Increased eye contact during parent-child versus clinician-child interactions in young children with autism

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Abstract

Accumulating evidence suggests that when parents are actively involved in therapy, children with Autism Spectrum Disorder (ASD) have better outcomes, yet it is unknown whether children with ASD significantly alter their social behaviour with their parent versus a clinician. During a face-to-face interaction, young children (N = 27, ages 18-60 months) with ASD demonstrated longer durations and higher frequencies of eye contact with their parent compared to a clinician. Children also made more eye contact during snack versus interactive play with both their parent and the clinician, which is consistent with our prior work. The findings suggest that despite social communication difficulties associated with ASD, children with ASD demonstrated increased eye contact with their parent.

Key Words: Autism, ASD, eye contact, gaze, parent-child interaction

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Reciprocal interactions are critical for the overall social well-being and emotional development of young children and lay the foundation for language development, social behavior and learning new skills (Adamson, Bakeman, Deckner, & Nelson, 2014; Feldman, 2015; Hudson, Levickis, Down, Nicholls, & Wake, 2015; Masur, Flynn, & Eichorst, 2005; Rowe, 2012; Tamis-LeMonda, Bornstein, & Baumwell, 2001). Increased maternal responses to a child's gestures or verbalizations are associated with improved language abilities (Hudson et al., 2015) and these reciprocal parent-child interactions increase social competence longitudinally (Fadda & Lucarelli, 2017). There is a significant literature about parent-child interactions in typically developing children as well as in children with Autism Spectrum Disorder (ASD) (Beurkens, Hobson, & Hobson, 2013; Doussard-Roosevelt, Joe, Bazhenova, & Porges, 2003; Watson, 1998). For example, Dawson et al. (1990) demonstrated that children with ASD look to the face of their mother as frequently as typically developing children and children with ASD had more positive affect with their caregiver than to a stranger (Kasari, 1993). Less is known about how eye contact may differ in children with ASD when interacting with their parent versus an unfamiliar adult. The present study focuses on face-to-face parent-child versus clinician-child interactions in preschool-age children with ASD, with the goal of better understanding the social strengths that children with ASD demonstrate when engaging with their parents (Dawson et al., 1990; Kasari, Sigman & Yirmiya, 1993).

Eye contact, defined as direct visual contact with another person's eyes, is a fundamental component of face-to-face interactions that facilitates communication (Hessels, Holleman, Kingstone, Hooge, & Kemner, 2019; Senju & Johnson, 2009b). Children with ASD have significant impairments in appropriately modulating or shifting their gaze during social

interactions (Dawson et al., 2004; Falck-Ytter, Fernell, Gillberg, & von Hofsten, 2010; Frazier et al., 2017; Lord & Jones, 2012). Children with ASD engage in less eye contact than typically developing children (Jones et al., 2017; Senju & Johnson, 2009a) and young children with ASD exhibit less preferential fixation to an adult's eyes that was associated with more severe social impairment (Jones, Carr, & Klin, 2008). Our prior work has also demonstrated that greater eye contact is associated with less severe autism symptoms (Jones et al., 2017) although others have not observed such a link (Guillon, Hadjikhani, Baduel, & Roge, 2014). Importantly, Elsabbagh et al. (2013) found that infants at 7 months who were at low and high risk for developing ASD spend a similar proportion of time looking at faces, regardless of clinical outcomes, showing that gaze deficits to faces may not emerge until the second year of life.

Eye contact behavior is modulated by contextual factors. Gaze dynamically changes during face-to-face interactions (Schilbach, 2015) and differs depending the activity that one is engaging in (Falck-Ytter, 2015). For example, children with ASD and typically developing children make less eye contact in the presence of toys compared to a face-to-face interaction when no toys were present (Jones et al., 2017)). These and related findings highlight the importance of considering the environment when assessing gaze behavior.

While irregular gaze behavior in children with ASD is well-documented, it remains unknown whether preschool-age children with ASD exhibit differential gaze patterns with their parent versus an unfamiliar adult. This question is urgent in light of accumulating evidence suggesting that children with ASD demonstrate a more robust treatment response when their parent is actively participating in the intervention (Aldred, Green, & Adams, 2004; Dawson et al., 2010; Jones, Dawson, Kelly, Estes, & Jane Webb, 2017; Lord & Jones, 2013; Scahill et al., 2016). A meta-analysis of parent-mediated interventions for young children with ASD suggests

that interventions that include parents, compared to those that do not, improve children's language scores and severity of autism symptoms (Oono, Honey, & McConachie, 2013). More specifically, interventions targeting parents' ability to partake in joint engagement have demonstrated clear positive effects on the child's social communication skills, as well as a reduction in autism symptom severity (Kasari, Gulsrud, Wong, Kwon, & Locke, 2010; Pickles et al., 2016; Shire et al., 2015). Despite the demonstrated treatment gains of incorporating parents into ASD behavioral interventions, how children with ASD socially interact with parents as opposed to unfamiliar adults (i.e. clinicians) is not well understood.

The goal of the present study was to test whether preschool-age children with ASD demonstrate differences in eye contact during a face-to-face play interaction with their parent versus with a clinician. We focused on naturalistic interactions because gaze behavior in toddlers with ASD is most atypical in social contexts such as face-to-face dyadic interactions (Wang, Campbell, Macari, Chawarska, & Shic, 2018). Studying differences in face-to-face gaze behavior with a parent versus with a clinician can provide insight into how parents can promote and possibly increase social behavior in young children with ASD.

We predicted that children with ASD would show more eye contact, in terms of both the duration and frequency of occurrence, with their parent than with a clinician. We further predicted that children with ASD would show increased eye contact duration and frequency when there was less distraction from objects in the environment, specifically when no toys were present (R. M. Jones et al., 2017), regardless of the partner.

Methods

Participants

29 children with a prior diagnosis of ASD from the Center for Autism and the Developing Brain (CADB) in White Plains, NY were recruited to participate, along with their parents (24 mothers, 5 fathers). Child participants were between 18 and 60 months of age (mean= 41.8 months; see Table 1). Two children were excluded from the sample due to technical problems with the video camera. Parents gave written consent for themselves and their child to participate. All procedures were approved by Weill Cornell Medicine's IRB.

Procedures

Participants completed the Autism Diagnostic Observation Schedule (ADOS-2 Toddler Module, Module 1- 2; Lord, Rutter, DiLavore, Risi, Gotham, & Bishop, 2012) at CADB within 12 months prior to the research visit. Calibrated Severity Scores (CSS) for Social Affect (SA) and for Restricted and Repetitive Behaviors (RRB) were derived from the ADOS on a scale from 1 to 10 (Hus, Gotham, & Lord, 2014). Prior to study participation, children also completed the Differential Abilities Scales Early Years (DAS) (Elliott, 2007) or the Mullen Scales of Early Learning (Mullen, 1995), based upon their developmental level, to calculate full scale IQ as well as verbal IQ (VIQ) and non-verbal IQ (NVIQ). The diagnosis of ASD was based upon ADOS scores, cognitive testing, and clinical judgement. At the time of the study visit, parents completed the Social Responsiveness Scales Second Edition (SRS-2; Constantino, 2012) to measure social impairment, general autism symptoms, and behavior problems. Three subjects were excluded from analyses involving the SRS-2 due to incomplete data. Descriptive statistics for these measures can be found in Table 1.

Play and Snack Interactions

In a single visit, participants completed a modified version of the Brief Observation of Social Communication Change (BOSCC), a 12-minute semi-structured interaction. Unlike the standardized administration of the BOSCC, which occurs on the floor (Grzadzinski et al. 2016), the procedures were completed at a table in order to easily capture instances of eye contact from the wearable glasses described below. There were two play segments (four minutes each) interspersed with two snack segments (two minutes each). All children first completed the procedures with an unfamiliar clinician (one of two females who administered assessments) and then completed the same procedures with their parent.

During the play segment, the adult presented the child with a box of standardized toys designed for minimally verbal children and prompted the child to pick one toy to play with. Each play segment had a unique set of standardized toys, and different toys were used by the clinician and the parent to maximize child engagement across both administrations. Children could request a new toy at any time if they no longer wanted to play with the toy they initially chose. Parents were specifically told to engage in free-play with their child at the table, and that the research assistant would inform them when to transition to the snack segment. At the end of each play segment, the adult prompted the child to help clean up the toys. During the snack segment, the child was presented with two snack options (pretzels and cookies) and could request what they preferred. Only the two snack options in clear containers were present on the table.

The social partner (clinician or parent) sat across the table from the child and wore a pair of Pivothead Kudu glasses, which has an outward facing camera embedded in the frame between the eyes, so that the video camera readily captured the child's face and shifts in gaze to the adult. Prior to participating, parents received instructions to minimize head motion while wearing the glasses and were briefed about how the play and snack segments would be divided. In addition to

the glasses, a Panasonic camera mounted on a tripod was used to record the sessions. Videos were manually synchronized using a film clapboard at the start of the sessions.

Gaze Coding

Two study members, trained to reliability, coded the videos at the frame level, using Mangold International's Interact video annotation software. The training involved coding practice videos, reviewing with a previously trained and reliable coder, and then independently coding eight videos for coding reliability purposes. The eight independently coded videos were then synced and compared to the codes of previously trained personnel and again reviewed by study members. Eye contact was defined as any instance when the child looked directly into the camera of the Pivothead glasses. Video footage from the Pivothead glasses was manually synchronized at the frame level with footage from the Panasonic camera with the film clapboard. The Panasonic camera was used to identify instances when eye contact from the Pivothead glasses was ambiguous. The videos were coded to mark the beginning and end of the following event types: (1) instances of eye contact to the partner; (2) play and snack segments; (3) periods of time when both of the child's eyes were entirely in frame; (4) segments of each individual toy during play. The two individuals who rated the videos each coded approximately 50% of the parent and 50% of the clinician videos. Inter-rater reliability was calculated on 20% of the total number of clinician and parent sessions, with both individuals coding those sessions independently. Kappas were calculated for eye contact during play, snack, with the clinician and the parent and were as follows: clinician play: 0.80; clinician snack: 0.80; parent play: 0.90; parent snack 0.92.

The coders were not blind to the identity of the interaction partner because the Panasonic captured the parent and clinician. Using the Pivothead glasses' video alone limited the ability to

capture the context and sometimes made it impossible to decipher ambiguous situations. However, to ensure that the results could not be explained by the coders knowing the identity of the interactive partner, a third researcher coded a subset of the videos (13%) only from the Pivothead glasses, blind to the partner's identity. The average kappa between the third rater and the other two raters was 0.85, demonstrating no annotation bias.

Pre-processing Data Analyses

Total play and total snack segment durations varied slightly across subjects (468-516 seconds for play, 205-256 seconds for snack). To compare eye contact across sessions with different durations of interactive play and snack segments, duration and frequency of eye contact were expressed as proportions and rates, respectively, relative to the duration of the segment. The terms *duration of eye contact* and *frequency of eye contact* refer to these calculated proportions and rates.

Duration and frequency of eye contact did not differ between the first and second play segment in either the clinician or parent session (ps > 0.147), nor did duration and frequency of eye contact differ between the first and second snack segments in either the clinician or parent session (ps > 0.064). Therefore, duration and frequency of eye contact from the two play segments and two snack segments were summed together for all subsequent analyses.

To control for potential differences in the clinician's versus the parent's ability to effectively capture the child's gaze, we calculated the amount of time that both of the child's eyes were entirely within the frame of the video recorded by the Pivothead glasses. There were no differences between the parents and clinicians in capturing the child's eyes (p = 0.85), confirming no differences across partners in data capture.

Statistical Analyses

To first assess differences in the duration and frequency of eye contact with the clinician versus the parent, data was collapsed across play and snack segments and entered into two paired samples t-tests, with separate analyses for duration and frequency data. Second, to assess differences in eye contact during play and snack segments, a two (context: play, snack) by two (partner: clinician, parent) repeated measures ANOVA, with duration and frequency data analyzed separately, was also conducted.

To investigate whether autism symptom severity influenced eye contact, the ADOS CSS SA and CSS RRB were included as covariates in 2 X 2 repeated measures ANOVAs described above. Additional covariates (VIQ, NVIQ, SRS-2 T scores, child's age and maternal education) were tested individually in the 2 X 2 repeated measures ANOVAs described above to determine whether general autism symptoms, verbal abilities, nonverbal abilities, age, or maternal education impacted the results. Significant covariate interactions were interrogated with post-hoc bivariate correlations.

Results

Children with ASD showed longer durations ($t(26) = 4.240$, $p < .001$) and higher frequencies ($t(26) = 3.720$, $p < .002$) of eye contact while interacting with their parent compared to a clinician (Fig. 1a & 1b). On average, children demonstrated eye contact with a parent for 7% of the time, compared to 4% of the time with a clinician. When examining differences between interactive play and snack segments, children with ASD exhibited longer durations ($F(1,26) = 64.850$, $p < 0.001$, $\eta_p^2 = 0.714$) and higher frequencies ($F(1,26) = 67.557$, $p < 0.001$, $\eta_p^2 = 0.722$) of eye contact during the snack segment versus the play segment. On average, children engaged in eye contact for 11% of the time during the snack segment versus 3% of the time during the

play segment. There was an interaction between partner (parent, clinician) and context (play, snack) for eye contact duration ($F(1,26) = 5.707$, $p < 0.024$, $\eta_p^2 = 0.180$) (Fig. 2), but not for frequency of eye contact ($p = 0.345$). This interaction was driven by the fact that the increase of eye contact during the snack segment was significantly larger for child-parent than child-clinician interactions as compared to the snack segment; on average, children showed an increase in eye contact duration of 6% during the snack segment with parents versus the clinician ($t(26) = 3.3272$, $p < 0.003$), whereas there was an increase of 2% during the play segment with parents versus the clinician ($t(26) = 3.471$, $p < 0.003$).

Relationship between Eye Contact and Child Characteristics

Analyses with the various covariates indicated a significant interaction between CSS RRB scores and eye contact duration during the play versus snack segment ($F(1,26) = 5.648$, $p < 0.026$, $\eta_p^2 = 0.184$), but no interaction with partner ($p = 0.163$). The relationship between CSS RRB scores and eye contact duration was not significant in post-hoc analyses for each activity separately (snack: $p = 0.072$; play: $p = 0.991$).

Children's VIQ scores were significantly associated with differences in eye contact duration during the play versus snack segment ($F(1,26) = 9.756$, $p < 0.005$, $\eta_p^2 = 0.281$), but not with any differences in eye contact duration with the parent versus clinician ($p = 0.336$). Follow up analyses demonstrated that children with higher VIQ scores exhibited longer durations of eye contact during the snack segment ($r = 0.527$, $p < 0.006$), with no relationship between VIQ and the duration of eye contact during play ($p = 0.12$). There were no significant relationships between VIQ and frequency of eye contact ($ps > 0.06$).

The frequency of eye contact during the play versus snack segment was significantly associated with age, as evidenced by a significant interaction between context and age ($F(1,26) =$

5.090, $p < 0.034$, $\eta_p^2 = 0.169$). Just as with the VIQ scores, follow-up analyses showed that the positive effect of age on eye contact was evident during the snack segment only (snack: $r = 0.407$, $p < 0.036$; play: $p = 0.171$). There were no relationships with duration of eye contact and age (ps > 0.129). There were no significant interactions with CSS SA, NVIQ, maternal education, SRS-2 and gaze behavior (ps > 0.07).

Discussion

In this work, we sought to characterize gaze behavior in young children with ASD as they interacted face-to-face with their parent or a clinician. Children showed more eye contact, longer durations and higher frequencies, with their parent than with a clinician. This difference was more pronounced during snack compared to interactive play with toys. Children also exhibited longer durations and higher frequencies of eye contact during the snack segment than the play segment overall. Together, these findings suggest that children's social behavior varies by context and social interaction partner.

The increased eye contact with parents is in line with prior work showing that children with ASD are just as likely as typically developing children to have a secure attachment style with their parents (Rogers, Ozonoff, & Maslin-Cole, 1991; Rozga et al., 2018; Sigman & Mundy, 1989). Our results are also consistent with literature demonstrating that children display clear preferences early in life for their parents over unfamiliar adults (Dixon et al., 1981; Melinder, Forbes, Tronick, Fikke, & Gredeback, 2010). The present findings are relevant to recent work showing that children with ASD exhibit greater treatment gains when their parent is involved with the treatment (Aldred, Green, & Adams, 2004; Dawson et al., 2010; Jones, Dawson, Kelly, Estes, & Jane Webb, 2017; Lord & Jones, 2013; Scahill et al., 2016). As gaze behavior guides many aspects of learning throughout development (Brooks & Meltzoff, 2008;

Frank, Amso, & Johnson, 2014; Mundy et al., 2007), it is possible that children with ASD are more receptive to learning opportunities when engaging with their caregiver. It is important to note that parents may do a better job of eliciting eye contact from their child than the clinician, which should be explored in future studies.

Our finding that social context matters is consistent with prior work showing that play versus snack elicited different symptoms during the BOSCC (Frost, Koehn, Russell, & Ingersoll, 2019), as well as our own work demonstrating that the presence of toys decreases the amount of eye contact in both typically developing children and those with ASD (R. M. Jones et al., 2017). The finding that children's eye contact varies between parent and clinician as a function of the context, snack or play, highlights the need for researchers and clinicians to be aware that a child's performance may be influenced by the presence of items used in the assessment. It is possible that snack segments were particularly motivating for children with ASD and subsequently elicited increased social overtures. Further, it is possible that the familiarity of snack with parents elicited greater eye contact from the child, although it is likely that children are also quite familiar playing with toys with their parents.

Interestingly, we did not find an association between the duration and frequency of eye contact and severity of ASD symptoms. This is inconsistent with our own prior findings (R. M. Jones et al., 2017) and those of others (Hobson, Tarver, Beurkens, & Hobson, 2016), who did in fact show that increased severity of ASD symptoms was associated with decreases in eye contact and poorer quality of parent-child interactions. This is also inconsistent with previous work indicating that dyadic pairs who scored higher on a measure of ASD traits made less eye contact during a social interaction (Hessels, Holleman, Cornelissen, Hooge, & Kemner, 2018). One possible explanation for this discrepancy is that in the present study, there was less eye contact

overall with both the clinician and the parent: children made eye contact for approximately 11% of the snack segments with both the parent and the clinician, compared to our prior work where school-age children with ASD made eye contact with a clinician for 34% of the conversation segments. This reduction and overall lower range of eye contact may explain a lack of an association with ASD symptoms. There was also a difference in administration: In the current study, children had a snack, whereas in our prior work, children had a conversation with the clinician (i.e. there was nothing on the table or in the child's hands to look at in that case). Future work examining eye contact with parents versus clinicians in school-age children with ASD, where conversation without materials is more readily feasible, may show higher rates of gaze behavior and stronger associations with ASD symptoms.

Limitations

It is important to note that the parent interaction always followed the clinician interaction. This raises the question whether the observed differences between parents and clinicians could be due to children becoming either more engaged or more relaxed over the course of the visit. Although this cannot be entirely ruled out, our pattern of results renders this explanation unlikely. Most prominently, we did not observe any order effects on gaze for the different contexts: children exhibited the same gaze patterns for the first play segment as second play segment, and for the first snack segment as the second snack segment, and this was true for both child-clinician and child-caregiver interactions. Further, children had been interacting with the clinician for at least 30 minutes prior to the videotaped interaction, leaving sufficient time for the child to adapt to the environment and the clinician. We collected no information about how much coaching the parent received prior to the study in terms of facilitating interactions with their child, a factor that can facilitate children's social communication (Matson, Mahan, & Matson,

2009). Finally, the low number of fathers or girls with ASD impeded our ability to examine any gender effects on gaze. These are important for future directions, given a growing body of literature suggesting differences in how ASD presents in females versus males with ASD (Beggiato et al., 2017; Lawson, Joshi, Barbaro, & Dissanayake, 2018).

Conclusions

Young children with ASD demonstrated longer duration and higher frequencies of eye contact with their parent than with a clinician, highlighting that the identity and familiarity of the person with whom the child is engaging is critical when measuring social behavior. Increasingly, assessments of social behavior in ASD are incorporating the parent (Green et al., 2017). By quantifying aspects of child-parent and child-clinician social interactions, the present study illustrates the importance of utilizing parents to engage children with ASD and stresses that probing social behavior during parent-child interactions may increase the captured range of social abilities in children with ASD.

Table 1 Demographics and descriptive statistics

	Participants
N	27
Males	24
Age (months)	41.89 (12)
VIQ	75.56 (32)
NVIQ	85.26 (31)
SRS-2 total Raw Score	90.96 (28)
ADOS CSS total	8.41 (1.78)
ADOS CSS SA	7.93 (2.02)
ADOS CSS RRB	8.48 (1.45)
Ethnicity	
Caucasian (%)	56
Hispanic (%)	11
Asian (%)	22
African American (%)	7
Biracial (%)	4
Maternal Highest Education	
Graduate/professional (%)	44
Baccalaureate degree (%)	44
Some college (%)	4
High school graduate (%)	8

VIQ verbal IQ, *NVIQ* nonverbal IQ, *SRS-2* social responsiveness scale second edition, *CSS total* calibrated severity score from ADOS, *CSS SA* ADOS calibrated severity score for social affect, *CSS RRB* ADOS calibrated severity score for restricted and repetitive behaviors. Age, VIQ, NVIQ, and SRS-2 expressed as Mean (Standard Deviation)

Table 2 Rates per minute and percent duration of eye contact during play versus snack with the clinician and parent

	Play	Snack
Clinician		
Duration of Eye Contact (%)	2.18 (1.91)	8.66 (5.47)
Frequency of Eye Contact (Number Per Minute)	1.64 (1.33)	4.78 (2.99)
Parent	3.90 (2.81)	14.35 (9.96)
Duration of Eye Contact (%)	2.59 (1.90)	6.12 (3.61)
Frequency of Eye Contact (Number Per Minute)		

All averages expressed as Mean (Standard Deviation)

Figure 1

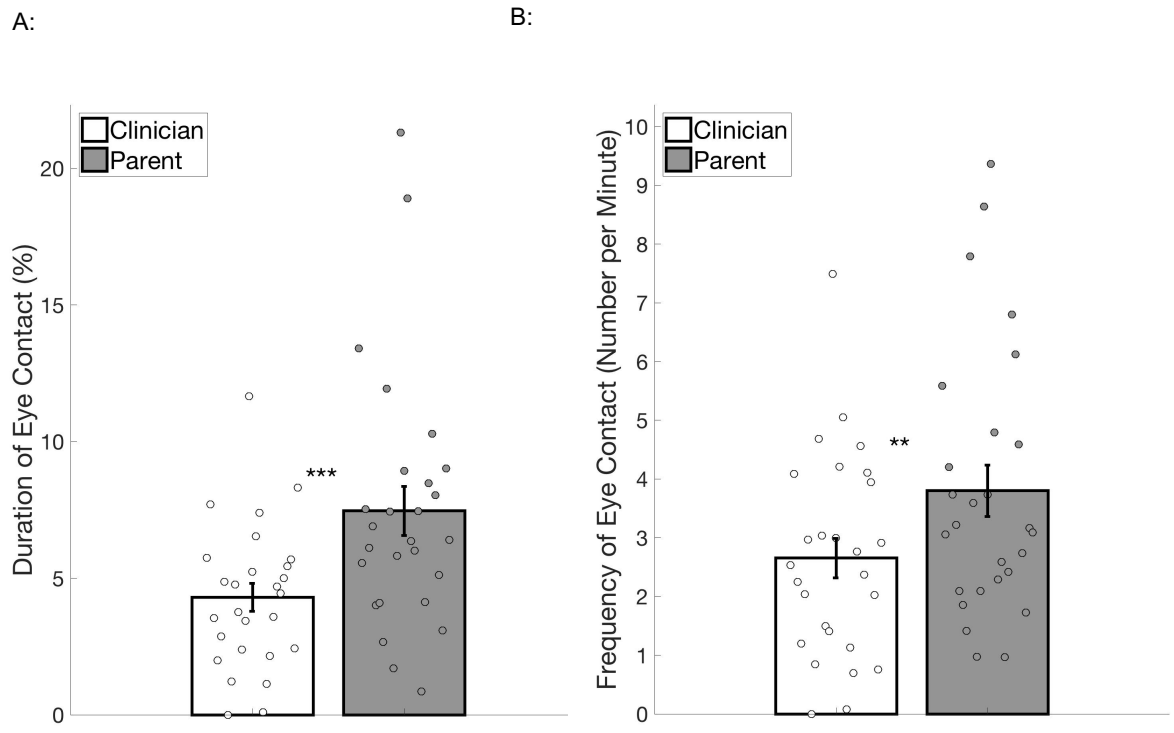
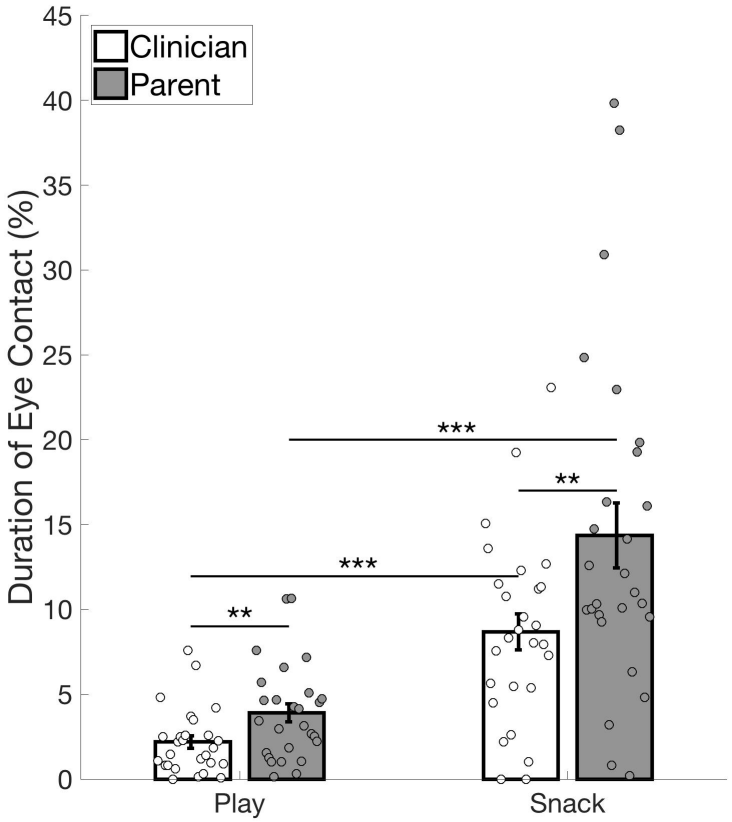

A:
B:
Clinician
Parent
Duration of Eye Contact (%)
0
5
10
15
20
***
Clinician
Parent
Frequency of Eye Contact (Number per Minute)
0
1
2
3
4
5
6
7
8
9
10
**

Figure 2


Clinician
Parent
Duration of Eye Contact (%)
45
40
35
30
25
20
15
10
5
0
***
**
***
**
Play
Snack

References

Adamson, L. B., Bakeman, R., Deckner, D. F., & Nelson, P. B. (2014). From interactions to conversations: the development of joint engagement during early childhood. *Child Dev, 85*(3), 941-955. doi: 10.1111/cdev.12189

Aldred, C., Green, J., & Adams, C. (2004). A new social communication intervention for children with autism: pilot randomised controlled treatment study suggesting effectiveness. *Journal of Child Psychology and Psychiatry, 45*(8), 1420-1430. doi: 10.1111/j.1469-7610.2004.00338.x

Beurkens, N. M., Hobson, J. A., & Hobson, R. P. (2013). Autism severity and qualities of parent-child relations. *J Autism Dev Disord, 43*(1), 168-178. doi: 10.1007/s10803-012-1562-4

Beggiato, A., Peyre, H., Maruani, A., Scheid, I., Rastam, M., Amsellem, F., . . . Delorme, R. (2017). Gender differences in autism spectrum disorders: Divergence among specific core symptoms. *Autism Res, 10*(4), 680-689. doi: 10.1002/aur.1715

Bevilacqua, D., Davidesco, I., Wan, L., Oostrik, M., Chaloner, K., Rowland, J., . . . Dikker, S. (2018). Brain-to-Brain Synchrony and Learning Outcomes Vary by Student-Teacher Dynamics: Evidence from a Real-world Classroom Electroencephalography Study. *J Cogn Neurosci*, 1-11. doi: 10.1162/jocn_a_01274

Brooks, R., & Meltzoff, A. N. (2008). Infant gaze following and pointing predict accelerated vocabulary growth through two years of age: a longitudinal, growth curve modeling study. *Journal of Child Language, 35*(01). doi: 10.1017/s030500090700829x

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

Davis, N. O., & Carter, A. S. (2008). Parenting stress in mothers and fathers of toddlers with autism spectrum disorders: associations with child characteristics. *J Autism Dev Disord, 38*(7), 1278-1291. doi: 10.1007/s10803-007-0512-z

Dawson, G., Hill, D., Spencer, A., Galpert, L., & Watson, L. (1990). Affective exchanges between young autistic children and their mothers. *J Abnorm Child Psychol, 18*(3), 335-345.

Dawson, G., Rogers, S., Munson, J., Smith, M., Winter, J., Greenson, J., . . . Varley, J. (2010). Randomized, controlled trial of an intervention for toddlers with autism: the Early Start Denver Model. *Pediatrics, 125*(1), e17-23. doi: 10.1542/peds.2009-0958

Dawson, G., Toth, K., Abbott, R., Osterling, J., Munson, J., Estes, A., & Liaw, J. (2004). Early social attention impairments in autism: social orienting, joint attention, and attention to distress. *Dev Psychol, 40*(2), 271-283. doi: 10.1037/0012-1649.40.2.271

Dixon, S. D., Yogman, M., Tronick, E., Adamson, L., Als, H., & Brazelton, T. B. (1981). Early infant social interaction with parents and strangers. *J Am Acad Child Psychiatry, 20*(1), 32-52.

Doussard-Roosevelt, J. A., Joe, C. M., Bazhenova, O. V., & Porges, S. W. (2003). Mother-child interaction in autistic and nonautistic children: characteristics of maternal approach behaviors and child social responses. *Dev Psychopathol, 15*(2), 277-295.

Elliott, C. D. (2007). *Differential Ability Scales Second Edition.* San Antonio, TX: Harcourt Assessment, Inc.

Elsabbagh, M., Gliga, T., Pickles, A., Hudry, K., Charman, T., Johnson, M. H., & Team, B. (2013). The development of face orienting mechanisms in infants at-risk for autism. *Behav Brain Res, 251*, 147-154. doi: 10.1016/j.bbr.2012.07.030

Fadda, R., & Lucarelli, L. (2017). Mother-Infant and Extra-Dyadic Interactions with a New Social Partner: Developmental Trajectories of Early Social Abilities during Play. *Front Psychol, 8*, 436. doi: 10.3389/fpsyg.2017.00436

Falck-Ytter, T. (2015). Gaze performance during face-to-face communication: A live eye tracking study of typical children and children with autism. *Research in Autism Spectrum Disorders, 17*, 78-85. doi: https://doi.org/10.1016/j.rasd.2015.06.007

Falck-Ytter, T., Fernell, E., Gillberg, C., & von Hofsten, C. (2010). Face scanning distinguishes social from communication impairments in autism. *Dev Sci, 13*(6), 864-875. doi: 10.1111/j.1467-7687.2009.00942.x

Feldman, R. (2015). Mutual influences between child emotion regulation and parent-child reciprocity support development across the first 10 years of life: Implications for developmental psychopathology. *Dev Psychopathol, 27*(4 Pt 1), 1007-1023. doi: 10.1017/S0954579415000656

Fitzpatrick, P., Mitchell, T., Schmidt, R. C., Kennedy, D., & Frazier, J. A. (2019). Alpha band signatures of social synchrony. *Neurosci Lett*. doi: 10.1016/j.neulet.2019.01.037

Frank, M. C., Amso, D., & Johnson, S. P. (2014). Visual search and attention to faces during early infancy. *J Exp Child Psychol, 118*, 13-26. doi: 10.1016/j.jecp.2013.08.012

Frazier, T. W., Strauss, M., Klingemier, E. W., Zetzer, E. E., Hardan, A. Y., Eng, C., & Youngstrom, E. A. (2017). A Meta-Analysis of Gaze Differences to Social and Nonsocial Information Between Individuals With and Without Autism. *J Am Acad Child Adolesc Psychiatry, 56*(7), 546-555. doi: 10.1016/j.jaac.2017.05.005

Frost, K. M., Koehn, G. N., Russell, K. M., & Ingersoll, B. (2019). Measuring child social communication across contexts: Similarities and differences across play and snack routines. *Autism Res*. doi: 10.1002/aur.2077

Green, J., Pickles, A., Pasco, G., Bedford, R., Wan, M. W., Elsabbagh, M., . . . British Autism Study of Infant Siblings, T. (2017). Randomised trial of a parent-mediated intervention for infants at high risk for autism: longitudinal outcomes to age 3 years. *J Child Psychol Psychiatry, 58*(12), 1330-1340. doi: 10.1111/jcpp.12728

Guillon, Q., Hadjikhani, N., Baduel, S., & Roge, B. (2014). Visual social attention in autism spectrum disorder: insights from eye tracking studies. *Neurosci Biobehav Rev, 42*, 279-297. doi: 10.1016/j.neubiorev.2014.03.013

Hessels, R. S., Holleman, G. A., Cornelissen, T. H. W., Hooge, I. T. C., & Kemner, C. (2018). Eye contact takes two – autistic and social anxiety traits predict gaze behavior in dyadic interaction. *Journal of Experimental Psychopathology*. doi: 10.5127/jep.062917

Hessels, R. S., Holleman, G. A., Kingstone, A., Hooge, I. T. C., & Kemner, C. (2019). Gaze allocation in face-to-face communication is affected primarily by task structure and social context, not stimulus-driven factors. *Cognition, 184*, 28-43. doi: 10.1016/j.cognition.2018.12.005

Hobson, J. A., Tarver, L., Beurkens, N., & Hobson, R. P. (2016). The Relation between Severity of Autism and Caregiver-Child Interaction: a Study in the Context of Relationship Development Intervention. *J Abnorm Child Psychol, 44*(4), 745-755. doi: 10.1007/s10802-015-0067-y

Hudson, S., Levickis, P., Down, K., Nicholls, R., & Wake, M. (2015). Maternal responsiveness predicts child language at ages 3 and 4 in a community-based sample of slow-to-talk toddlers. *Int J Lang Commun Disord, 50*(1), 136-142. doi: 10.1111/1460-6984.12129

Hus, V., Gotham, K., & Lord, C. (2014). Standardizing ADOS domain scores: separating severity of social affect and restricted and repetitive behaviors. *J Autism Dev Disord, 44*(10), 2400-2412. doi: 10.1007/s10803-012-1719-1

Jones, E. J. H., Dawson, G., Kelly, J., Estes, A., & Jane Webb, S. (2017). Parent-delivered early intervention in infants at risk for ASD: Effects on electrophysiological and habituation measures of social attention. *Autism Res, 10*(5), 961-972. doi: 10.1002/aur.1754

Jones, R. M., Southerland, A., Hamo, A., Carberry, C., Bridges, C., Nay, S., . . . Rozga, A. (2017). Increased Eye Contact During Conversation Compared to Play in Children With Autism. *J Autism Dev Disord, 47*(3), 607-614. doi: 10.1007/s10803-016-2981-4

Jones, W., Carr, K., & Klin, A. (2008). Absence of preferential looking to the eyes of approaching adults predicts level of social disability in 2-year-old toddlers with autism spectrum disorder. *Arch Gen Psychiatry, 65*(8), 946-954. doi: 10.1001/archpsyc.65.8.946

Kasari, C., Sigman, M., & Yirmiya, N. (1993). Focused and social attention of autistic children in interactions with familiar and unfamiliar adults: A comparison of autistic, mentally retarded, and normal children. *Dev Psychopathol, 5*(3), 403-414. doi: doi:10.1017/S0954579400004491

Kasari, C., Gulsrud, A. C., Wong, C., Kwon, S., & Locke, J. (2010). Randomized controlled caregiver mediated joint engagement intervention for toddlers with autism. *J Autism Dev Disord, 40*(9), 1045-1056. doi: 10.1007/s10803-010-0955-5

Lawson, L. P., Joshi, R., Barbaro, J., & Dissanayake, C. (2018). Gender Differences During Toddlerhood in Autism Spectrum Disorder: A Prospective Community-Based Longitudinal Follow-Up Study. *J Autism Dev Disord, 48*(8), 2619-2628. doi: 10.1007/s10803-018-3516-y

Leong, V., Byrne, E., Clackson, K., Georgieva, S., Lam, S., & Wass, S. (2017). Speaker gaze increases information coupling between infant and adult brains. *Proc Natl Acad Sci U S A, 114*(50), 13290-13295. doi: 10.1073/pnas.1702493114

Lord, C., & Jones, R. M. (2012). Annual research review: re-thinking the classification of autism spectrum disorders. *J Child Psychol Psychiatry, 53*(5), 490-509. doi: 10.1111/j.1469-7610.2012.02547.x

Lord, C., & Jones, R. M. (2013). New strategies and findings for behavioral interventions in autism spectrum disorders. *Ann N Y Acad Sci, 1304*, 70-76. doi: 10.1111/nyas.12311

Lord, C., Rutter, M., DiLavore, P. C., Risi, S., Gotham, K., & Bishop, S. L. (2012). *Autism diagnostic observation schedule, Second Edition (ADOS-2) manual (Part 1): Modules 1–4.* Torrence, CA: Western Psychological Services.

Masur, E. F., Flynn, V., & Eichorst, D. L. (2005). Maternal responsive and directive behaviours and utterances as predictors of children's lexical development. *J Child Lang, 32*(1), 63-91.

Melinder, A., Forbes, D., Tronick, E., Fikke, L., & Gredeback, G. (2010). The development of the still-face effect: mothers do matter. *Infant Behav Dev, 33*(4), 472-481. doi: 10.1016/j.infbeh.2010.05.003

Mullen, E. M. (1995). *Mullen Scales of Early Learning: AGS edition.* Circle Pines, MN: American Guidance Service.

Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of joint attention in infancy. *Child Dev, 78*(3), 938-954. doi: 10.1111/j.1467-8624.2007.01042.x

Oono, I. P., Honey, E. J., & McConachie, H. (2013). Parent-mediated early intervention for young children with autism spectrum disorders (ASD). *Cochrane Database Syst Rev*(4), CD009774. doi: 10.1002/14651858.CD009774.pub2

Pickles, A., Le Couteur, A., Leadbitter, K., Salomone, E., Cole-Fletcher, R., Tobin, H., . . . Green, J. (2016). Parent-mediated social communication therapy for young children with autism (PACT): long-term follow-up of a randomised controlled trial. *The Lancet, 388*(10059), 2501-2509. doi: 10.1016/s0140-6736(16)31229-6

Rogers, S. J., Ozonoff, S., & Maslin-Cole, C. (1991). A comparative study of attachment behavior in young children with autism or other psychiatric disorders. *J Am Acad Child Adolesc Psychiatry, 30*(3), 483-488. doi: 10.1097/00004583-199105000-00021

Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Dev, 83*(5), 1762-1774. doi: 10.1111/j.1467-8624.2012.01805.x

Rozga, A., Hesse, E., Main, M., Duschinsky, R., Beckwith, L., & Sigman, M. (2018). A short-term longitudinal study of correlates and sequelae of attachment security in autism. *Attach Hum Dev, 20*(2), 160-180. doi: 10.1080/14616734.2017.1383489

Scahill, L., Bearss, K., Lecavalier, L., Smith, T., Swiezy, N., Aman, M. G., . . . Johnson, C. (2016). Effect of Parent Training on Adaptive Behavior in Children With Autism Spectrum Disorder and Disruptive Behavior: Results of a Randomized Trial. *J Am Acad Child Adolesc Psychiatry, 55*(7), 602-609 e603. doi: 10.1016/j.jaac.2016.05.001

Schilbach, L. (2015). Eye to eye, face to face and brain to brain: novel approaches to study the behavioral dynamics and neural mechanisms of social interactions. *Current Opinion in Behavioral Sciences, 3*, 130-135. doi: https://doi.org/10.1016/j.cobeha.2015.03.006

Senju, A., & Johnson, M. H. (2009a). Atypical eye contact in autism: models, mechanisms and development. *Neurosci Biobehav Rev, 33*(8), 1204-1214. doi: 10.1016/j.neubiorev.2009.06.001

Senju, A., & Johnson, M. H. (2009b). The eye contact effect: mechanisms and development. *Trends Cogn Sci, 13*(3), 127-134. doi: 10.1016/j.tics.2008.11.009

Shire, S. Y., Goods, K., Shih, W., Distefano, C., Kaiser, A., Wright, C., . . . Kasari, C. (2015). Parents' Adoption of Social Communication Intervention Strategies: Families Including Children with Autism Spectrum Disorder Who are Minimally Verbal. *J Autism Dev Disord, 45*(6), 1712-1724. doi: 10.1007/s10803-014-2329-x

Sigman, M., & Mundy, P. (1989). Social attachments in autistic children. *J Am Acad Child Adolesc Psychiatry, 28*(1), 74-81. doi: 10.1097/00004583-198901000-00014

Tamis-LeMonda, C. S., Bornstein, M. H., & Baumwell, L. (2001). Maternal responsiveness and children's achievement of language milestones. *Child Dev, 72*(3), 748-767.

Wang, Q., Campbell, D. J., Macari, S. L., Chawarska, K., & Shic, F. (2018). Operationalizing atypical gaze in toddlers with autism spectrum disorders: a cohesion-based approach. *Mol Autism, 9*, 25. doi: 10.1186/s13229-018-0211-y

Watson, L. R. (1998). Following the child's lead: mothers' interactions with children with autism. *J Autism Dev Disord, 28*(1), 51-59.