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Early Social Communication Development in Infants with Autism Spectrum Disorder

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Abstract

Social-communication differences are a robust and defining feature of autism spectrum disorder (ASD) but identifying early points of divergence in infancy has been a challenge. The current study examines social communication in 9–12-month-old infants who develop ASD (N=30; 23% female; 70% white) compared to typically developing (TD) infants (N=94, 38% female; 88% white). Results demonstrate that infants later diagnosed with ASD were already exhibiting fewer social-communication skills using eye gaze, facial expression, gestures, and sounds at 9 months (ES: 0.42–0.89). Moreover, three unique patterns of change across distinct social-communication skills were observed within the ASD group. This study documents that observable social-communication differences for infants with ASD are unfolding by 9 months, pointing to a critical window for targeted intervention.

Introduction

Social communication and interaction impairments comprise a core feature of autism spectrum disorder (ASD) in the second year of life and beyond, but these deficits are difficult to identify in the prelinguistic period – prior to the emergence of a rich and robust social-communicative repertoire. Stable diagnoses of ASD are achievable as early as 14 months of age (Pierce et al., 2019), yet readily observable behavioral features associated with ASD in the first year of life remain elusive (Szatmari et al., 2016). In response, this

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study examines the emergence of early social, communication, and play skills in infants at 9 and 12 months of age who are later diagnosed with ASD compared to infants who are typically developing (TD).

The foundation for social communication development begins to form at birth, when newborns prefer to orient to the faces over non-faces and caregivers over strangers (Field, Cohen, Garcia, & Greenberg, 1984; Johnson, Dziurawiec, Ellis, & Morton, 1991; Shultz, Klin, & Jones, 2018). Social smiling emerges between 6–8 weeks and reciprocal social babbling is observed by 6 months of age. At 9 months, increasingly refined motoric control affords new opportunities for interaction and communication, for instance giving and showing objects. Between 9–12 months of age, prelinguistic skills emerge and communication broadens in both means and function. Infants begin to use facial expression, eye gaze, gestures, and vocalizations to request, share attention, and interact (Wetherby, Allen, Cleary, Kublin, & Goldstein, 2002; Wetherby & Prizant, 1993). Such prelinguistic skills set the stage for the burst of language development to come in the months ahead (Brady, Marquis, Fleming, & McLean, 2004; Watt, Wetherby, & Shumway, 2006). This period marks a critical time in typical development as children make the transition to symbolic communication. The emergence of representational gestures that stand alone as symbols without the presence of a referent signals the onset of this transition (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bates, Bretherton, & Snyder, 1988). Not surprisingly, many 2–3-year-olds with social-communication challenges, such as ASD, carry a limited repertoire of prelinguistic skills (Delehanty, Stronach, Guthrie, Slate, & Wetherby, 2018; Dow, Guthrie, Stronach, & Wetherby, 2017; Luyster, Kadlec, Carter, & Tager-Flusberg, 2008). Toddlers with ASD exhibit lower rates of communication and fewer gestures (Delehanty et al., 2018; Shumway & Wetherby, 2009) as well as fewer instances of joint attention, social referencing, and shared positive affect (Bedford et al., 2012; Cornew, Dobkins, Akshoomoff, McCleery, & Carver, 2012; Landa, Holman, & Garrett-Mayer, 2007; Naber et al., 2008).

Prospective studies of infants who develop ASD have highlighted the importance of developmental trajectories in uncovering unique neurodevelopmental and behavioral profiles that cannot be identified from examining a single point in time (Klin & Jones, 2015). Stable and persistent social and communication challenges for many children with ASD manifest by 12–14 months of age (Landa, Gross, Stuart, & Faherty, 2013; Pierce et al., 2019), but the foundational importance of prelinguistic skills prior to this point suggests that communication trajectories for infants with ASD may diverge earlier – possibly as early as 9 months. If the developmental pathway to socially directed communication begins in the first year of life with robust social attention, vocalizations, and gestures, then one would expect the entire developmental course of early social and communication skills to be disrupted in ASD, with a divergence occurring well before the toddler period. Disruption in early social-communication behaviors for infants with ASD is becoming evident in early trajectories of infant behavior using parent-report (Sacrey et al., 2018; Veness, Prior, Eadie, Bavin, & Reilly, 2014) and experimental measures (Elsabbagh et al., 2013; Hazlett et al., 2017; Jones & Klin, 2013), suggesting that divergent neurodevelopmental processes are already underway as early as 2–6 months of age. Structural and functional brain differences are present in the first year of life for infants who later develop ASD and are associated with specific developmental outcomes. Predictive brain-behavior relationships exist between the white matter connectome and cognitive performance (Girault et al., 2019), cortical hyperexpansion and social deficits (Hazlett et al., 2012), and subcortical volume and language outcome (Swanson et al., 2017). This evidence suggests a complex interaction between brain structure and connectivity, genetic liability, and environment that may set the stage for altered experience-dependent trajectories for infants with ASD during a critical developmental window when symbolic communication is just emerging.

Very few studies have identified observable differences in emerging social-communication skills during naturalistic social interactions for infants younger than 12 months who are later diagnosed with ASD. In infants with ASD, attention to caregivers and clinicians is significantly diminished at 12 months (Filliter et al., 2015; Wan et al., 2013), but is evidently undisrupted prior to this time (Rozga et al., 2011; Schwichtenberg, Kellerman, Young, Miller, & Ozonoff, 2019; Young, Merin, Rogers, & Ozonoff, 2009). One exception is a recent study by Macari and colleagues (2020) that identified differences in gaze behavior in 6-month-old infants who were later diagnosed with ASD during a semi-structured play task with an examiner. Together, this research suggests that consistent and frequent attention to faces in the first year may be necessary for acquisition of social and communication skills, but thus far vulnerabilities in infants with ASD have been difficult to detect prior to 12 months.

The growth in social-communication skills between 6–12 months is tremendous and research has yet to determine whether early social-communication vulnerabilities are evident via standardized clinical observation prior to the first birthday and how change within this time period may differ for infants with ASD. For example, it remains unknown whether prelinguistic skills emerge more slowly in ASD compared to typically developing infants, whether some skills remain preserved, and whether some early skills simply fail to emerge. Examining the performance of infants later diagnosed with ASD on existing, widely used clinician-administered measures that are sensitive to changes in early-developing social communication skills is a potential pathway for improving early identification. Careful analysis of the emergence of social-communication skills, from their developmental onset, using clinical behavioral assessment will establish the earliest observable vulnerabilities in ASD and define precise intervention targets, motivating further development of very early interventions in the first year of life.

Honing in on social communication differences during or even prior to the key developmental transition to symbolic communication could pave the way for interventions that capitalize on existing infant abilities and parent scaffolding. As children expand their repertoires of symbols and use them with increased frequency, caregiver responses that map onto the child's focus of attention become correspondingly more complex. Parental use of expansions, recasts, and "translations" of child gesture are language-developing mechanisms that also maintain children's engagement in interaction (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007; Justice, Jiang, & Strasser, 2018). Thus, developmental change can be influenced by enriched opportunities provided by communication partners within the child's immediate environment (Tomasello & Farrar, 1986). For children with ASD, a reduced rate of communicative acts for the purpose of establishing joint attention provides fewer opportunities for caregivers to respond (Delehanty & Wetherby, 2021). Just as pivotal, a limited repertoire or delayed development of pre-symbolic and symbolic communication and joint attention may diminish the quality of caregivers' input (Iverson & Wozniak, 2016). These circumstances are not optimal and may even create cascading effects on development (Iverson & Wozniak, 2016; Wetherby, Woods, & Lord, 2007). To ascertain whether social-communication differences are observable at this pivotal juncture in language development for infants who are later diagnosed with ASD, this study maps change in foundational prelinguistic social, communication, and play skills between 9–12 months of age for infants with ASD compared to typically developing peers.

Method

Participants

Participants included 124 infants (35% female, 84% white) who were enrolled in a prospective, longitudinal study of social development prior to six months of age and either diagnosed with ASD (N=30) or confirmed to be typically developing (N=94) at 24 months. Study enrollment occurred between years 2012–2016. Participants were classified as being at high or low familial likelihood of developing ASD. High-likelihood participants had an older full-biological sibling with ASD that was confirmed through clinical review of a diagnostic evaluation report and scores within the ASD range on the Social Responsiveness Scale-2 (Constantino, 2012) and the Social Communication Questionnaire (Rutter, Bailey, & Lord, 2003). The diagnostic evaluation report was required to be completed within the past five years and contain a documented ADOS with scores in the ASD range. If the diagnostic evaluation report did not meet these requirements, then the older sibling was brought into the clinic for a diagnostic evaluation, including an ADOS. Low-likelihood participants were infant siblings with no familial history of ASD in first- or second-degree relatives. Exclusion criteria for all participants included fist-born infants, gestational age below 35 weeks, major hearing and/or visual impairment, a non-febrile seizure disorder, a known genetic syndrome, and significant pre- or perinatal complications.

All participants received a full gold-standard diagnostic evaluation at 24 months. Using a clinical best estimate diagnostic procedure (see below), participants were included in the current study if they were diagnosed with ASD or confirmed to be typically developing. Due to the low number of participants who presented with non-ASD challenges, including global developmental delay and language delay (n=8) and subclinical features of ASD (e.g., the broader autism phenotype, n=12), these groups were excluded from analyses.

Procedures

Participants were enrolled into the longitudinal study prior to age 6 months and were administered a communication assessment using the *Communication and Symbolic Behavior Scales-Developmental Profile, Behavior Sample* (CSBS; Wetherby & Prizant, 2002) at 9 and 12 months of age, administered by licensed speech-language pathologists (SLPs) with expertise in infant development and ASD. In order to provide clinical care and continuity for high-likelihood families enrolled in the study, the SLPs who administered and scored the CSBS were not masked to participant group (HL vs. LL). A trained and reliable CSBS administrator who was masked to group assignment co-scored a random selection of 20% of the CSBS behavior samples, exceeding an overall intraclass correlation of 0.89 (Social Composite: 0.836, Speech Composite: 0.897, Symbolic Composite: 0.933), indicating high agreement among masked and unmasked raters (Mitchell, 1979; Wetherby et al., 2002). All participants were then seen at 24 months for a comprehensive diagnostic evaluation to determine a clinical best estimate diagnosis. Psychologists who conducted the ADOS were masked to participant group.

Measures

Communication Assessment.—The CSBS is a standardized communication assessment for infants and toddlers containing 20 items that make up seven clusters, three composites (Social, Speech, and Symbolic), and a Total score. For this study, weighted raw scores were used in lieu of standard scores to model meaningful gains and because standard scores are not available for infants younger than 12 months.

The Social composite includes the Emotion and Eye Gaze, Communication, and Gestures clusters (score ranges 0–18, 0–24, and 0–22, respectively). The Emotion and Eye Gaze cluster includes gaze shifts, shared positive affect, and response to joint attention. The Communication cluster measures the frequency and purpose of communicative acts across activities. The Gestures cluster measures use of conventional and distal gestures. The Speech composite includes the Sounds and Words cluster. The Sounds cluster (range: 0–26) includes inventory and frequency of syllables with consonants. The Words cluster was omitted from these analyses due young participant age. The Symbolic composite includes the Understanding and Object Use clusters (score ranges 0–33, 0–29 respectively).

Clinical Best Estimate Diagnosis.—At 24 months, a clinical best estimate (CBE) diagnosis was determined for all participants (N=124) based on a gold standard ASD evaluation consisting of the Mullen, ADOS-2, and Vineland-II. The Mullen (Mullen, 1995) is a comprehensive measure of cognitive functioning. The ADOS-2 is a semi-structured diagnostic assessment for ASD. The ADOS Calibrated Severity Score (CSS) was calculated as a measure of ASD severity (Esler et al., 2015). The CBE was determined by a multidisciplinary team (licensed clinical psychologist and speech-language pathologist), based on the child's performance, and using DSM-5 criteria (American Psychiatric Association, 2013). A diagnosis of ASD was given if the child met DSM-5 criteria for ASD. A judgment of typical development was made if the child did not show symptoms of ASD during the evaluation and if developmental scores from the Mullen did not indicate language delay (i.e., scores within 1.5 standard deviations of the mean in both Expressive and Receptive language domains) or developmental delay (within 1.5 standard deviations of the mean in at least four of five domains and no more than 2 standard deviations below the mean in any domain). Children who did not exhibit symptoms of ASD, but demonstrated non-ASD challenges, including developmental or language delays, were excluded from the present study. Participants who exhibited atypical, subthreshold features associated with ASD that were lower in frequency and/or intensity than the diagnostic threshold for ASD, consistent with the broader autism phenotype (BAP; Ozonoff et al., 2014), were also excluded from the present study. A nonverbal developmental quotient (NVDQ) outcome was estimated for each participant as a proxy for cognitive abilities using the Visual Reception and Fine Motor scales of the 24-month Mullen, as has been done in previous studies (Bradshaw, Gillespie, Klaiman, Klin, & Saulnier, 2019).

Statistical Analyses

Confirmatory analyses were used to test the hypothesis that infants with ASD demonstrate attenuated social communication skills starting at 9 months of age compared to TD infants. Between-group differences across demographic variables were first examined using independent two-sample t-tests and Chi square tests of independence. Linear mixed models were then used to evaluate differences between ASD and TD infants on CSBS raw scores at 9 and 12 months. A negative binomial regression was used for the Speech composite and Sounds cluster due to low variability in scores and a non-normal distribution. Next, general linear models were used in exploratory analyses to examine which specific composites and clusters showed between-group differences in social-communication change from 9 to 12 months. A Kruskal-Wallis test was used for the Speech composite due to limited variability and a non-normal distribution. Analytic models were run with and without nonverbal developmental quotient at outcome (24 months) as a covariate. Results are presented as model-based means with accompanying test statistics and p-values. Effect sizes (Cohen's *d*) are included to aide clinical interpretation. Significance was assessed at the 0.05 level, unless otherwise noted, and all tests were two-sided. Analyses were conducted using SAS v. 9.4 (Cary, NC).

Results

Demographic information is displayed in Table 1. There were significant differences between ASD and TD participants in regard to race, maternal education, household income, and outcome ADOS and Mullen scores. As expected, participants with ASD had higher ADOS and lower Mullen scores. In regard to demographic differences, the ASD group was comprised of more racial/ethnic minority participants with lower maternal education and household incomes. This difference was driven by whether participants were of high or low familial likelihood for ASD. When this variable (high- vs. low-likelihood) was included in models of demographic differences (Table 1), the effect of race, maternal education, and family income became non-significant, suggesting that the low-likelihood group carried a higher socioeconomic status than the high-likelihood group. Demographic covariates (race, maternal education, household income) were initially included in primary statistical models. Maternal education has been shown to covary significantly with income and race (Harding, Morris, & Hughes, 2015) and when income, race, and maternal education were are all included as covariates, race and income were not significant. Therefore, maternal education was retained in final statistical models as a proxy for SES-related health inequalities (Généreux, Auger, Goneau, & Daniel, 2008) and to account for the documented association between maternal education and child language (e.g., Justice, Jiang, Bates, & Koury, 2020; Letts, Edwards, Sinka, Schaefer, & Gibbons, 2013).

Results from the linear mixed models are presented in Table 2 (see also Supplemental Table 3). At 9 months, infants later diagnosed with ASD performed significantly lower on: 1)

Total score, 2) Social composite and associated Emotion and Eye Gaze, Communication, and Gestures clusters, 3) Speech composite and associated Sounds cluster, and 4) Symbolic composite. Effect sizes were medium to large with the largest effects observed for the Social composite and Total score, followed by the three Social clusters. At 12 months, infants with ASD were observed to perform significantly lower than their TD peers on all CSBS composites and all but one cluster (Understanding). Effect sizes were larger than those observed at 9 months, with the Social composite having the largest effect, followed by the Total score. Of the clusters, Communication and Gestures had the largest effect sizes, followed by Object Use and Emotion and Eye Gaze. Significant interactions were observed for the following models: 1) Total score, 2) Social composite and associated Communication and Gestures clusters, and 3) Objects cluster. Controlling for overall cognitive abilities using NVDQ (see Supplemental Table 1) resulted in a largely similar pattern of results, with four exceptions. The Gestures cluster and Symbolic composite at 9 months and Diagnosis x Age interactions for the Social composite and Objects cluster were no longer significant. Overall, these results suggest that the diagnostic groups differed in their growth from 9 to 12 months and were further probed using generalized linear models.

Generalized linear models show that all infants made significant gains from 9–12 months across all CSBS domains, with the exception of the Emotion and Eye Gaze cluster for infants with ASD (see Table 3). Comparing change from 9–12 months between ASD and TD infants, infants with ASD made significantly fewer gains in: 1) Total score, 2) Social composite and associated Communication and Gestures clusters, and 3) Object Use cluster. Effect sizes for between-group differences in change from 9–12 months were generally small to medium when considering change from 9–12 months (all < 0.60), which is in contrast to the large effects observed at each time point. Controlling for NVDQ in these models resulted in a similar pattern of results except for the Objects cluster in which the ASD and TD groups demonstrated similar change over time (see Supplemental Table 2).

Discussion

Delineation of the earliest observable social-communication vulnerabilities in infants later diagnosed with ASD contribute to our understanding of the emergence of a core feature of ASD in the first year of life amidst a pivotal transition in communication. This study leverages a commonly used, clinician-administered communication assessment, to identify unique patterns of communication development between 9 and 12 months of age that are characteristic of infants with ASD. At 9 months, infants with ASD were already exhibiting significantly fewer social and early speech skills than their TD peers. Despite lower performance compared to TD infants, 9-month-olds with ASD did not show a complete absence of communication using eye gaze and facial expression at this early age. Infants with ASD also had a lower rate of communication and used fewer gestures. Interestingly, when controlling for nonverbal cognitive abilities at outcome, the difference in 9-month gestures was no longer observed, suggesting that the variability in very early gesture use may be more associated with broader developmental abilities. Additional research should investigate concurrent associations between early fine motor and cognitive skills on gesture development (Estes et al., 2015; LeBarton & Landa, 2019). The variability for the Sounds cluster score was quite small across both groups, but the vast majority of infants with

ASD were not observed to use any sounds to communicate during the 9-month assessment. Effect sizes were large for all significant differences, with the Emotion and Eye Gaze and Communication clusters resulting in the largest effects of the six clusters. Infant symbolic use of objects did not significantly differ between infants with and without ASD at 9 months, likely due to the limited number of symbolic play skills expected at this age, coupled with the constraints afforded by newly emerging fine motor skills.

By 12 months, infants with ASD differed significantly from TD infants on most social-communication skills. The largest effect was observed for the Social composite, followed by the Communication and Gestures clusters, suggesting that these developmental domains are the most salient areas of vulnerability for 12-month-olds with ASD. The Object Use cluster significantly differentiated the groups at 12 months, suggesting that delays in symbolic play skills may not emerge until after 9 months for infants with ASD. The only cluster that was not significantly different at 12 months was Understanding. Infants scored quite low on this domain at 9 and 12 months, suggesting that receptive communication, measured via identification of objects, body parts, and people, is slower to emerge compared to other nonverbal communicative skills and may not be useful in understanding the development of ASD during this time period.

Unique Patterns of Social-Communication Development in ASD

Recent research has shown utility in examining unique trajectories of behavior for infants with ASD across the first and second years of life as a way of understanding evolving, dynamic brain-behavior relationships and revealing developmental cascades (Bradshaw et al., 2019, 2020; Jones & Klin, 2013; Wolff, Jacob, & Elison, 2018). Given the varied developmental onset of distinct communication skills, we examined specific patterns of change across each cluster of social-communication behavior. Infants with ASD made significant gains in most areas of social communication, but these gains fell short when compared to those made by their TD peers. These findings can be characterized by three distinct patterns of change from 9–12 months. On measures of eye gaze, facial expression, and sounds, infants with ASD demonstrated skills that were *consistently low* compared to their TD peers. Infants with ASD performed significantly lower at both 9 and 12 months, but they made parallel gains during this developmental window. Critically, infants with ASD did not exhibit a complete absence of using eye gaze, facial expression, and sounds to communicate, but instead these skills were less robust when compared to TD infants. In contrast, a pattern of *later divergence* was observed for symbolic use of objects. Here, infants with ASD were comparable to TD infants at 9 months but made significantly fewer gains in the following 3 months; by 12 months they were scoring significantly lower. The final group of vulnerable behaviors were reduced frequency and function of communication and use of gestures and can be characterized as a *growing gap* for infants with ASD. This pattern describes behaviors for which infants with ASD performed lower at 9 and 12 months and evidenced significantly less change between the two time points. Thus, infants with ASD are not only already lagging in these skills at 9 months, but they are also failing to keep subsequent pace with their TD peers, let alone close the gap. This is consistent with retrospective studies of infants with ASD showing lower rates of communication and a smaller inventory of unique gestures between 9–15 months (Colgan et al., 2006; Watson, Crais, Baranek, Dykstra, & Wilson, 2013) and prospective studies showing slower growth in gestures, words, and gesture-vocalization coordination within this time window (Parladé & Iverson, 2015).

Strengths and Limitations

This prospective, longitudinal study identified observable communication differences in 9–12-month-old infants later diagnosed with ASD compared to TD infants utilizing a direct clinical assessment. In contrast to other studies that use granular, customized coding schemes of infant behavior, this study identified differences using a standard clinical assessment that can be scored immediately following the evaluation. However, several sampling issues limit the generalizability of these findings. We did not include a non-ASD developmentally delayed comparison group due to sample size. Analyses that controlled for the effect of nonverbal development resulted in minor changes in results and mild-to-moderate reductions in effect size. In addition, the TD group combined typically developing siblings of children with and without ASD. Infant siblings with any clinical or subclinical atypical behaviors were excluded from this group, however it is possible that subtle developmental differences may exist even in typically developing siblings of children with ASD (Dabrowska & Pisula, 2010). This study used an infant sibling research design rather than a community-attained epidemiological sample, raising the possibility of sampling biases (Micheletti et al., 2020). There were also socio-demographic differences between the diagnostic groups, driven by differences between infants at high familial likelihood and low familial likelihood for ASD. While this is, in some ways, an expected trend given increased resources for high SES, low-likelihood families to participate in research, this finding demonstrates a gap in opportunity and access for some families. This disparity will need to be addressed in our future studies to ensure diversity and inclusion in research. While all analytic models included maternal education as a covariate, it will be important to replicate these findings with a low-likelihood, typically developing group of similar demographic makeup to the ASD group.

By design, the clinicians who administered the CSBS were not masked to participant group in order to provide families with appropriate clinical care and accurate clinical feedback at each study visit. This strategy is not dissimilar from community clinicians who generally have access to all family history of their patients. While this issue was addressed by reporting inter-rater reliability for a portion of behavior samples that were scored by a masked rater, it is important to note this as a potential study limitation. Finally, diagnostic ascertainment was performed at 24 rather than 36 months. Research suggests high diagnostic stability at 24 months (Chawarska, Klin, Paul, Macari, & Volkmar, 2009; Ozonoff et al., 2015; Zwaigenbaum et al., 2016), but suggest a 12–13% false negative rate (Ozonoff et al., 2015). These results should be replicated with a larger sample of participants that includes 36-month outcome data and control groups with non-ASD developmental and communication delays.

Conclusions

Findings from this study have broad implications for understanding the developmental course of social communication. In the first year of life the presence and magnitude of change in eye gaze, facial expression, gestures, and sounds appears to be critical in the typical emergence of social and language skills. Awareness of normative changes in the frequency and variety of communicative behavior between 9–12 months can be invaluable for the development of early screeners and studies of brain-behavior relationships during this developmental window. In particular, this report suggests unique patterns of change for social, speech, and symbolic skills that characterize early social communication development for infants with ASD. Speech remains the primary first concern for parents of children with ASD, but the dramatic gains, or lack thereof, in the frequency and variety of gestures and sounds used to request, share, and interact between 9–12 months may go unnoticed. Critically, this study points to a small but foundational set of skills for 9-month-old infants with ASD that may be leveraged in early intervention. Intervention studies for infants between 9–12 months are beginning to emerge and this study provides a rationale for beginning intervention prior to the first birthday, as infants with ASD exhibit fewer social-communicative behaviors and make fewer gains during this time. Very early intervention that occurs in the midst of the transition to symbolic communication, that capitalizes on existing communicative abilities, and that leverages parent scaffolding to increase moments of joint engagement and enrich the language environment may help shift developmental trajectories for infants with ASD. In particular, targeting skills that remain *consistently low* or show a *growing gap* could result in a protective effect, boosting resiliency and improving developmental outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

American Psychiatric Association. (2013). Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition: DSM-5. Arlington, VA: American Psychiatric Association.

Bates E, Benigni L, Bretherton I, Camaioni L, & Volterra V. (1979). The emergence of symbols: Cognition and communication in infancy. New York, NY: Academic Press.

Bates E, Bretherton I, & Snyder L. (1988). From first words to grammar: Individual differences and dissociable mechanisms. New York, NY: Cambridge University Press.

Bedford R, Elsabbagh M, Gliga T, Pickles A, Senju A, Charman T, … team, the B. (2012). Precursors to Social and Communication Difficulties in Infants At-Risk for Autism: Gaze Following and Attentional Engagement. Journal of Autism and Developmental Disorders, 42(10), 2208–2218. 10.1007/s10803-012-1450-y [PubMed: 22278030]

Bradshaw J, Gillespie S, Klaiman C, Klin A, & Saulnier C. (2019). Early emergence of discrepancy in adaptive behavior and cognitive skills in toddlers with autism spectrum disorder. Autism, 23(6), 1485–1496. 10.1177/1362361318815662 [PubMed: 30525959]

Bradshaw J, Klin A, Evans L, Klaiman C, Saulnier C, & McCracken C. (2020). Development of attention from birth to 5 months in infants at risk for autism spectrum disorder. Development and Psychopathology, 32(2), 491–501. 10.1017/S0954579419000233 [PubMed: 31012398]

Brady NC, Marquis J, Fleming K, & McLean L. (2004). Prelinguistic Predictors of Language Growth in Children With Developmental Disabilities. Journal of Speech, Language, and Hearing Research, 47(3), 663–677. 10.1044/1092-4388(2004/051)

Chawarska K, Klin A, Paul R, Macari S, & Volkmar F. (2009). A prospective study of toddlers with ASD: short-term diagnostic and cognitive outcomes. Journal of Child Psychology and Psychiatry, 50(10), 1235–1245. 10.1111/j.1469-7610.2009.02101.x [PubMed: 19594835]

Colgan SE, Lanter E, McComish C, Watson LR, Crais ER, & Baranek GT (2006). Analysis of Social Interaction Gestures in Infants with Autism. Child Neuropsychology, 12(4–5), 307–319. 10.1080/09297040600701360 [PubMed: 16911975]

Constantino JN (2012). Social Responsiveness Scale, Second Edition (SRS-2). Los Angeles: Western Psychological Services.

Cornew L, Dobkins KR, Akshoomoff N, McCleery JP, & Carver LJ (2012). Atypical Social Referencing in Infant Siblings of Children with Autism Spectrum Disorders. Journal of Autism and Developmental Disorders, 42(12), 2611–2621. 10.1007/s10803-012-1518-8 [PubMed: 22456817]

Dabrowska A, & Pisula E. (2010). Parenting stress and coping styles in mothers and fathers of pre-school children with autism and Down syndrome. Journal of Intellectual Disability Research, 54(3), 266–280. 10.1111/j.1365-2788.2010.01258.x [PubMed: 20146741]

Delehanty AD, Stronach S, Guthrie W, Slate E, & Wetherby AM (2018). Verbal and nonverbal outcomes of toddlers with and without autism spectrum disorder, language delay, and global developmental delay. Autism & Developmental Language Impairments, 3, 239694151876476. 10.1177/2396941518764764

Delehanty AD, & Wetherby AM (2021). Rate of communicative gestures and developmental outcomes in toddlers with and without autism spectrum disorder during a home observation. American Journal of Speech-Language Pathology, 30(2), 649–662. 10.1044/2020_AJSLP-19-00206 [PubMed: 33751898]

Dow D, Guthrie W, Stronach ST, & Wetherby AM (2017). Psychometric analysis of the Systematic Observation of Red Flags for autism spectrum disorder in toddlers. Autism : The International Journal of Research and Practice, 21(3), 301–309. 10.1177/1362361316636760

Elsabbagh M, Fernandes J, Jane Webb S, Dawson G, Charman T, & Johnson MH (2013). Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. Biological Psychiatry, 74(3), 189–194. 10.1016/j.biopsych.2012.11.030 [PubMed: 23374640]

Esler AN, Bal VH, Guthrie W, Wetherby A, Ellis Weismer S, & Lord C. (2015). The Autism Diagnostic Observation Schedule, Toddler Module: Standardized Severity Scores. Journal of Autism and Developmental Disorders, 45(9), 2704–2720. 10.1007/s10803-015-2432-7 [PubMed: 25832801]

Estes A, Zwaigenbaum L, Gu H, St. John T, Paterson S, Elison JT, … Piven J. (2015). Behavioral, cognitive, and adaptive development in infants with autism spectrum disorder in the first 2 years of life. Journal of Neurodevelopmental Disorders, 7(1), 24. 10.1186/s11689-015-9117-6 [PubMed: 26203305]

Field TM, Cohen D, Garcia R, & Greenberg R. (1984). Mother-stranger face discrimination by the newborn. Infant Behavior and Development, 7(1), 19–25. 10.1016/S0163-6383(84)80019-3

Filliter JH, Longard J, Lawrence MA, Zwaigenbaum L, Brian J, Garon N, … Bryson SE (2015). Positive Affect in Infant Siblings of Children Diagnosed with Autism Spectrum Disorder. Journal of Abnormal Child Psychology, 43(3), 567–575. 10.1007/s10802-014-9921-6 [PubMed: 25117578]

Généreux M, Auger N, Goneau M, & Daniel M. (2008). Neighbourhood socioeconomic status, maternal education and adverse birth outcomes among mothers living near highways. Journal of Epidemiology and Community Health, 62(8), 695–700. 10.1136/jech.2007.066167 [PubMed: 18621954]

Girault JB, Munsell BC, Puechmaille D, Goldman BD, Prieto JC, Styner M, & Gilmore JH (2019). White matter connectomes at birth accurately predict cognitive abilities at age 2. NeuroImage, 192, 145–155. 10.1016/j.neuroimage.2019.02.060 [PubMed: 30825656]

Goldin-Meadow S, Goodrich W, Sauer E, & Iverson J. (2007). Young children use their hands to tell their mothers what to say. Developmental Science, 10(6), 778–785. 10.1111/j.1467-7687.2007.00636.x [PubMed: 17973795]

Harding JF, Morris PA, & Hughes D. (2015). The Relationship Between Maternal Education and Children's Academic Outcomes: A Theoretical Framework. Journal of Marriage and Family, 77(1), 60–76. 10.1111/jomf.12156

Hazlett HC, Gu H, Munsell BC, Kim SH, Styner M, Wolff JJ, … Statistical Analysis. (2017). Early brain development in infants at high risk for autism spectrum disorder. Nature, 542(7641), 348–351. 10.1038/nature21369 [PubMed: 28202961]

Hazlett HC, Poe MD, Lightbody AA, Styner M, MacFall JR, Reiss AL, & Piven J. (2012). Trajectories of early brain volume development in fragile X syndrome and autism. Journal of the American Academy of Child and Adolescent Psychiatry, 51(9), 921–933. 10.1016/j.jaac.2012.07.003 [PubMed: 22917205]

Iverson JM, & Wozniak RH (2016). Transitions to intentional and symbolic communication in typical development and in autism spectrum disorder. In Prelinguistic and Minimally Verbal Communicators on the Autism Spectrum (pp. 51–72). 10.1007/978-981-10-0713-2_4

Johnson M, Dziurawiec S, Ellis H, & Morton J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. Cognition, 40(1–2), 1–19. 10.1016/0010-0277(91)90045-6 [PubMed: 1786670]

Jones W, & Klin A. (2013). Attention to eyes is present but in decline in 2–6-month-old infants later diagnosed with autism. Nature, 504(7480), 427–431. 10.1038/nature12715 [PubMed: 24196715]

Justice LM, Jiang H, Bates R, & Koury A. (2020). Language Disparities Related to Maternal Education Emerge by Two Years in a Low-Income Sample. Maternal and Child Health Journal, 24(11), 1419–1427. 10.1007/s10995-020-02973-9 [PubMed: 32632843]

Justice LM, Jiang H, & Strasser K. (2018). Linguistic environment of preschool classrooms: What dimensions support children's language growth? Early Childhood Research Quarterly, 42, 79–92. 10.1016/j.ecresq.2017.09.003

Klin A, & Jones W. (2015). Measurement and Mismeasurement of Social Development in Infants Later Diagnosed with Autism Spectrum Disorder | Klin | International Journal of Statistics in Medical Research. International Journal of Statistics in Medical Research, 4(2), 180–187.

Landa RJ, Holman K, & Garrett-Mayer E. (2007). Social and communication development in toddlers with early and later diagnosis of autism spectrum disorders. Archives of General Psychiatry, 64(7), 853–864. Retrieved from http://archpsyc.ama-assn.org/cgi/reprint/64/7/853%5Cnhttp://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=emed8&NEWS=N&AN=2007324911 [PubMed: 17606819]

Landa Rebecca J., Gross AL, Stuart EA, & Faherty A. (2013). Developmental Trajectories in Children With and Without Autism Spectrum Disorders: The First 3 Years. Child Development, 84(2), 429–442. 10.1111/j.1467-8624.2012.01870.x [PubMed: 23110514]

LeBarton ES, & Landa RJ (2019). Infant motor skill predicts later expressive language and autism spectrum disorder diagnosis. Infant Behavior and Development, 54, 37–47. 10.1016/j.infbeh.2018.11.003 [PubMed: 30557704]

Letts C, Edwards S, Sinka I, Schaefer B, & Gibbons W. (2013). Socio-economic status and language acquisition: Children's performance on the new Reynell Developmental Language Scales. International Journal of Language and Communication Disorders, 48(2), 131–143. 10.1111/1460-6984.12004 [PubMed: 23472954]

Luyster RJ, Kadlec MB, Carter A, & Tager-Flusberg H. (2008). Language Assessment and Development in Toddlers with Autism Spectrum Disorders. Journal of Autism and Developmental Disorders, 38(8), 1426–1438. 10.1007/s10803-007-0510-1 [PubMed: 18188685]

Macari S, Milgramm A, Reed J, Shic F, Powell KK, Macris D, & Chawarska K. (2020). Context-Specific Dyadic Attention Vulnerabilities During the First Year in Infants Later Developing

Autism Spectrum Disorder. Journal of the American Academy of Child and Adolescent Psychiatry. 10.1016/j.jaac.2019.12.012

Micheletti M, McCracken C, Constantino JN, Mandell D, Jones W, & Klin A. (2020). Research Review: Outcomes of 24- to 36-month-old children with autism spectrum disorder vary by ascertainment strategy: a systematic review and meta-analysis. Journal of Child Psychology and Psychiatry, 61(1), 4–17. 10.1111/jcpp.13057 [PubMed: 31032937]

Mitchell SK (1979). Interobserver agreement, reliability, and generalizability of data collected in observational studies. Psychological Bulletin, 86(2), 376–390. 10.1037/0033-2909.86.2.376

Mullen EM (1995). Mullen Scales of Early Learning. AGS Edition. Circle Pines, MN: American Guidance Service. Inc.

Naber FBA, Bakermans-Kranenburg MJ, Van IJzendoorn MH, Dietz C, Van Daalen E, Swinkels SHN, … Van Engeland H. (2008). Joint attention development in toddlers with autism. European Child and Adolescent Psychiatry, 17(3), 143–152. 10.1007/s00787-007-0648-6 [PubMed: 17849078]

Ozonoff S, Young GS, Belding A, Hill M, Hill A, Hutman T, … Iosif A-M (2014). The Broader Autism Phenotype in Infancy: When Does It Emerge? Journal of the American Academy of Child & Adolescent Psychiatry, 53(4), 398–407.e2. 10.1016/j.jaac.2013.12.020

Ozonoff S, Young GS, Landa RJ, Brian J, Bryson S, Charman T, … Iosif A-M (2015). Diagnostic stability in young children at risk for autism spectrum disorder: a baby siblings research consortium study. Journal of Child Psychology and Psychiatry, 56(9), 988–998. 10.1111/jcpp.12421 [PubMed: 25921776]

Parladé MV, & Iverson JM (2015). The Development of Coordinated Communication in Infants at Heightened Risk for Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 45(7), 2218–2234. 10.1007/s10803-015-2391-z [PubMed: 25689930]

Pierce K, Gazestani VH, Bacon E, Barnes CC, Cha D, Nalabolu S, … Courchesne E. (2019). Evaluation of the Diagnostic Stability of the Early Autism Spectrum Disorder Phenotype in the General Population Starting at 12 Months. JAMA Pediatrics, 173(6), 578. 10.1001/jamapediatrics.2019.0624 [PubMed: 31034004]

Rozga A, Hutman T, Young GS, Rogers SJ, Ozonoff S, Dapretto M, & Sigman M. (2011). Behavioral Profiles of Affected and Unaffected Siblings of Children with Autism: Contribution of Measures of Mother–Infant Interaction and Nonverbal Communication. Journal of Autism and Developmental Disorders, 41(3), 287–301. 10.1007/s10803-010-1051-6 [PubMed: 20568002]

Rutter M, Bailey A, & Lord C. Social Communication Questionnaire (SCQ)., (2003).

Sacrey LAR, Bryson S, Zwaigenbaum L, Brian J, Smith IM, Roberts W, … Garon N. (2018). The Autism Parent Screen for Infants: Predicting risk of autism spectrum disorder based on parent-reported behavior observed at 6–24 months of age. Autism, 22(3), 322–334. 10.1177/1362361316675120 [PubMed: 29671640]

Schwichtenberg AJ, Kellerman AM, Young GS, Miller M, & Ozonoff S. (2019). Mothers of children with autism spectrum disorders: Play behaviors with infant siblings and social responsiveness. Autism, 23(4), 821–833. 10.1177/1362361318782220 [PubMed: 29950114]

Shultz S, Klin A, & Jones W. (2018). Neonatal Transitions in Social Behavior and Their Implications for Autism. Trends in Cognitive Sciences, 22(5), 452–469. 10.1016/j.tics.2018.02.012 [PubMed: 29609895]

Shumway S, & Wetherby AM (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. 10.1044/1092-4388(2009/07-0280)

Swanson MR, Shen MD, Wolff JJ, Elison JT, Emerson RW, Styner MA, … Gu H. (2017). Subcortical Brain and Behavior Phenotypes Differentiate Infants With Autism Versus Language Delay. Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 2(8), 664–672. 10.1016/j.bpsc.2017.07.007 [PubMed: 29560900]

Szatmari P, Chawarska K, Dawson G, Georgiades S, Landa R, Lord C, … Halladay A. (2016). Prospective Longitudinal Studies of Infant Siblings of Children With Autism: Lessons Learned and Future Directions. Journal of the American Academy of Child & Adolescent Psychiatry. 10.1016/j.jaac.2015.12.014

Tomasello M, & Farrar MJ (1986). Joint Attention and Early Language. Child Development, 57(6), 1454. 10.2307/1130423 [PubMed: 3802971]

Veness C, Prior M, Eadie P, Bavin E, & Reilly S. (2014). Predicting autism diagnosis by 7 years of age using parent report of infant social communication skills. Journal of Paediatrics and Child Health, 50(9), 693–700. 10.1111/jpc.12614 [PubMed: 24909517]

Wan MW, Green J, Elsabbagh M, Johnson M, Charman T, Plummer F, … Volein A. (2013). Quality of interaction between at-risk infants and caregiver at 12–15 months is associated with 3-year autism outcome. Journal of Child Psychology and Psychiatry and Allied Disciplines, 54(7), 763–771. 10.1111/jcpp.12032

Watson LR, Crais ER, Baranek GT, Dykstra JR, & Wilson KP (2013). Communicative Gesture Use in Infants With and Without Autism: A Retrospective Home Video Study. American Journal of Speech-Language Pathology, 22(1), 25–39. 10.1044/1058-0360(2012/11-0145) [PubMed: 22846878]

Watt N, Wetherby AM, & Shumway S. (2006). Prelinguistic Predictors of Language Outcome at 3 Years of Age. Journal of Speech, Language, and Hearing Research, 49(6), 1224–1237. 10.1044/1092-4388(2006/088)

Wetherby AM, Allen L, Cleary J, Kublin K, & Goldstein H. (2002). Validity and Reliability of the Communication and Symbolic Behavior Scales Developmental Profile With Very Young Children. Journal of Speech, Language, and Hearing Research, 45(6), 1202–1218. 10.1044/1092-4388(2002/097)

Wetherby AM, & Prizant BM (1993). Profiling Communication and Symbolic Abilities in Young Children. Journal of Childhool Communication Disorders, 15(1), 23–32. 10.1177/152574019301500105

Wetherby AM, & Prizant BM (2002). Communication and symbolic behavior scales: developmental profile. Paul H Brookes Publishing.

Wetherby AM, Woods J, & Lord C. (2007). ESAC: Early Screening for Autism and Communication Disorders. Unpublished manual, Florida State University, Tallahassee, FL.

Wolff JJ, Jacob S, & Elison JT (2018). The journey to autism: Insights from neuroimaging studies of infants and toddlers. Development and Psychopathology, 30(2), 479–495. 10.1017/S0954579417000980 [PubMed: 28631578]

Young GS, Merin N, Rogers SJ, & Ozonoff S. (2009). Gaze behavior and affect at 6 months: Predicting clinical outcomes and language development in typically developing infants and infants at risk for autism. Developmental Science, 12(5), 798–814. 10.1111/j.1467-7687.2009.00833.x [PubMed: 19702771]

Zwaigenbaum L, Bryson SE, Brian J, Smith IM, Roberts W, Szatmari P, … Vaillancourt T. (2016). Stability of diagnostic assessment for autism spectrum disorder between 18 and 36 months in a high-risk cohort. Autism Research, 9(7), 790–800. 10.1002/aur.1585 [PubMed: 26613202]

Table 1

Participant Demographics

	ASD N=30	TD N=94	Test statistic
Familial Likelihood			$\chi^2 = 53.8$, $p < .0001$
High Likelihood	27 (90%)	16 (17%)	
Low Likelihood	3 (10%)	78 (83%)	
Age at Visit			
9-Month Visit	9.76 (0.51)	9.80 (0.48)	$t(118) = 0.42$, $p = .674$
12-Month Visit	12.33 (0.55)	12.41 (0.61)	$t(122) = 0.65$, $p = .516$
Gestational Age	39.12 (2.02)	39.27 (2.02)	$t(118) = 0.47$, $p = .642$
Sex			$\chi^2 = 2.2$, $p = .13$
Male	23 (77%)	58 (62%)	
Female	7 (23%)	36 (38%)	
Child's Race[a]			$p < .05$
White	21 (70%)	83 (88%)	
Black	7 (23%)	4 (4%)	
Asian	0	1 (1%)	
Mixed Race	2 (7%)	6 (6%)	
Maternal Education[a]			$p < .0001$
High School	2 (7%)	0	
Some College	9 (30%)	3 (3%)	
College Degree	11 (37%)	35 (37%)	
Graduate Degree	8 (26%)	56 (60%)	
Household Income[a,b]			$p < .001$
< $40,000	9 (33%)	3 (3%)	
$40,000 – $80,000	3 (11%)	15 (17%)	
$80,000 – $125,000	8 (30%)	33 (37%)	
> $125,000	7 (26%)	39 (43%)	
ADOS Total CSS [c]	6.79 (2.37)	1.67 (1.16)	$t(120) = -15.74$, $p < .0001$
Mullen Scales of Early Learning T-Scores [c]			
Expressive Language	39.83 (13.06)	57.32 (12.14)	$t(109) = 6.15$, $<.0001$
Receptive Language	38.58 (15.17)	57.95 (7.23)	$t(109) = 8.87$, $p < .0001$
Visual Reception	50.54 (13.09)	61.10 (10.48)	$t(109) = 4.13$, $p < .0001$
Fine Motor	47.33 (10.45)	55.89 (9.65)	$t(109) = 3.78$, $p < .001$

[a]Fisher's exact

[b]N=7 participants declined to state

[c]The *ADOS* and *Mullen* were administered at 24 months

Table 2

CSBS Weighted Raw Scores Least Squares Means and Differences

	9 Months				12 Months				Interaction
	ASD N=29	TD N=91	Mean Difference	Cohen's *d*	ASD N=30	TD N=94	Mean Difference	Cohen's *d*	
Social	19.35 (16.54, 22.17)	25.83 (23.27, 28.38)	6.47^{***} (3.37, 9.57)	0.89	28.54 (25.49, 31.59)	39.98 (37.36, 42.60)	11.44^{***} (8.09, 14.79)	1.48	$F(235) = 5.37^{*b}$
Emotion and Eye Gaze	12.24 (11.31, 13.17)	13.96 (13.14, 14.78)	1.72^{**} (0.70, 2.74)	0.73	13.33 (12.41, 14.25)	15.12 (14.31, 15.93)	1.79^{***} (0.78, 2.78)	0.76	$F(237) = 0.01$
Communication	3.68 (2.29, 5.07)	6.40 (5.13, 7.67)	2.72^{***} (1.19, 4.24)	0.75	8.98 (7.43, 10.54)	14.43 (13.11, 15.75)	5.45^{***} (3.74, 7.16)	1.40	$F(233) = 6.43^{*}$
Gestures	3.41 (2.17, 4.65)	5.42 (4.30, 6.53)	2.01^{**b} (0.64, 3.38)	0.63	6.20 (4.91, 7.49)	10.37 (9.25, 11.49)	4.17^{***} (2.76, 5.59)	1.27	$F(237) = 5.48^{*}$
Speech [a]	0.67 (0.33, 1.37)	2.19 (1.14, 3.43)	3.24^{**} (1.37, 7.64)	-	3.61 (1.92, 6.79)	9.19 (5.45,15.49)	2.54^{**} (1.34, 4.82)	-	$F(115) = 0.23$
Sounds [a]	0.68 (0.33, 1.37)	2.17 (1.23, 3.81)	3.21^{**} (1.36, 7.58)	-	3.61 (1.92, 6.80)	8.32 (4.93, 14.04)	2.30^{*} (1.21, 4.37)	-	$F(119) = 0.43$
Symbolic	2.68 (1.81, 3.54)	3.66 (2.81, 4.52)	0.99^{*b} (0.05, 1.93)	0.42	7.23 (5.68, 8.77)	9.60 (8.48, 10.71)	2.37^{**} (0.63, 4.11)	0.68	$F(176) = 2.11$
Understanding [a]	0.47 (0.19, 1.17)	1.18 (0.60, 2.33)	2.53 (0.92, 6.92)	-	2.33 (1.19, 4.57)	3.69 (1.92, 7.07)	1.58 (0.70, 3.59)	-	$F(115) = 0.44$
Objects	2.15 (1.60, 2.69)	2.49 (1.95, 3.04)	0.35 (−0.25, 0.94)	0.23	4.92 (3.97, 5.86)	6.63 (5.94, 7.32)	1.72^{**} (0.66, 2.78)	0.80	$F(181) = 5.50^{*b}$
Total Score	23.40 (19.58, 27.23)	32.00 (28.37, 35.64)	8.60^{***} (4.41, 12.79)	0.84	39.14 (34.12, 44.15)	56.84 (52.80, 60.88)	17.70^{***} (12.13, 23.27)	1.46	$F(217) = 7.63^{**}$

* $p < .05$

** $p < .01$

*** $p < .001$

[a] Negative binomial regression was used due to a score of 0 at 9-month visit for ~50% of participants. Cohen's *d* not calculated for these measures.

[b] These results are no longer significant ($p > .1$) when controlling for nonverbal developmental quotient (NVDQ). See Supplemental Table 1 for full report of results controlling for NVDQ.

Table 3

Difference in Estimated Differences

	Mean Change ASD	Mean Change TD	Difference in Differences (ASD – TD)	Statistic	Effect Size
Social Composite	9.20*** (5.54, 12.86)	14.12*** (12.06, 16.19)	−4.92* (−9.12, −0.71)	z = −2.29*	0.42
Emotion and Eye Gaze	1.11 (−0.06, 2.28)	1.14** (0.48, 1.80)	−0.03 (−1.37, 1.31)	z = −0.04	0.01
Communication	5.30*** (3.46, 7.14)	8.03*** (7.00, 9.07)	−2.73* (−4.85, −0.61)	z = −2.53*	0.47
Gestures	2.79** (1.24 4.35)	4.95*** (4.07, 5.83)	−2.16* (−3.95, −0.37)	z = −2.36*	0.43
Speech Composite [a]	3.99** (1.69, 9.43)	4.05*** (2.62, 6.26)	−0.98* (−2.59, 0.37)	z = −0.03	0.01
Sounds [a]	4.00** (1.69, 9.47)	3.71*** (2.39, 5.76)	1.08 (0.41, 2.84)	z = 0.15	0.03
Symbolic Composite	4.56*** (2.93, 6.18)	5.93*** (5.01, 6.84)	−1.37 (−3.23, 0.50)	z = −1.44	0.26
Understanding [a]	5.24** (1.87, 14.70)	3.11*** (1.83, 5.28)	1.68 (0.53, 5.37)	z = 0.88	0.16
Objects	2.77*** (1.77, 3.76)	4.14*** (3.58, 4.70)	−1.37*[a] (−2.51, 0.23)	z = −2.35*[b]	0.43
Total Score	15.74*** (10.09, 21.38)	24.80*** (21.61, 27.99)	−9.07** (−15.55, −2.58)	z = −2.74**	0.51

* $p < .05$

** $p < .01$

*** $p < .001$

[a] Negative binomial regression was used due to a score of 0 at visit 9-month visit for ~50% of participants.

[b] These results are no longer significant ($p > .05$) when controlling for nonverbal developmental quotient (NVDQ). See Supplemental Table 2 for results controlling for NVDQ.