical syllables to investigate speech production neural systems (Kumar et al., 2016). The Laryngeal Motor Cortex (LMC) in the frontal primary motor cortex participates in speech motor control (Eichert et al., 2020). Functional MRI studies of vowel production show overlapping cortical regions controlling laryngeal and jaw muscles, suggesting this overlap supports coupling between vocalization and jaw oscillation to generate syllable structure (Brown et al., 2021). Frontal cortical cognitive functions also modulate vocal control (Hage, 2018). However, ASD children exhibit excessive prefrontal and other cortical growth before age 2 (Bonnet-Brilhault et al., 2018; Hazlett et al., 2017; Hazlett et al., 2011; Kaushik & Zarbalis, 2016), potentially impairing vocal motor control and resulting in atypical vocal complexity. The specific neuromotor mechanisms underlying how ASD children coordinate vocal organs to produce speech-like vocalizations remain unclear and require future research.

Delayed postural development may significantly contribute to reduced vocal complexity in ASD. Sitting posture provides biomechanical support for jaw movement, and speech-like vocalizations are produced through jaw opening and closing (Green et al., 2002). Research comparing 6-month-old infants who could and could not sit independently found differences in syllable production: 41% of independent sitters produced syllables versus only 9% of non-sitters (Leezenbaum, 2016). Retrospective studies show ASD children achieve stable sitting at 9 months on average, later than TD children's 7.9 months (Ucuz & Cicek, 2020). Prospective research confirms these findings, with high-risk ASD infants showing different sitting patterns (Kyvelidou et al., 2021) and significantly less independent sitting time at 6 months compared to low-risk infants (Leezenbaum & Iverson, 2019). These findings suggest that slower sitting acquisition limits opportunities for exploring new vocalizations while upright, thereby affecting canonical syllable acquisition (Iverson, 2018).

Damage to the vagal complex is associated with atypical fundamental frequency patterns and reflects respiratory regulation and cry timing (LaGasse et al., 2005). Changes in fundamental frequency are achieved through muscular modifications

of vocal fold physical properties (length, mass per unit length, tension, stiffness), controlled primarily by the vagus nerve (Dankbaar & Pameijer, 2014). Research indicates reduced vagal tone in ASD children (Benevides & Lane, 2015), potentially leading to poor vocal fold control and poor coordination of respiratory muscles (Sheinkopf et al., 2016), resulting in higher cry fundamental frequency and shorter pause lengths and durations.

Perceptual-Oriented Theory

Auditory processing deficits and atypical processing of speech stimuli in ASD (Filipe et al., 2018; Soskey et al., 2017; Vlaskamp et al., 2017; Yau et al., 2016) may affect vocal complexity. Speech-evoked auditory brainstem response studies show immature brainstem-level speech auditory processing in ASD children (Chen et al., 2019). ASD children exhibit atypical auditory processing of infant-directed speech (IDS), which fails to elicit neural enhancement responses (Chen et al., 2021). Weak name recognition responses further confirm impaired speech stimulus processing, with 9-month-old ASD infants less likely to respond to their names, persisting through 24 months (Miller et al., 2017) and 36 months (Hatch et al., 2021). High-risk infant studies similarly show reduced responses to speech stimuli at 6 months (Paterson et al., 2019). This suggests ASD infants are less influenced by caregiver speech, missing opportunities for vocal learning and affecting vocal complexity development. Recent research demonstrates interactions between auditory and speech motor cortices, with speech perception influencing motor cortex responses (Cheung et al., 2016) and speech motor activity affecting perceptual cortex responses (Daliri & Max, 2016). The interaction mechanisms between speech auditory cortex and speech-like vocal motor cortex in ASD require further investigation.

Social Feedback-Oriented Theory

The social feedback loop theory partially explains reduced vocal complexity in ASD. This theory emphasizes the role of adult responses in children's vocal development, proposing that adults are more likely to respond to children's speech-like vocalizations, which in turn increases the probability of subsequent vocalizations (Warlaumont et al., 2014). Using Language ENvironment Analysis (LENA) software—which demonstrates strong reliability and validity for analyzing child-adult vocal interactions in naturalistic settings (Harbison et al., 2018; Jones et al., 2019; Richards et al., 2017; Woynaroski et al., 2017)—Warlaumont et al. (2014) conducted microanalyses of TD child-adult interactions and confirmed this model. Comparisons between ASD and TD children reveal reduced effectiveness of the social feedback loop in ASD, manifested in two ways: fewer speech-like vocalizations produced by ASD children, and reduced adult responsiveness contingent on the speech-like quality of ASD children's vocalizations. Consequently, fewer iterations of the social feedback loop lead to further reductions in speech-like vocalizations over time.

Future Research Directions

Specificity of Vocal Markers to ASD

The reviewed evidence demonstrates early vocal atypicalities in ASD compared to TD children. However, these features may also characterize children with other disorders. For instance, infants with fragile X syndrome aged 9-12 months produce fewer canonical syllables than TD infants (Belardi et al., 2017). Studies including both ASD and developmental delay (DD) children yield inconsistent conclusions: some find ASD children show fewer communicative vocalizations than DD children (Lee et al., 2018), while others find no significant differences (Dow et al., 2020; Wetherby et al., 2004). Regarding atypical nonspeech vocalizations, Wetherby et al. (2004) found no differences between ASD and DD children, whereas Lee et al. (2018) found ASD children produced more atypical vocalizations. Large-scale prospective studies including other developmental disorders are essential to examine whether vocal atypicalities represent unique early identification markers for ASD.

Cry-Based Screening Studies

Atypical crying patterns may serve as early identification markers for ASD, yet empirical data on cry-based screening remain limited. Recent research suggests atypical crying may affect ASD outcomes, as caregiver difficulty interpreting ASD children's cries impacts care quality and long-term development (Bornstein et al., 2016). Adults can reliably differentiate ASD and TD children's cries, with parents of both ASD and TD infants rating ASD infants' cries as more distressing and less typical (English et al., 2019). Future research should investigate cry-based early screening for ASD, potentially incorporating both distress and non-distress cry samples. Non-distress samples can be collected during naturalistic states (e.g., Bornstein et al., 2016), while distress cries—potentially more sensitive early indicators—can be elicited in standardized settings such as during vaccination. Strengthening cry-based screening research will clarify its value and inform early intervention.

Optimal Acoustic Parameter Models

Current research primarily analyzes vocal complexity, communicative vocalizations, and cry fundamental frequency. Recent studies have used acoustic parameter sets to classify ASD children (e.g., Khozaei et al., 2020; Pokorny et al., 2017, August), with cross-validation demonstrating good classification accuracy (Pokorny et al., 2017, August; Santos et al., 2013, October). However, these studies do not identify the most predictive acoustic features. For example, Santos et al. (2013) analyzed acoustic features (fundamental frequency, formants, intensity, etc.) of babbling and cries from 18-month-old ASD and TD infants, achieving 97% classification accuracy using support vector machines and probabilistic neural networks. Pokorny et al. (2017) analyzed 88 acoustic parameters from 10-month-old ASD infants' babbling, correctly identifying 75% of ASD

infants using support vector machines and bidirectional long short-term memory neural networks. While these studies explore different parameter types and quantities, optimal predictive parameters remain unclear.

Recent findings suggest gender differences in acoustic parameters. Khozaei et al. (2020) trained classification models using timbre and intensity parameters on male ASD and TD children, then applied them to toddlers (21 ASD, language level around 12 months; TD controls aged 18-51 months), achieving 7% higher accuracy for males than females. Meta-analyses indicate acoustic features are promising early markers, with multiple parameters yielding higher accuracy than single parameters in machine learning models (Fusaroli et al., 2017). Future research should construct optimally predictive acoustic parameter sets and develop automated classification models to provide intelligent methods for early ASD screening.

Motivational Mechanisms Underlying Vocal Development

As reviewed, speech-like vocalizations develop gradually through intrinsic motivation and social interaction with adults. While recent studies have begun examining motivational influences on high-risk infants (Long et al., 2021), empirical research remains extremely limited, particularly regarding diagnosed ASD children. Future research should: (1) Investigate mechanisms through which intrinsic motivation affects vocal complexity in ASD, such as how special interest motivation influences consonant diversity. Computational modeling—an efficient, automated approach applied in TD infant research—could be adapted to examine ASD vocal development. (2) Examine how social motivation impacts vocal complexity. Social motivation directs attention to social signals, yields social rewards, and maintains relationships, enabling children to acquire more speech-like vocalizations through interaction. The specific mechanisms by which social motivation deficits affect vocal complexity in ASD require further investigation.

Neural Mechanisms of Atypical Speech-Like Vocalizations

As discussed, immature neuromotor systems and their interaction with speech auditory perceptual cortex may contribute to atypical vocal complexity. However, the neural mechanisms remain unclear. Future research should explore: (1) Speech apraxia perspectives, as apraxia affects speech movement coordination and may affect up to 60% of children with ASD aged 24-55 months (Tierney et al., 2015). Recent comparisons of ASD children with apraxia to children with apraxia alone found abnormal brain structures important for speech production (increased parietal and frontal cortical volume) in the apraxia-only group but not the ASD group (Conti et al., 2020). However, these ASD children had established verbal abilities, potentially confounding results. Future studies should include minimally verbal ASD children. (2) Interactions between speech auditory cortex and vocal motor cortex. TD research shows vocal motor-auditory perceptual mapping exists before speech onset, with oral motor activity at 3 months

affecting auditory discrimination of canonical syllables (Choi et al., 2021). Investigating this domain in ASD may provide new evidence supporting neural mechanisms of speech-like vocal development.

References

- Acevedo-Valle, J. M., Angulo, C., & Moulin-Frier, C. (2018). Autonomous discovery of motor constraints in an intrinsically motivated vocal learner. *IEEE Transactions on Cognitive and Developmental Systems*, 10(2), 417-428.
- Adamson, L. B., Bakeman, R., Suma, K., & Robins, D. L. (2019). An expanded view of joint attention: Skill, engagement, and language in typical development and autism. *Child Development*, 90(1), e1-e18.
- Akhtar, N., Jaswal, V. K., Dinishak, J., & Stephan, C. (2016). On social feedback loops and cascading effects in autism: A commentary on Warlaumont, Richards, Gilkerson, and Oller (2014). *Psychological Science*, 27(11), 1528-1530.
- American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (DSM-5®)* (5th ed.). Washington, DC: American Psychiatric Publishing.
- Bacon, E. C., Courchesne, E., Barnes, C. C., Cha, D., Pence, S., Schreibman, L., ..., & Pierce, K. (2018). Rethinking the idea of late autism spectrum disorder onset. *Development and Psychopathology*, 30(2), 553-569.
- Belardi, K., Watson, L. R., Faldowski, R. A., Hazlett, H., Crais, E., Baranek, G. T., ..., & Oller, D. K. (2017). A retrospective video analysis of canonical babbling and volubility in infants with fragile X syndrome at 9-12 months of age. *Journal of Autism and Developmental Disorders*, 47(4), 1193-1206.
- Benevides, T. W., & Lane, S. J. (2015). A review of cardiac autonomic measures: Considerations for examination of physiological response in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 45(2), 560-575.
- Bonnet-Brilhault, F., Rajerison, T. A., Paillet, C., Guimard-Brunault, M., Saby, A., Ponson, L., ..., & Roux, S. (2018). Autism is a prenatal disorder: Evidence from late gestation brain overgrowth. *Autism Research*, 11(12), 1635-1644.
- Bornstein, M. H., Costlow, K., Truzzi, A., & Esposito, G. (2016). Categorizing the cries of infants with ASD versus typically developing infants: A study of adult accuracy and reaction time. *Research in Autism Spectrum Disorders*, 31, 66-72.
- Boterberg, S., Charman, T., Marschik, P. B., Bölte, S., & Roeyers, H. (2019). Regression in autism spectrum disorder: A critical overview of retrospective findings and recommendations for future research. *Neuroscience and Biobehavioral Reviews*, 102, 24-55.

- Brown, S., Yuan, Y., & Belyk, M. (2021). Evolution of the speech-ready brain: The voice/jaw connection in the human motor cortex. *Journal of Comparative Neurology*, 529(5), 1018-1028.
- Chen, F., Zhang, H., Ding, H., Wang, S., Peng, G., & Zhang, Y. (2021). Neural coding of formant exaggerated speech and nonspeech in children with and without autism spectrum disorders. *Autism Research*, 14(7), 1357-1369.
- Chen, J., Liang, C., Wei, Z., Cui, Z., Kong, X., Dong, C. J., ..., & Wan, G. (2019). Atypical longitudinal development of speech-evoked auditory brainstem response in preschool children with autism spectrum disorders. *Autism Research*, 12(7), 1022-1031.
- Chenausky, K., Nelson, C., & Tager-Flusberg, H. (2017). Vocalization rate and consonant production in toddlers at high and low risk for autism. *Journal of Speech, Language, and Hearing Research*, 60(4), 865-876.
- Chericoni, N., de Brito Wanderley, D., Costanzo, V., Diniz-Gonçalves, A., Leitgel Gille, M., Parlato, E., ..., & Muratori, F. (2016). Pre-linguistic vocal trajectories at 6-18 months of age as early markers of autism. *Frontiers in Psychology*, 7, Article 1595.
- Cheung, C., Hamilton, L. S., Johnson, K., & Chang, E. F. (2016). The auditory representation of speech sounds in human motor cortex. *eLife Sciences*, 5, Article e12577.
- Chevallier, C., Kohls, G., Troiani, V., Brodtkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences*, 16(4), 231-239.
- Choi, D., Dehaene-Lambertz, G., Peña, M., & Werker, J. F. (2021). Neural indicators of articulator-specific sensorimotor influences on infant speech perception. *Proceedings of the National Academy of Sciences*, 118(20), Article e2025043118.
- Clements, C. C., Zoltowski, A. R., Yankowitz, L. D., Yerys, B. E., Schultz, R. T., & Herrington, J. D. (2018). Evaluation of the social motivation hypothesis of autism: A systematic review and meta-analysis. *JAMA Psychiatry*, 75(8), 797-808.
- Conti, E., Retico, A., Palumbo, L., Spera, G., Bosco, P., Biagi, L., ..., & Calderoni, S. (2020). Autism spectrum disorder and childhood apraxia of speech: Early language-related hallmarks across structural MRI study. *Journal of Personalized Medicine*, 10(4), Article 275.
- Cychoz, M., Cristia, A., Bergelson, E., Casillas, M., Baudet, G., Warlaumont, A. S., ..., & Seidl, A. (2021). Vocal development in a large-scale crosslinguistic corpus. *Developmental Science*, 24(5), Article e13090.
- Daliri, A., & Max, L. (2016). Modulation of auditory responses to speech vs. nonspeech stimuli during speech movement planning. *Frontiers in Human Neuroscience*, 10, Article 234.

- Dankbaar, J. W., & Pameijer, F. A. (2014). Vocal cord paralysis: Anatomy, imaging and pathology. *Insights into Imaging*, 5(6), 743-751.
- Di Domenico, S. I., & Ryan, R. M. (2017). The emerging neuroscience of intrinsic motivation: A new frontier in self-determination research. *Frontiers in Human Neuroscience*, 11, Article 145.
- Dow, D., Day, T. N., Kutta, T. J., Nottke, C., & Wetherby, A. M. (2020). Screening for autism spectrum disorder in a naturalistic home setting using the systematic observation of red flags (SORF) at 18-24 months. *Autism Research*, 13(1), 122-133.
- Dow, D., Guthrie, W., Stronach, S. T., & Wetherby, A. M. (2017). Psychometric analysis of the systematic observation of red flags for autism spectrum disorder in toddlers. *Autism*, 21(3), 301-309.
- Eichert, N., Papp, D., Mars, R. B., & Watkins, K. E. (2020). Mapping human laryngeal motor cortex during vocalization. *Cerebral Cortex*, 30(12), 6254-6269.
- Elmlinger, S. L., Schwade, J. A., & Goldstein, M. H. (2019). The ecology of prelinguistic vocal learning: Parents simplify the structure of their speech in response to babbling. *Journal of Child Language*, 46(5), 998-1011.
- English, M. S., Tenenbaum, E. J., Levine, T. P., Lester, B. M., & Sheinkopf, S. J. (2019). Perception of cry characteristics in 1-month-old infants later diagnosed with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49(3), 834-844.
- Esposito, G., del Carmen Rostagno, M., Venuti, P., Haltigan, J. D., & Messinger, D. S. (2014). Brief report: Atypical expression of distress during the separation phase of the strange situation procedure in infant siblings at high risk for ASD. *Journal of Autism and Developmental Disorders*, 44(4), 975-980.
- Esposito, G., Hiroi, N., & Scattoni, M. L. (2017). Cry, baby, cry: Expression of distress as a biomarker and modulator in autism spectrum disorder. *International Journal of Neuropsychopharmacology*, 20(6), 498-503.
- Esposito, G., Nakazawa, J., Venuti, P., & Bornstein, M. H. (2012). Perceptions of distress in young children with autism compared to typically developing children: A cultural comparison between Japan and Italy. *Research in Developmental Disabilities*, 33(4), 1059-1067.
- Esposito, G., Nakazawa, J., Venuti, P., & Bornstein, M. H. (2013). Componential deconstruction of infant distress vocalizations via tree-based models: A study of cry in autism spectrum disorder and typical development. *Research in Developmental Disabilities*, 34(9), 2717-2724.
- Esposito, G., Valenzi, S., Islam, T., & Bornstein, M. H. (2015). Three physiological responses in fathers and non-fathers' to vocalizations of typically developing infants and infants with autism spectrum disorder. *Research in Developmental Disabilities*, 43-44, 43-50.

- Esposito, G., & Venuti, P. (2009). Comparative analysis of crying in children with autism, developmental delays, and typical development. *Focus on Autism and Other Developmental Disabilities*, 24(4), 240-247.
- Esposito, G., & Venuti, P. (2010a). Developmental changes in the fundamental frequency (f0) of infants' cries: A study of children with autism spectrum disorder. *Early Child Development and Care*, 180(8), 1093-1102.
- Esposito, G., & Venuti, P. (2010b). Understanding early communication signals in autism: A study of the perception of infants' cry. *Journal of Intellectual Disability Research*, 54(3), 216-223.
- Estes, A., Munson, J., Rogers, S. J., Greenon, J., Winter, J., & Dawson, G. (2015). Long-term outcomes of early intervention in 6-year-old children with autism spectrum disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 54(7), 580-587.
- Eyben, F., Scherer, K., Schuller, B., Sundberg, J., André, E., Busso, C., ..., & Truong, K. (2016). The Geneva minimalistic acoustic parameter set (GeMAPS) for voice research and affective computing. *IEEE Transactions on Affective Computing*, 7(2), 190-202.
- Filipe, M. G., Watson, L., Vicente, S. G., & Frota, S. (2018). Atypical preference for infant-directed speech as an early marker of autism spectrum disorders? A literature review and directions for further research. *Clinical Linguistics and Phonetics*, 32(3), 213-231.
- Frazier, T. W., Klingemier, E. W., Anderson, C. J., Gengoux, G. W., Youngstrom, E. A., & Hardan, A. Y. (2021). A longitudinal study of language trajectories and treatment outcomes of early intensive behavioral intervention for autism. *Journal of Autism and Developmental Disorders*. Advance online publication.
- Fusaroli, R., Lambrechts, A., Bang, D., Bowler, D. M., & Gaigg, S. B. (2017). Is voice a marker for autism spectrum disorder? A systematic review and meta-analysis. *Autism Research*, 10(3), 384-407.
- Gabrielsen, T. P., Farley, M., Speer, L., Villalobos, M., Baker, C. N., & Miller, J. (2015). Identifying autism in a brief observation. *Pediatrics*, 135(2), e330-e338.
- Garrido, D., Watson, L. R., Carballo, G., Garcia-Retamero, R., & Crais, E. R. (2017). Infants at-risk for autism spectrum disorder: Patterns of vocalizations at 14 months. *Autism Research*, 10(8), 1372-1383.
- Goel, R., Hong, J. S., Findling, R. L., & Ji, N. Y. (2018). An update on pharmacotherapy of autism spectrum disorder in children and adolescents. *International Review of Psychiatry*, 30(1), 78-95.
- Green, J. R., Moore, C. A., & Reilly, K. J. (2002). The sequential development of jaw and lip control for speech. *Journal of Speech, Language, and Hearing Research*, 45(1), 66-79.

- Grove, R., Roth, I., & Hoekstra, R. A. (2016). The motivation for special interests in individuals with autism and controls: Development and validation of the special interest motivation scale. *Autism Research*, 9(6), 677-688.
- Hage, S. R. (2018). Dual neural network model of speech and language evolution: New insights on flexibility of vocal production systems and involvement of frontal cortex. *Current Opinion in Behavioral Sciences*, 21, 138-145.
- Harbison, A. L., Woynaroski, T. G., Tapp, J., Wade, J. W., Warlaumont, A. S., & Yoder, P. J. (2018). A new measure of child vocal reciprocity in children with autism spectrum disorder. *Autism Research*, 11(6), 903-915.
- Hatch, B., Iosif, A. M., Chuang, A., de la Paz, L., Ozonoff, S., & Miller, M. (2021). Longitudinal differences in response to name among infants developing ASD and risk for ADHD. *Journal of Autism and Developmental Disorders*, 51(4), 827-836.
- Hazlett, H. C., Gu, H., Munsell, B. C., Kim, S. H., Styner, M., Wolff, J. J., ..., & Piven, J. (2017). Early brain development in infants at high risk for autism spectrum disorder. *Nature*, 542(7641), 348-351.
- Hazlett, H. C., Poe, M. D., Gerig, G., Styner, M., Chappell, C., Smith, R. G., ..., & Piven, J. (2011). Early brain overgrowth in autism associated with an increase in cortical surface area before age 2 years. *Archives of General Psychiatry*, 68(5), 467-476.
- Heymann, P., Northrup, J. B., West, K. L., Parladé, M. V., Leezenbaum, N. B., & Iverson, J. M. (2018). Coordination is key: Joint attention and vocalisation in infant siblings of children with autism spectrum disorder. *International Journal of Language and Communication Disorders*, 53(5), 1007-1020.
- Iverson, J. M. (2018). Early motor and communicative development in infants with an older sibling with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research*, 61(11), 2673-2684.
- Jones, R. M., Skwerer, D. P., Pawar, R., Hamo, A., Carberry, C., Ajodan, E. L., ..., & Tager-Flusberg, H. (2019). How effective is LENA in detecting speech vocalizations and language produced by children and adolescents with ASD in different contexts? *Autism Research*, 12(4), 628-635.
- Kaushik, G., & Zarbalis, K. S. (2016). Prenatal neurogenesis in autism spectrum disorders. *Frontiers in Chemistry*, 4, Article 12.
- Kent, R. D. (2015). Nonspeech oral movements and oral motor disorders: A narrative review. *American Journal of Speech-Language Pathology*, 24(4), 763-789.
- Khozaei, A., Moradi, H., Hosseini, R., Pouretmad, H., & Eskandari, B. (2020). Early screening of autism spectrum disorder using features. *PLoS ONE*, 15(12), Article e0241690.

- Kumar, V., Croxson, P. L., & Simonyan, K. (2016). Structural organization of the laryngeal motor cortical network and its implication for evolution of speech production. *Journal of Neuroscience*, 36(15), 4170-4181.
- Kyvelidou, A., Kelsey, K., Wickstrom, J., Howard, N., Fisher, w. w., & Deveney, S. L. (2021). Postural control may drive the development of other domains in infancy. *Clinical Biomechanics*, 82(5), Article 105273.
- LaGasse, L. L., Neal, A. R., & Lester, B. M. (2005). Assessment of infant cry: Acoustic cry analysis and parental perception. *Developmental Disabilities Research Reviews*, 11(1), 83-93.
- Lee, K. S., Shin, Y. J., Yoo, H. J., Lee, G. J., Ryu, J., Son, O., & Cho, S. W. (2018). Vocalization of emotional and social expressions in korean-speaking toddlers with autism spectrum disorder and those with developmental delay. *Yonsei Medical Journal*, 59(3), 425-430.
- Leezenbaum, N. B. (2016). *Posture development and vocalization production in infants at heightened risk for autism spectrum disorder* (Unpublished doctoral dissertation). University of Pittsburgh.
- Leezenbaum, N. B., & Iverson, J. M. (2019). Trajectories of posture development in infants with and without familial risk for autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 49(8), 3257-3277.
- Lester, B. M., & Gasse, L. L. (2020). Crying. In *Encyclopedia of infant and early childhood development* (2nd ed., pp. 358-369). Oliver Walter.
- Long, H. L., Bowman, D. D., Yoo, H., Burkhardt-Reed, M. M., Bene, E. R., & Oller, D. K. (2020). Social and endogenous infant vocalizations. *PLoS ONE*, 15(8), Article e0224956.
- Long, H. L., Ramsay, G., Bowman, D. D., Burkhardt-Reed, M. M., & Oller, D. K. (2021). Social and endogenous motivations in the emergence of canonical babbling in infants at low and high risk for autism (Manuscript submitted for publication). University of Wisconsin-Madison.
- Lord, C., Brugha, T. S., Charman, T., Cusack, J., Dumas, G., Frazier, T., ..., & Veenstra-Vanderweele, J. (2020). Autism spectrum disorder. *Nature Reviews Disease Primers*, 6(1), Article 5.
- Maenner, M. J., Shaw, K. A., Baio, J., Washington, A., Patrick, M., DiRienzo, M., ..., & Dietz, P. M. (2020). Prevalence of autism spectrum disorder among children aged 8 years —autism and developmental disabilities monitoring network, 11 sites, United States, 2016. *MMWR Surveillance Summaries*, 69(4), 1-12.
- Marschik, P. B., Pokorny, F. B., Peharz, R., Zhang, D., O' Muircheartaigh, J., Roeyers, H., ..., & Kaufmann, W. E. (2017). A novel way to measure and predict development: A heuristic approach to facilitate the early detection of

neurodevelopmental disorders. *Current Neurology and Neuroscience Reports*, 17(5), 43.

Mcdaniel, J., Yoder, P., Estes, A., & Rogers, S. J. (2020). Validity of vocal communication and vocal complexity in young children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 50(9), 3105-3117.

Miller, M., Iosif, A. M., Hill, M., Young, G. S., Schwichtenberg, A. J., & Ozonoff, S. (2017). Response to name in infants developing autism spectrum disorder: A prospective study. *Journal of Pediatrics*, 183, 141-146.

Moulin-Frier, C., Nguyen, S. M., & Oudeyer, P. Y. (2014). Self-organization of early vocal development in infants and machines: The role of intrinsic motivation. *Frontiers in Psychology*, 4, Article 1006.

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

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

Oller, D. K., Caskey, M., Yoo, H., Bene, E. R., & Vohr, B. (2019). Preterm and full term infant vocalization and the origin of language. *Scientific Reports*, 9(1), Article 14734.

Oller, D. K., Griebel, U., & Warlaumont, A. S. (2016). Vocal development as a guide to modeling the evolution of language. *Topics in Cognitive Science*, 8(2), 382-392.

Ozturk, Y., Bizzego, A., Esposito, G., Furlanello, C., & Venuti, P. (2018). Physiological and self-report responses of parents of children with autism spectrum disorder to children crying. *Research in Developmental Disabilities*, 73, 31-39.

Paterson, S. J., Wolff, J. J., Elison, J. T., Winder-Patel, B., Zwaigenbaum, L., Estes, A., ..., & Piven, J. (2019). The importance of temperament for understanding early manifestations of autism spectrum disorder in high-risk infants. *Journal of Autism and Developmental Disorders*, 49(1), 2849-2863.

Patten, E., Belardi, K., Baranek, G. T., Watson, L. R., Labban, J. D., & Oller, D. K. (2014). Vocal patterns in infants with autism spectrum disorder: Canonical babbling status and vocalization frequency. *Journal of Autism and Developmental Disorders*, 44(10), 2413-2428.

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

Plumb, A. M., & Wetherby, A. M. (2013). Vocalization development in toddlers with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research*, 56(2), 721-734.

Pokorny, F. B., Schuller, B. W., Marschik, P. B., Brueckner, R., Nyström, P., Cummins, N., ..., & Falck-Ytter, T. (2017, August). Earlier identification of children with autism spectrum disorder: An automatic vocalisation-based approach. Paper presented at the meeting of the Interspeech, Stockholm, Sweden.

Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017). The human fetus preferentially engages with face-like visual stimuli. *Current Biology*, 27(12), 1825-1828.

Richards, J. A., Xu, D., Gilkerson, J., Yapanel, U., Gray, S., & Paul, T. (2017). Automated assessment of child vocalization development using LENA. *Journal of Speech, Language, and Hearing Research*, 60(7), 2048-2060.

Sacre, L. R., Zwaigenbaum, L., Bryson, S., Brian, J., Smith, I. M., Roberts, W., ..., & Garon, N. (2021). Screening for behavioral signs of autism spectrum disorder in 9-month-old infant siblings. *Journal of Autism and Developmental Disorders*, 51, 839-848.

Santos, J. F., Brosh, N., Falk, T. H., Zwaigenbaum, L., Bryson, S. E., Roberts, W., ..., & Brian, J. A. (2013, October). Very early detection of autism spectrum disorders based on acoustic analysis of pre-verbal vocalizations of 18-month old toddlers. Paper presented at the International Conference on Acoustics, Speech and Signal Processing, Vancouver, BC, Canada.

Schoen, E., Paul, R., & Chawarska, K. (2011). Phonology and vocal behavior in toddlers with autism spectrum disorders. *Autism Research*, 4(3), 177-188.

Schoen Simmons, E. (2021). Vocalization. In *Encyclopedia of autism spectrum disorders* (2nd ed., pp. 5150-5151). Springer International Publishing.

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 disorder. *Autism Research*, 5(5), 331-339.

Sheinkopf, S. J., Righi, G., Marsit, C. J., & Lester, B. M. (2016). Methylation of the glucocorticoid receptor (NR3C1) in placenta is associated with infant cry acoustics. *Frontiers in Behavioral Neuroscience*, 10, Article 100.

Shumway, S., & Wetherby, A. M. (2009). Communicative acts of children with autism spectrum disorders in the second year of life. *Journal of Speech, Language, and Hearing Research*, 52(5), 1139-1156.

Sigafoos, J., & Waddington, H. (2016). 6 year follow-up supports early autism intervention. *Lancet*, 388(10059), 2380-2381.

Soskey, L. N., Allen, P. D., & Bennetto, L. (2017). Auditory spatial attention to speech and complex non-speech sounds in children with autism spectrum disorder. *Autism Research*, 10(8), 1405-1416.

Supekar, K., Kochalka, J., Schaer, M., Wakeman, H., Qin, S., Padmanabhan, A., & Menon, V. (2018). Deficits in mesolimbic reward pathway underlie social interaction impairments in children with autism. *Brain*, 141(9), 2795-2805.

- Swanson, M. R., Shen, M. D., Wolff, J. J., Boyd, B., Clements, M., Rehg, J., ..., & Piven, J. (2018). Naturalistic language recordings reveal “hypervocal” infants at high familial risk for autism. *Child Development*, 89(2), e60-e73.
- Talbott, M. R., Nelson, C. A., & Tager-Flusberg, H. (2016). Maternal vocal feedback to 9-month-old infant siblings of children with ASD. *Autism Research*, 9(4), 460-470.
- Tan, C., Frewer, V., Cox, G., Williams, K., & Ure, A. (2021). Prevalence and age of onset of regression in children with autism spectrum disorder: A systematic review and meta-analytical update. *Autism Research*, 14(3), 438-458.
- Tierney, C., Mayes, S., Lohs, S. R., Black, A., Gisin, E., & Veglia, M. (2015). How valid is the checklist for autism spectrum disorder when a child has apraxia of speech? *Journal of Developmental and Behavioral Pediatrics*, 36(8), 569-574.
- Ucuz, I., & Cicek, A. U. (2020). Artificial neural networks based-prediction of autism spectrum disorder. *Journal of Cognitive Systems*, 5(2), 78-82.
- Unwin, L. M., Bruz, I., Maybery, M. T., Reynolds, V., Ciccone, N., Dissanayake, C., ..., & Whitehouse, A. J. O. (2017). Acoustic properties of cries in 12-month old infants at high-risk of autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 47(7), 2108-2119.
- van' t Hof, M., Tisseur, C., Berckeleer-Onnes, I. V., Nieuwenhuyzen, A. V., Daniels, A. M., Deen, M., ..., & Ester, W. A. (2021). Age at autism spectrum disorder diagnosis: A systematic review and meta-analysis from 2012 to 2019. *Autism*, 25(4), 857-861.
- Venuti, P., Caria, A., Esposito, G., De Pisapia, N., Bornstein, M. H., & de Falco, S. (2012). Differential brain responses to cries of infants with autistic disorder and typical development: An fMRI study. *Research in Developmental Disabilities*, 33(6), 2255-2264.
- Vlaskamp, C., Oranje, B., Madsen, G. F., Jepsen, J. R. M., Durston, S., Cantio, C., ..., & Bilenberg, N. (2017). Auditory processing in autism spectrum disorder: Mismatch negativity deficits. *Autism Research*, 10(11), 1857-1865.
- Warlaumont, A. S., Richards, J. A., Gilkerson, J., & Oller, D. K. (2014). A social feedback loop for speech development and its reduction in autism. *Psychological Science*, 25(7), 1314-1324.
- Werner, E., & Dawson, G. (2005). Validation of the phenomenon of autistic regression using home videotapes. *Archives of General Psychiatry*, 62(8), 889-895.
- Wetherby, A. M., Watt, N., Morgan, L., & Shumway, S. (2007). Social communication profiles of children with autism spectrum disorders late in the second year of life. *Journal of Autism and Developmental Disorders*, 37(5), 960-975.
- Wetherby, A. M., Woods, J., Allen, L., Cleary, J., Dickinson, H., & Lord, C. (2004). Early indicators of autism spectrum disorders in the second year of life.

Journal of Autism and Developmental Disorders, 34(5), 473-493.

Wetherby, A. M., Woods, J., Guthrie, W., Delehanty, A., Brown, J. A., Morgan, L., ..., & Lord, C. (2018). Changing developmental trajectories of toddlers with autism spectrum disorder: Strategies for bridging research to community practice. *Journal of Speech, Language, and Hearing Research*, 61(11), 2615-2628.

Winder, B. M., Wozniak, R. H., Paradé, M. V., & Iverson, J. M. (2013). Spontaneous initiation of communication in infants at low and heightened risk for autism spectrum disorders. *Developmental Psychology*, 49(10), 1931-1942.

Woynaroski, T., Oller, D. K., Keceli-Kaysili, B., Xu, D., Richards, J. A., Gilkerson, J., ..., & Yoder, P. (2017). The stability and validity of automated vocal analysis in preverbal preschoolers with autism spectrum disorder. *Autism Research*, 10(3), 508-519.

Yau, S. H., Brock, J., & McArthur, G. (2016). The relationship between spoken language and speech and nonspeech processing in children with autism: A magnetic event-related field study. *Developmental Science*, 19(5), 825-843.

Yirmiya, N., & Charman, T. (2010). The prodrome of autism: Early behavioral and biological signs, regression, peri- and post-natal development and genetics. *Journal of Child Psychology and Psychiatry*, 51(4), 432-458.

Yoder, P. J., Woynaroski, T., Watson, L., Gardner, E., Newsom, C. R., & Keceli-Kaysili, B. (2016). Early predictors of growth in diversity of key consonants used in communication in initially preverbal children with autism spectrum disorder. *Journal of Autism and Developmental Disorders*, 46(3), 1013-1024.

Zhou, H., Xu, X., Yan, W., Zou, X., Wu, L., Luo, X., ..., & Wang, Y. (2020). Prevalence of autism spectrum disorder in china: A nationwide multi-center population-based study among children aged 6 to 12 years. *Neuroscience Bulletin*, 36(9), 961-971.

Abstract: Early identification and intervention for children with autism spectrum disorder (ASD) are critical for developmental outcomes. Vocalizations—sounds produced before spoken language—represent potential early identification markers in children under 2 years. Research indicates that both nonspeech-like and speech-like vocalizations show atypical patterns in ASD. Theoretical explanations include motivation-oriented, neuromotor-oriented, perceptual-oriented, and social feedback-oriented theories. Future directions include: (1) examining specificity of vocal markers to ASD versus other disorders, (2) strengthening cry-based screening research, (3) developing automated classification models with optimal acoustic parameters, (4) analyzing motivational influences on speech-like vocalizations, and (5) investigating neural mechanisms of atypical vocal development. This evidence may facilitate early identification and intervention for children with ASD.

Keywords: autism spectrum disorder (ASD), potential early identification markers, unusual vocalizations, theoretical explanations

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv –Machine translation. Verify with original.