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Social and Object Attention Is Influenced by Biological Sex and Toy Gender-Congruence in Children with and Without Autism

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Abstract

Emerging research suggests social attention in ASD girls is enhanced relative to ASD boys, but may also be affected by the type of social and nonsocial content presented. This study examined how biological sex and gender norms interact to influence visual attention in 79 school-aged children observing scenes that included gender-associated toys and actors of both sexes. Attention to social (faces) and object activity (hands with toys) stimuli were measured. Previously described distinctions between social attention in ASD boys and girls were replicated, with ASD girls looking more at faces than ASD boys. Irrespective of diagnosis, males and females attended more to actors that shared their same sex, and attended more to toys with gender-associations that were consistent with their own sex, suggesting that social and object salience increases for children under sex-consistent conditions. Importantly, ASD and TD children increased their gaze to faces when male actors were shown playing with female-associated toys (but not vice versa) suggesting that both groups of children are sensitive to societal messages about the acceptability of males playing with female-associated toys. Our findings provide further evidence of heightened attention

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Authors' contributions. CH, NS and JPM initiated the idea for and design of the study, and secured funding through grants. CH, DJ, SZ, NS and JPM developed the stimuli and task parameters. CH, DJ and JPM programmed the stimuli and parameters into Tobii. CH and DJ led recruitment for families. DJ, SZ and SWN under the supervision of CH assisted with the collection of behavioral and eye tracking data. CH, DJ and JPM extracted raw data and wrote programs to clean the data. DJ conducted data management. DJ, CH and JPM analyzed the data in consultation with co-authors. NS and JPM consulted on design and analyses throughout the study. CH and JPM wrote the manuscript, with edits and contributions from all other authors. All authors read/approved the final manuscript.
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to faces in ASD girls relative to ASD boys, and indicate that social attention in ASD and TD children is influenced by *who* (male or female actor) and *what* (male- or female-associated toy) is being observed. Collectively, these results present a nuanced profile of attention in ASD that adds to a growing body of research indicating subtle phenotypic differences in ASD girls that may impact identification, assessment, and intervention.

Lay Abstract

Sex differences observed in typical development may also be present in individuals with autism. In this study, we developed an eye-tracking paradigm featuring videos of boys and girls playing with toys that varied in their gender-associations. Attention to faces differed between autistic and non-autistic children, but was also influenced by the sex of the actor and gender-association of toys. Autistic females demonstrated subtle attention differences that distinguished them from autistic males and may influence referral, diagnosis, and intervention.

Keywords

Sex differences; gender; eye tracking; attention

Introduction

Sexual dimorphism in attention to social and non-social (object) stimuli has been reported across a range of methodologies from infancy through adulthood (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000; Gluckman & Johnson, 2013; Maccoby, 1998). These differences manifest through differential attention to faces and attention/engagement with images of objects, such as toys. At the same time, research suggests that young girls, on average, demonstrate a preference for playing with toys such as dolls and domestic items (e.g. tea sets, cooking), whereas males tend to engage more with vehicles and construction toys. These differences have been found in eye-tracking studies (Alexander, Wilcox, & Woods, 2009; Alexander & Charles, 2008; Harrop et al., 2018), preferential looking paradigms (Jadva, Hines, & Golombok, 2010) and during free play sessions (Caldera, Huston, & O'Brien, 1989; Harrop, Green, & Hudry, 2017; Hines & Kaufman, 1994; Jacklin, DiPietro, & Maccoby, 1984; Todd et al., 2018), and are theorized to reflect a combination of biological and social influences on development. Specifically, they are presumed to reflect the intersection between biological sex and socially constructed gender norms and expectations that are impressed upon infants and toddlers.

The aim of this study is to better understand how biological sex and gender norms (such as the congruency of child sex and toy gender-typicality; "girls like girl toys, boys like boy toys") interact with each other in the context of Autism Spectrum Disorder (ASD). ASD is a neurodevelopmental disorder with a well-reported sex imbalance in diagnosis (Christensen et al., 2016) in which phenotypic differences between males and females appear to align with traditional gender norms (Boorse et al., 2019; Harrop, Green, & Hudry, 2017; Harrop et al., 2018a; Hiller, Young, & Weber, 2014; Sutherland, Hodge, Bruck, Costley, & Klieve, 2017).

The Female Phenotype of ASD

Females with ASD present with a different phenotypic profile than males with ASD. Specifically, verbally fluent females report higher social motivation than boys with comparable cognitive profiles (Sedgewick, Hill, Yates, Pickering, & Pellicano, 2016). Girls with ASD also show compensatory behaviors that may mitigate some of their social challenges (Dean, Harwood, & Kasari, 2017; Parish-Morris et al., 2017), but can be difficult to sustain over time (Hull et al., 2017). A number of studies have reported that ASD girls display fewer/different restricted and repetitive behaviors (RRBs) than males, particularly higher order RRBs such as circumscribed interests (Frazier, Georgiades, Bishop, & Hardan, 2014; Hiller, Young, & Weber, 2016). However, the interests displayed by females with ASD may be overlooked clinically, as they tend to be less systematizing and align more closely with interests and hobbies commonly observed in typically developing girls (Sutherland et al., 2017). In contrast, common *male* interests (Lego, cars, trains) are more frequently associated with autism, in large part because previous studies of RRBs included predominately male samples (DeLoache, Simcock, & Macari, 2007; Klin, Danovitch, Merz, & Volkmar, 2007).

Evidence from parent and teacher reports, observational studies and, more recently, eye-tracking studies, suggests that interests in ASD girls overlap more with those of neurotypical girls than their ASD boy peers (Harrop et al., 2018a, 2018b; Hiller et al., 2014, 2016; Nowell, Jones, & Harrop, 2019; Sutherland et al., 2017). This could serve as a potential barrier to early identification as clinicians may not view typically *female* interests as compatible with an ASD diagnosis. However, not all studies have reported differences between ASD boys and girls; results appear to be dependent on the focus of the study, whether samples were matched and/or controlled for IQ, and the methodology utilized (see Ferri, Abel, & Brodkin, 2018; Halladay et al., 2015; Lai, Lombardo, Auyeung, Chakrabarti, & Baron-Cohen, 2015 for recent reviews).

Sex Differences in Attention to Social and Object Stimuli in ASD

In a series of recent eye-tracking studies, we reported increased attention to faces in girls with ASD relative to boys with ASD, and also found patterns of attention to images of interests/toys that fall along traditional gender lines. In a replication and extension of Sasson and Touchstone (2014), we reported that when paired with a competing image of *high autism interest* objects like trains and computers, ASD girls (ages 6–10) oriented to faces faster and spent longer attending to social images than did ASD boys (Harrop et al., 2018). Patterns of attention to social stimuli for girls with ASD, on the other hand, aligned more closely with patterns found in neurotypical girls. A similar effect was also found in a dynamic eye-tracking paradigm developed by Chevalier and colleagues (2015): ASD girls attended more to faces than ASD boys, but only when the dynamic scene did not convey an interaction between the two actors (i.e., a socially *lean* scenario; Harrop et al., 2019). These eye-tracking findings align with behavioral reports of heightened social motivation in ASD girls (Sedgewick et al., 2016) and suggest that the social complexity of stimuli impacts attention, with social context influencing attention more in ASD girls than ASD boys.

When presented with an array of *gendered* images (classified as male-associated, female-associated, or neutral), ASD and neurotypical girls also attended more to images that aligned with their biological sex/gender (Harrop et al., 2018a) than images that did not. The same was true for ASD and neurotypical boys. There were no differences in attention to neutral images. Together, these studies indicate that the biological sex of individuals with ASD and the *gender-association* of object stimuli impact attentional patterns in ASD, and that previous studies of social and object attention in ASD may have failed to detect these patterns because they relied on predominantly male samples.

Children's toys are often associated to a greater degree with one gender or the other, and strongly gender-typical toys (e.g., baby dolls) are often marketed in sex-specific ways (Auster & Mansbach, 2012; Murnen, Greenfield, Younger, & Boyd, 2016; Reich, Black, & Foliaki, 2018; Spinner, Cameron, & Calogero, 2018). However, sex-gender toy congruency (the match between children's biological sex and *gender-association* of toys) has yet to be explored in ASD. There is some evidence to suggest that sex-congruence is important in ASD in other domains, but may differ for girls versus boys. For example, two recent studies examining friendships in ASD have reported a number of sex-specific findings. Locke et al. (2018) found that the sex of friends was an important predictor of connectedness in the social networks of children aged 5 to 12. The authors found that males with ASD had better social network connectivity if they had same sex peers, but the same was not true for ASD girls. Further, Dean et al. (2014) found that children with ASD preferred, were accepted by, and primarily socialized with same-sex friends. Taken together, prior research suggests that congruency between participant sex and the sex of people being observed – and the gender-association of toys – may exert an impact on attentional behaviors in ASD.

Aims and Hypotheses

In this study, we combine various elements of our previous eye tracking paradigms to test how actor biological sex and toy *gender-associations* interact to modify patterns of visual attention in ASD and TD boys and girls. Our goal was to extend our previous findings of intact gender-typical object preferences in ASD boys and girls by embedding *gender-associated* toys within naturalistic, dynamic scenes. This research combines two potential areas of distinction between ASD boys and girls in a single eye tracking paradigm: social motivation (Harrop et al., 2018b; Harrop et al., 2019.; Sedgewick et al., 2016) and gendered patterns of circumscribed interests (Harrop et al., 2018a; Hiller et al., 2016; Sutherland et al., 2017).

For the purposes of this study, *sex* refers to the biological and physiological characteristics that define males and females, and *gender* refers to the socially constructed roles, behaviors, activities and attributes that a given society considers appropriate for men and women and boys and girls (Lai et al., 2015). Here, we seek to understand how the *gender-association*s of items within a social scene – and the sex of the actors depicted playing with the toys in those scenes – influence patterns of visual attention across participant sex (male vs. female) and diagnosis (ASD vs. no ASD).

Based on prior literature, we predicted that:

1. Females in both groups (ASD and typical development – TD) would show greater attention to social stimuli (faces) than males in both groups. We anticipated that the potential *protective* effect of female sex on social attention in ASD – observed in our previous studies using static and dynamic stimuli (Harrop et al., 2018b; Harrop et al., 2019) – would be replicated in this new paradigm.

2. Given the young age of our participants and prior literature showing that school-aged children with ASD tend to associate with same-sex peers (Dean et al., 2014; Locke et al., 2018), we predicted an effect of sex on looking to male vs. female faces, such that girls would look more at female actors and males would look more at male actors.

3. Extending the findings of Harrop et al. (2018a) from static images, we also predicted that visual attention to objects would be modulated based on the *gender-association* of the toy featured in the scene. We expected this to fall along traditional gender lines, irrespective of diagnosis, such that all girls would look more at female-associated toys and all males would look more at male-associated toys.

4. Additionally, we explored whether congruence between an actor's sex and a featured toy's gender-association would influence social attention across sex and diagnosis. Given societal messages about gendered toy play in the U.S., we hypothesized that children would be interested in the less commonly observed scenario of male actors playing with female-associated toys (and vice versa) and would therefore increase their looking to faces during these *incongruent* scenes.

Methods

Participants

Four participant groups were recruited to examine the contributions of (a) ASD and (b) biological sex to visual attention: (1) ASD boys (N = 27); (2) ASD girls (N = 22); (3) TD boys (N = 16); and (4) TD girls (N = 17). Two ASD participants (1 girl; 1 boy) did not complete the eye tracking task due to behavioral or attentional difficulties during the calibration procedure, and one ASD boy completed the task but was not included in the final sample due to insufficient attention (<20% total gaze on screen; an a priori cut off of at least 20% gaze time directed to the screen was set based on prior research; Harrop et al., 2018a, 2018b; Harrop et al., 2019), resulting in a final sample of 79 children (Table 1). All participants met the following general inclusion criteria: age between 6 and 10 years; absence of seizure disorder, and acute medical or genetic condition. Parents were asked about their child's vision prior to the study visit to ensure the absence of any visual impairment uncorrectable with eyewear. Six years was selected as a lower age cutoff due to a recent meta-analysis that reported divergence in the way that ASD core symptoms manifest for girls (vs. males) aged six years and older (Van Wijngaarden-Cremers et al., 2014).

Participants with ASD were recruited via the University of North Carolina at Chapel Hill Autism Research Registry. Inclusion in the Autism Research Registry requires a clinical diagnosis of ASD from a licensed psychologist or psychiatrist with the majority of referrals to the registry stemming from regional diagnostic and treatment clinics using gold-standard diagnostic measures (such as the ADOS; Lord et al., 2012 and ADI-R; Rutter, Le Couteur, & Lord, 2003). Clinical diagnosis was corroborated by elevated scores on the Social Communication Questionnaire (SCQ; Rutter, Bailey, & Lord, 2003). TD children were recruited via an email sent to the University of North Carolina at Chapel Hill Child Development Research Registry, advertisements on social media and word of mouth. Children were excluded if they had a history of developmental or psychiatric disorders and/or had an immediate family member with an ASD diagnosis. Parents completed the SCQ (Rutter et al., 2003) to screen for elevated rates of ASD symptoms, which were not found in any included TD children.

All children completed the Core Battery of the Differential Abilities Scales (DAS-II; Elliot, 2007). The DAS-II is a measure of cognitive abilities that is appropriate for use with children aged 30 months to 17 years, 11 months. It has been used successfully in studies of ASD (Bishop, Guthrie, Coffing, & Lord, 2011; Joseph, Tager-Flusberg, & Lord, 2002). The Core Battery includes six scales to derive nonverbal, verbal, and spatial ability scores as well as mental age equivalents (MA). The majority of children completed the School Years Battery, however four children (1 ASD Boy, 2 ASD Girls and 1 TD Boy) completed the Early Years Battery. We did not purposefully match groups on developmental abilities for a number of reasons: first, we expected our ASD samples to have lower developmental ages than our TD group, especially our ASD girls who frequently require co-occurring intellectual disabilities to receive an ASD diagnosis (Dworzynski, Ronald, Bolton, & Happe, 2012). Second, given the difficulty in recruiting ASD girls, we did not want to limit our recruitment. Finally, the eye tracking paradigm required simple passive viewing, which has low cognitive demands.

Based on preliminary analyses, the final ASD and TD groups did not differ on MA (p=.084), but the ASD group was chronologically older than the TD group (t=3.67, p<.001) and had significantly higher SCQ scores (t=10.96, p<.001). Overall, males and females across the diagnostic groups did not differ significantly on chronological age (p=.09), but males had slightly higher MA equivalent scores (t=2.10, p=.04). Seven ASD girls and five ASD boys received a GCA score of 80 or below on the DAS-II, indicating below average to very low cognitive abilities. One caregiver rated their child as non-verbal on the SCQ (ASD boy). SCQ scores did not differ between males and females (p=.34).

ASD boys were chronologically older than TD boys (t=4.87, p<.001), but did not differ on MA (p=.45). There were no differences in chronological age between the ASD and TD girls (p=.35), but the ASD girls had a lower MA (t=−2.23, p=.03). ASD girls were chronologically younger (t=2.83, p=.007) and had a lower MA (t=2.23, p=.03) than ASD males, but did not differ on SCQ scores. TD boys and girls did not differ on chronological age, MA, or SCQ scores. Due to between-group differences in mental and chronological age, these variables were included as covariates in all subsequent analyses.

Children were reimbursed with a gift card for their participation in a wider study. Parents provided informed written consent. Children over age 7 (and when developmentally appropriate) provided written assent to participate. All children were given the opportunity to ask questions and provide verbal assent. The research protocol was approved by the Institutional Review Board at University of North Carolina at Chapel Hill.

Eye Tracking Stimuli

Stimuli included 18 silent video clips of child actors (1 or 2) playing with objects (toys) at a table (Figure 1). Toys were selected to align with images of toys featured in our visual search array study (Harrop et al., 2018a). Stimuli were developed based on the following rationale: (1) differences in social attention are most apparent in ASD when naturalistic scenes are used (Chawarska, Macari, & Shic, 2013; Chevallier et al., 2015; Harrop et al., 2019); (2) ASD girls demonstrate greater social motivation than ASD boys across a range of study designs (Dean et al., 2014; Harrop et al., 2018b; Sedgewick et al., 2016); and (3) interests in ASD girls may align more closely to what is commonly observed in typical female development than typical male development (Harrop et al., 2018a; Sutherland et al., 2017)..

Actors played with sets of toys classed as either male-associated (Lego, action hero, science kit) or female-associated (My Little Pony, Barbie, cooking set). The classification of toys as male- or female-associated was based on previous developmental literature (Caldera et al., 1989; Cherney, Kelly-Vance, Gill Glover, Ruane, & Oliver Ryalls, 2003; DeLoache et al., 2007) and our recent eye tracking study that found differences in attention to gendered images in ASD (Harrop et al., 2018a). With each toy set, actors either played alone (1 actor, male or female), in parallel (2 actors, male and female) or together (2 actors, male and female; Figure 1).

Play routines in each scene consisted of a simple sequence of play actions (e.g. walking a figure alone, stopping, and adding an item to the figure). In the solo condition, the actor completed play sequences by themselves. In the parallel scene, one actor completed play sequences by themselves with a *gendered* toy, and the other actor played with a neutral toy. In the joint condition, actors completed the same play sequence with the gendered toy, but the different actions and steps were divided between the actors and the gender-neutral toy was left on the table. The sex of the primary actor and the gender-association of the toy were either matched (e.g. male actor and male-associated toy) or mismatched (e.g. male actor and female-associated toy) to examine whether the congruency between participant sex and the gender-association of the toy gender-association influenced attention.

Clips were taken from longer recordings and selected to maximize social salience and naturalistic play. All clips were shot in the same room with consistent natural and artificial lighting. Actors wore plain clothes (i.e. no logos, images, or neon). The background and setup of each scene were consistent and the number of actors and type of play routine was balanced across scenes so that the primary factors that varied were (1) actor sex and (2) toy gender-association. Each video clip was presented for 15.5 seconds followed by a one second crosshair in the center of the screen to reorient attention between clips. The clips were presented in a random order by Tobii software to ensure that 1) the clips using the same toy set (3 of each) were not consistently shown in the same sequence and 2) minimize habituation to the toy sets. The paradigm lasted approximately 5 minutes.

Stimuli were shown on a screen with a pixel (p) resolution of 1920p × 1080p. Dynamic Areas of Interest (AOIs) were drawn onto each clip using Tobii studio. Face AOIs were ovals approximately 340p wide (~9cm) and 440p tall (~11.64cm), depending on face sizes of individual child actors, which translates to visual angles of ~8.58° by ~11.08° at 60cm viewing distance. Face AOIs were drawn slightly outside the stimulus bounds to account for possible drift due to slouching and other participant movement (e.g., ovals captured the actor's face, part of her/his neck, and part of her/his hairline). Key frames created using Tobii Studio were used to adjust oval size and location as actors moved in 3D space (i.e., ovals became larger as actors moved closer to the camera and smaller as they receded), with dynamic interpolation between key frames. Face AOIs and hands playing with toys AOIs were grouped separately within each scene for analysis. Fixation durations for each AOI group were summed across all scenes, to create Total Fixation Duration (TFD) variables for each AOI type (in seconds). An AOI that covered the entire screen for each trial was also created, in order to measure overall visual attention to the full screen. Attention to all AOIs is available in Supplementary Table 1.

Eye Tracking Procedures and Parameters

Eye-tracking data were collected using a Tobii Pro 60XL screen-based eye tracker. Eye tracking took place in a quiet, dimly lit room where children sat on a chair or on a cushion/ booster seat to ensure a distance of approximately 60 cm from a 24" widescreen monitor. Following a five-point calibration procedure, the eye tracker recorded participants' gaze patterns at a rate of 60Hz. Children were told that they would see videos of children playing and that they could look at them however they wanted. Calibration was completed a maximum of five times to ensure all points were calibrated. As described above, two ASD subjects failed to successfully complete this step.

Gaze data was exported from Tobii Studio using a filter based on the Velocity-Threshold Identification (I-VT) fixation classification algorithm (Olsen, 2012). Fixation parameters were as follows: Gap fill-in using linear interpolation was enabled, with a maximum gap length of 75 milliseconds. An average of the right and left eyes was used to calculate fixation. Noise reduction was disabled, and the velocity calculator was set at 20 milliseconds. Adjacent fixations were merged, with the maximum time between merged fixations set to 75 milliseconds and the maximum angle between merged fixations set to 0.5 degrees. Merging fixations close in time and proximity prevents longer fixations from being separated into shorter fixations because of data loss or noise. Fixations shorter than 30 milliseconds that did not meet criteria for merging were discarded.

Data reduction and dependent variables

Eye tracking analyses focused on gaze duration (Total Fixation Duration; TFD) to two primary AOI groups: 1) faces – as a proxy for social attention that may differ by actor sex; and 2) hands playing with toys – to assess attention to object activity and potential effects of toy gender-association on gaze duration. Raw TFD (in seconds) to these AOIs was summed across scenes for the paradigm overall, by actor sex, and by toy gender-association (male-associated or female-associated toys). An a priori cut off of at least 20% gaze time directed to the screen was set based on our previous research (Harrop et al., 2018a, 2018b; Harrop et al., 2019). We did not examine attention to neutral toys (either whilst being played with in the parallel condition or when left to one side in the solo and joint conditions). This was based on prior research indicating that (1) interests in ASD boys and girls commonly fall along traditional gender lines (Sutherland et al., 2017) and (2) attention to neutral toys does not differ between ASD boys and girls (Harrop et al., 2018a). We also did not examine specific attention to hands without integrating toys, because hands were almost always engaged with toys due to the dynamic nature of the scenes. As a result, our object-based analyses focused on the combined variable of hands with toy.

Statistical approach

Analyses were completed in R Studio (R Studio Team, 2015) and the LME4 package (Bates, Mächler, Bolker, & Walker, 2015). T-tests assessed simple between-group (ASD/TD, Boy/Girl) differences in clinical and demographic variables. To account for individual differences in basic attention to the task (see Preliminary Analyses, below), raw gaze to face and hands with toys (object activity) AOIs was analyzed using generalized linear regression models (GLM) for between-subjects factors (diagnosis, sex) and generalized mixed effects regression models (GLMER) for the combined effects of between- and within- (actor sex, toy gender-association) subjects variables. Random effects of participant ID (intercept) were included to account for repeated within-subjects measures (e.g., comparing gaze to male vs. female actors or to male- vs. female-associated toys). In our GLM and GLMER models, gaze to the face (or toy) was coded as a "hit", while gaze to the rest of the screen was coded as a "miss". This allowed us to examine gaze to face (or toy) AOIs relative to each individual's total attention to the screen (rounded to the nearest second), answering the question of relative gaze distribution (preference) while controlling for basic differences in attention. GLMER were fit using maximum likelihood with a logit link, and reported as an estimate of the standard error (SE), z-value (a statistic similar to the t-value from continuous linear models), and *p*-value. Between-subjects variables were coded as follows: Diagnosis: TD = 0, ASD = 1; Sex: female = 0, male = 1. Within-subjects variables (repeated measures) were coded as follows: Actor sex: female = 0, male = 1; Toy gender-association: female = 0, male = 1.

Four omnibus models were constructed to assess: (1) Overall effects of sex and diagnostic group on gaze to faces, (2) Effects of actor sex on gaze to faces, (3) Effects of toy gender-association on gaze to toys, and (4) Effects of (in)congruence between toy gender-association and actor sex on gaze to faces. All models controlled for chronological age (age; centered across the sample) and mental age (MA; centered across the sample). Interactive effects are reported; conditional main effects are affected by the presence of an interaction in GLM/GLMER and are therefore not reported. Rather, to understand the directionality of interactions, estimated marginal means (EMM; R package emmeans; Lenth, Singmann, Love, Buerkner, & Herve, 2019) of each subgroup within each of the four GLM/GLMER models were compared using the Tukey method to correct for multiple comparisons. EMM comparisons were performed on the log odds ratio scale, resulting in an odds ratio (OR; greater than 1 indicates greater likelihood, less than 1 indicates reduced likelihood), standard error (SE), z ratio (z) and *p* value (*p*).

Preliminary analyses

Based on prior research showing basic visual attention differences in ASD, we conducted preliminary analyses to assess whether total fixation duration (TFD) the to the full screen differed by diagnosis and sex. After controlling for age and MA, a binomial GLM revealed a significant interactive effect of diagnosis and sex on TFD to the full screen (Estimate: −.22, SE: .09, z = −2.65, $p = .008$). Tukey-corrected comparisons of estimated marginal means revealed that TD boys and girls looked equally at the screen (boys: 90%, girls: 89%; OR: .97, SE: .07, z = −.45, $p = .97$), and both TD boys and girls looked significantly more at the screen than ASD girls (85%) and ASD boys (82%; all *p*s < .0001). There was also a sex difference in the ASD group, such that ASD girls looked significantly more at the screen than ASD boys (OR: 1.22, SE: .06, z = 3.88, $p = .0006$). To account for differences between diagnostic and sex subgroups in total attention to the screen, subsequent analyses were conducted relative to each individual child's total attention to the full screen (see Statistical Approach).

Results

Overall effects of sex and diagnostic group on gaze to faces.

First, based on prior research showing differential patterns of gaze to faces in boys and girls with and without ASD (Harrop et al., 2018b; Harrop et al., 2019), we examined overall attention to faces by participant sex and diagnosis. After controlling for age and MA, GLM revealed a significant interaction of sex and diagnosis on gaze to faces (Estimate: −.47, SE: .09, z = −5.36, $p < .0001$; Figure 2). Tukey-corrected comparisons of estimated marginal means revealed a diagnostic group difference that was significant in boys (TD boys looked longer at faces than ASD boys, OR: 1.68, SE: 0.12, z = 7.572, $p <.0001$) but not in girls (i.e., patterns of face gaze in ASD girls and TD girls did not significantly differ from one another, OR: 1.06, SE: .07, z = .88, $p = .82$), suggesting that girls with and without ASD did not differ significantly in attention to faces. There was also a sex difference in the ASD group but not in the TD group, such that ASD girls looked longer at faces than ASD boys (OR: 1.38, SE: .08, z = 5.19, $p < .0001$), but TD girls and boys did not differ significantly from one another (OR: .86, SE: .05, z = −2.37, $p = .08$). TD girls were significantly more likely to look at faces than ASD boys (OR: 1.46, SE: .10, z = 5.70, $p < .0001$), and ASD girls were less likely to look at faces than TD boys (OR: .82, SE: .05, z = −3.02, $p = .01$). In summary, whereas children with ASD generally looked less at faces compared to TD peers, this effect was driven by a significant diagnostic group difference in males that was not present in females.

Effects of actor sex on gaze to faces.

Next, we assessed whether actor sex modulated attention to faces. That is, we measured whether girls and boys with and without ASD differentially looked toward actors of different sexes. An omnibus GLMER controlling for age and MA revealed a non-significant 3-way interaction between diagnosis, participant sex, and actor sex on gaze to faces, and a significant 2-way interaction between participant sex and actor sex. The two-way interaction between participant sex and actor sex was replicated in a simplified model controlling for age, MA, and diagnosis (Estimate: .32, SE: .08, z = 3.91, $p < .0001$). Tukey-corrected comparisons of estimated marginal means revealed that, regardless of the participant's diagnostic group, girls looked longer at female actors than male actors (OR: 1.19, SE: .07, z = 2.98, $p = .02$) and boys looked longer at male actors than female actors (OR: .86, SE: .05, z = −2.55, $p = .05$). No other sex differences were significant.

Effects of toy gender-association on gaze to toys.

To test the hypothesis that toy gender-association, participant sex, and participant diagnostic group affect gaze duration object activity, we constructed a GLMER controlling for age and MA, with a 3-way interaction between participant sex, diagnostic group, and toy gender-association. The 3-way interaction was not significant, but a significant two-way interaction emerged between participant sex and toy gender-association. The two-way interaction between participant sex and toy gender-association was replicated in a simplified model controlling for age, MA, and diagnosis (Estimate: .38, SE: .05, z = 8.47, $p < .0001$). Tukey-corrected comparisons of estimated marginal means revealed that, regardless of diagnostic group, children looked longer at toys with gender-associations that were congruent with their own biological sex (i.e., girls looked longer at female-associated than male-associated toys, and males looked longer at male-associated than female-associated toys). The extent of the difference did not differ by sex. That is, the length of children's gaze toward toys with gender-associations that overlapped (OR: 1.16, SE: .10, z = 1.63, $p = .36$) or did not overlap (OR: 1.02, SE: .09, z = .25, $p = .99$) with their own biological sex did not differ between male and female participants. Comparing gaze by participant sex revealed that girls looked longer at female-associated toys than did boys (OR: 1.29, SE: .12, z = 2.81, $p = .03$), but boys and girls looked equally long at male-associated toys (OR: .88, SE: .08, z = −1.42, $p = .49$).

Effects of (in)congruence between toy gender-association and actor sex on gaze to faces.

To test the hypothesis that congruence (or incongruence) between toy gender-association and actor sex would differentially affect attention to faces in ASD and TD girls and boys, we constructed a model that tested effects of age, MA, and the four-way interaction of diagnosis, participant sex, actor sex, and toy gender-association on gaze to faces. The four-way interaction was not significant, but there was a significant two-way interaction between toy gender-association and actor sex. The two-way interaction between diagnostic group and toy gender-association was replicated in a simplified model controlling for age, MA, diagnostic group, and participant sex (Estimate: −1.03, SE: .12, z = −8.64, $p < .0001$). Tukey-corrected comparisons of estimated marginal means revealed that, regardless of participant sex or diagnostic group, children looked longer at faces when male actors were depicted playing with female-associated toys (incongruent) than when male actors were shown playing with male-associated toys (congruent; OR: 1.90, SE: .15, z = 7.89, $p < .0001$). Similarly, children looked longer at the faces of female actors playing with male-associated toys (incongruent) than when female actors were depicted playing with female-associated toys (congruent; OR: .67, SE: .06, z = −4.46, $p < .0001$). Children looked significantly longer at faces when male actors played with female-associated toys than when female actors played with male-associated toys (OR: 1.37, SE: .10, z = 4.30, $p = .0001$), suggesting that children paid more attention to incongruencies between actor sex and toy gender-association when actors were male. Gaze to faces did not differ when males were shown playing with male-associated toys and females were shown playing with female-associated toys (OR: .93, SE: .09, z = −.72, *p* = .89), suggesting less interest or surprise when actor sex and toy gender-association were congruent.

Summary of results.

Attention to faces differed as a function of participant sex, diagnosis, actor sex and the gender-association of toys. There was an interaction between participant sex and diagnosis, with ASD boys attending less to faces than TD boys. In contrast, there were no differences in attention to faces between ASD and TD girls. Attention to faces fell on a continuum, with ASD boys attending the least, followed by ASD girls, followed by no significant differences in attention between TD girls and boys. Actor sex also influenced attention to faces, irrespective of diagnosis, with girls attending more to female faces and boys attending more to male faces. Children attended more to toys that were associated with their gender. That is, females looked more at *female-associated* toys and males looked more at *male-associated* toys, again irrespective of diagnosis. Across all groups, when there was incongruence between an actor's sex and the gender-association of the toy they were playing with, attention to faces was greater compared to when there was a match – and this difference was particularly pronounced for boys shown playing with female-associated toys.

Discussion

The goal of this study was to understand the interactive effects of biological sex (participant and actors within scenes) and gender-associated toys on social and object attention in ASD. Our results suggest a nuanced profile of social and object attention in ASD girls that is modulated by a number of factors, including the sex of the depicted actors, the gender-association of toys, and the match (or mismatch) between actor sex and toy gender-association. In this paradigm, ASD girls attended to faces to the same degree as TD girls, and showed typical patterns of interest in female faces and female-associated toys. ASD boys showed diminished overall attention to faces, but typical *patterns* of attention to male faces and male-associated toys. This data adds to a growing body of research that suggests different profiles of social and object attention in ASD girls as compared to boys with ASD (Chawarska, Macari, Powell, DiNicola, & Shic, 2016; Harrop et al., 2018b; Harrop et al., 2019) that potentially underpin observed sex differences in other behavioral domains (Dean et al., 2014; Nowell et al., 2019; Sedgewick et al., 2016; Sutherland et al., 2017).

Interestingly, this study found smaller effects of diagnosis on social attention than previously reported. Only one interaction between diagnosis and biological sex was found (for attention to faces), but diagnostic effects were not as encompassing as have been reported in previous eye tracking studies (Chawarska et al., 2013; Chevallier et al., 2015; Sasson & Touchstone, 2014). ASD boys attended to faces for the least amount of time. Their social attention was lower than both TD boys and ASD girls. There were no differences in attention to faces between ASD and TD girls, and within the ASD group, girls attended significantly more to faces than boys. These findings suggest that while previous diagnostic group effects on social attention hold for ASD boys, they do not extend fully to ASD girls. As with our previous studies (Harrop et al., 2018b; Harrop et al., 2019), attention to faces in ASD girls was more similar to attention in TD girls, and supports the conclusion that ASD girls exhibit heightened attention to faces relative to ASD boys.

Children also attended more to toys with gender-associations that aligned with their biological sex. That is, boys attended more to male-associated toys and girls attended more to female-associated toys. This was especially true for girls, extending upon previous studies using static eye tracking paradigms (Harrop et al., 2018a) and parent report (Hiller et al., 2016; Nowell et al., 2019; Sutherland et al., 2017). Additionally, this suggests that paradigms need to be designed in ways that capture the attention of not just ASD boys but also ASD girls, who may have more *female gender-typical* patterns of interests. Overall, our findings support the need for carefully designed paradigms that are sensitive to subtle differences in social attention in boys and girls with ASD.

Actor sex and toy gender-association both exerted independent and combined effects on social attention in this study. Irrespective of diagnosis, children attended more to faces when the actor's sex aligned with their own biological sex. However, when scenes were analyzed based on whether they were congruent (male actor-male toy; female actor-female toy) or incongruent, a more nuanced pattern of attention to faces emerged: toy gender-association and actor sex interacted such that attention to faces was greater when scenes were *gender-incongruent*. This effect was found across all subjects, regardless of diagnosis and biological sex, and was found for both female and male incongruent scenes. This suggests an effect of novelty – perhaps indicating that gender incongruent pairings violated expectations, resulting in greater attention. Consistent with broader societal trends toward greater acceptance of girls playing with traditionally male-associated than boys playing with traditional female-associated toys (Pike & Jennings, 2005; Shell & Eisenberg, 1990; Spinner et al., 2018), the effect was significantly greater when a male actor was paired with a *female-associated* toy.

There are a number of potential explanations for our overall pattern of findings. First, differential attention to *gendered toys* and to more social aspects of scenes in girls may be rooted in a form of behavioral camouflage, developed over time to fit in with neurotypical girls (or to avoid standing out). That is, they may have learned to attend to faces and to express interest in and play with *gender-typical* toys and same-sex peers. Thus, differential visual attention in ASD girls may not reflect intrinsic motivation to attend to female-associated toys or that ASD girls are indeed more socially motivated. Alternatively, girls with ASD may be girls first, having developed their attentional patterns and interests through a combination of societal shaping and (perhaps) more biologically-rooted tendencies, which differentiate them from ASD boys.

Importantly, our findings do not provide support for the Extreme Male Brain (EMB) theory of ASD (Baron-Cohen, 2002). ASD girls across our eye-tracking studies have failed to demonstrate the *hyper-masculinized* attentional profile (Harrop et al., 2018b, 2018a; Harrop et al., 2019) that would be expected based upon the EMB theory, although they did sometimes differ from TD girls. Further, ASD boys, while demonstrating the least attention to faces, did not overly attend to *male* toys compared to TD boys. Thus, while some children with ASD may fit the EMB profile, the participants in this sample largely did not.

Finally, visual attention to the paradigm in this study averaged around 83% in the ASD group, compared to 90% in TD controls. While this difference was significant, our basic attention rates in our ASD group were relatively high compared to other research using dynamic stimuli (Chawarska et al., 2016; Chevallier et al., 2015). This highlights the importance of considering subtle characteristics of toys/objects and activities when designing research paradigms, to select stimuli that optimally capture and maintain the attention of children with ASD.

Implications

Our results add to a growing body of research aimed at thoroughly defining the female ASD phenotype and exploring how subtle phenotypic differences in girls with ASD may impact identification, assessment, and intervention for this critically understudied subgroup. Importantly, research suggests that girls are less likely to receive an ASD diagnosis than boys, even when they are equally impaired (Dworzynski et al., 2012). This has led to an underestimation of the prevalence of ASD in girls (Loomes, Hull, & Mandy, 2017), which is now thought to be closer to 3:1 than earlier estimates that were 4:1 or higher (Fombonne, 2009).

The current study has implications for our conceptualization of how autism manifests in females, particularly those who are verbally fluent without intellectual disability. Despite a Gold Standard diagnosis and comparable SCQ scores to boys, ASD girls in our sample nonetheless showed patterns of visual attention to faces and objects that were more comparable to TD girls than to ASD boys. This suggests that when placed in a roomful of toys or in a social context, females may appear more superficially "typical" than ASD boys because they demonstrate more normative attentional patterns to people and may not play with/fixate on *male-associated* toys that are also viewed as more "autism-related." Instead, girls may attend to and/or play with more stereotypically female toys, which are more social in nature and perhaps not immediately viewed as "autism-related". Thus, gender-typical-presenting ASD girls who nonetheless experience autism-related impairments relative to same-sex peers may be overlooked, and may not receive timely diagnoses, services, or interventions. Careful consideration about how to adjust identification, referrals, diagnosis, and treatment based upon girl-typical ASD behavioral manifestations is warranted.

Limitations and future directions

This study represents a first attempt to understand the interactive effects of gender-associated toys and actor sex on visual attention within a naturalistic eye tracking paradigm, but there are a handful of limitations worth mentioning. Children entering the study were assigned to male or female groups based on their biological sex. We did not ask children or parents what gender they identified with (if any). This is particularly important as emerging evidence suggests that individuals with ASD are more likely than non-ASD individuals to identify as transgender, non-binary, or otherwise gender diverse (Jacobs, Rachlin, Erickson-Schroth, & Janssen, 2014; Strang et al., 2018). We also did not collect details about family make-up (e.g., the sex of siblings), or specific questions about children's favorite toys and their exposure to gendered toys/messages at home. However, children in the present sample included 91% of the sample reported in Nowell, Jones, & Harrop (2019) in which boys with

ASD were more likely to report primary interests in the stereotypical male category of physics (e.g., trains, electronics) than females with ASD whose primary interests mainly fell into the categories of media consumption (e.g., YouTube videos, tablet watching) or in more stereotypical female social categories (e.g., dolls, dramatic play).

Our paradigms featured toys that have been described in previous literature as being male- or female-associated (Cherney et al., 2003; DeLoache et al., 2007; Serbin, Poulin-Dubois, Colburne, Sen, & Eichstedt, 2001; Spinner et al., 2018; Todd et al., 2018). Unfortunately, much of this research is outdated and there has been little research in the past 30 years questioning this broad categorization of toys and roles. However, a recent meta-analysis of 16 studies found that girls played with female-associated toys more than boys did, and vice versa (Todd et al., 2018). Importantly, this analysis revealed an effect of length of time since publication, with earlier studies reporting greater congruency between child sex and toy gender-association. Although this suggests that social norms may be changing, more up-to-date research is needed to confirm whether this is indeed the case – and whether it is occurring equally for boys and girls. The current study suggests that while children show increased interest or surprise when observing gender-incongruent toy play, this pattern is most evident when viewing boys playing with girl-associated toys. Thus, recent trends toward tolerating egalitarian toy play may not be equally distributed between the sexes.

Recent research has also highlights the importance of using naturalistic social scenes during eye tracking, such as the scenes implemented here (Chawarska, Macari, & Shic, 2012; Chevallier et al., 2015). However, caution must be exercised when considering whether social attention patterns in screen-based tasks translate to real-world behavior. Grossman and colleagues (2019) reported that while attention to social scenes and real-life interactions were associated in TD, this relationship did not hold in children with ASD. Further, while group differences in gaze behavior were found in the context of screen-based observation, there were no group differences in gaze behaviors between TD and ASD children during live interactions (Grossman, Zane, Mertens, & Mitchell, 2019). Future work is warranted to probe whether the results of the current study hold when visual attention is assessed during live interaction rather than screen-based observation.

Our sample of ASD girls is substantial and larger than many previous studies, but it is still relatively small in absolute terms and limits our ability to look beyond our primary variables of interest (Faces and Object Activity) to other AOIs that may also be relevant. Further examination of additional AOIs, such as background and distractor objects, could provide a more complete profile of visual attention in girls with ASD relative to ASD boys and TD peers (e.g., attention (particularly in ASD) may have been directed to AOIs not included within our analysis, consistent with other studies (e.g. Chawarska, Macari, & Shic, 2012; Constantino et al., 2017; Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Klin, Jones, Schultz, Volkmar, & Cohen, 2002)). It also could be argued that hands playing with toys, grouped together as one AOI in this analysis, may in fact represent two distinct AOIs, with hands representing attention to social stimuli and/or movement and toys representing object-focused attention. In our paradigm, it would have been very difficult to disentangle these overlapping AOIs due to the hands directly manipulating the toys. However future paradigms could examine attention to hands independent of objects, as this has been shown to be elevated in toddlers with ASD (Chawarska et al., 2012).

It should be noted that the majority of our ASD participants were verbally fluent and did not have intellectual disability; therefore, our findings may not generalize to a broader sample. Our TD control groups were smaller than the ASD groups due to increased focus on recruitment efforts for our ASD girl sample. They also had above average developmental quotients, suggesting that our findings might not generalize to less cognitively able TD subjects.

The age range included in this sample (6 to 10 years) was purposefully selected based on a recent meta-analysis that reported divergence in autism symptom expression between males and females at 6 years. However, future work should extend downward to younger, or even pre-diagnosis, children to understand when sex differences emerge in ASD and to gain a deeper understanding of when *gendered* stereotypes about toys and toy play begin to exert an influence on visual attention. This has implications for treatment as it may be that autistic girls and boys respond differentially to toys and therapists based on their biological sex, and therefore require different intervention materials or methods.

Although this study focused only on ASD, our paradigm has the potential to inform research in other neurodevelopmental and genetic disorders, particularly those with sex differences in prevalence and/or phenotypic expression. For example, there are well-established sex differences in the prevalence and severity of Fragile X Syndrome (Hunter et al., 2014; Keysor & Mazzocco, 2002). It is possible that sex differences in social attention could be detected using eye tracking, in a sensitive paradigm designed to elicit heterogeneous response patterns within these individuals.

Conclusions

This study represents the first attempt to understand how child sex, actor sex and toy gender-associations impact patterns of visual attention to faces and objects in participants with ASD and TD peers. We add to a growing body of literature indicating subtle differences in attention in ASD girls and boys that may be modulated not only by biological sex, but also by contextual cues about gender and gendered play expectations (e.g., typically male-associated vs. female-associated toys). Increased understanding of the interaction between sex and gender in ASD and its impact on behavior is needed for earlier recognition of ASD girls, as well as for sensitive assessment and intervention practices that integrate these important variables.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Alexander GM, Wilcox T, & Woods R (2009). Sex differences in infants' visual interest in toys. Arch Sex Behav, 38(3), 427–433. 10.1007/s10508-008-9430-1 [PubMed: 19016318]

Alexander Gerianne M, & Charles N (2008). Sex Differences in Adults' Relative Visual Interest in Female and Male Faces, Toys, and Play Styles. 10.1007/s10508-008-9429-7

Auster CJ, & Mansbach CS (2012). The Gender Marketing of Toys: An Analysis of Color and Type of Toy on the Disney Store Website. Sex Roles, 67(7–8), 375–388. 10.1007/s11199-012-0177-8

Baron-Cohen Simon S (2002). The extreme male brain theory of autism. Trends in Cognitive Sciences, 1866(6), 248–254. 10.1016/B978-0-444-53630-3.00011-7

Bates D, Mächler M, Bolker BM, & Walker SC (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67(1). 10.18637/jss.v067.i01

Bishop SL, Guthrie W, Coffing M, & Lord C (2011). Convergent validity of the Mullen Scales of Early Learning and the Differential Ability Scales in children with autism spectrum disorders. American Journal on Intellectual and Developmental Disabilities, 116(5), 331–343. 10.1352/1944-7558-116.5.331 [PubMed: 21905802]

Boorse J, Cola M, Plate S, Yankowitz L, Pandey J, Schultz RT, & Parish-Morris J (2019). Linguistic markers of autism in girls: evidence of a "blended phenotype" during storytelling. Molecular Autism, 10(1), 14. 10.1186/s13229-019-0268-2 [PubMed: 30962869]

Caldera YM, Huston AC, & O'Brien M (1989). Social interactions and play patterns of parents and toddlers with feminine, masculine, and neutral toys. Child Development, 60(1), 70–76. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/2702876 [PubMed: 2702876]

Chawarska K, Macari S, Powell K, DiNicola L, & Shic F (2016). Enhanced Social Attention in Female Infant Siblings at Risk for Autism. J Am Acad Child Adolesc Psychiatry, 55(3), 188–95 e1. 10.1016/j.jaac.2015.11.016 [PubMed: 26903252]

Chawarska K, Macari S, & Shic F (2012). Context modulates attention to social scenes in toddlers with autism. J Child Psychol Psychiatry, 53(8), 903–913. 10.1111/j.1469-7610.2012.02538.x [PubMed: 22428993]

Chawarska K, Macari S, & Shic F (2013). Decreased spontaneous attention to social scenes in 6-month-old infants later diagnosed with autism spectrum disorders. Biol Psychiatry, 74(3), 195–203. 10.1016/j.biopsych.2012.11.022 [PubMed: 23313640]

Cherney ID, Kelly-Vance L, Gill Glover K, Ruane AMY, & Oliver Ryalls B (2003). The Effects of Stereotyped Toys and Gender on Play Assessment in Children Aged 18–47 Months. Educational Psychology, 23(1), 95–106. 10.1080/01443410303222

Chevallier C, Parish-Morris J, McVey A, Rump KM, Sasson NJ, Herrington JD, & Schultz RT (2015). Measuring social attention and motivation in autism spectrum disorder using eye-tracking: Stimulus type matters. Autism Res, 8(5), 620–628. 10.1002/aur.1479 [PubMed: 26069030]

Christensen DL, Baio J, Van Naarden Braun K, Bilder D, Charles J, Constantino JN, … Yeargin-Allsopp M (2016). Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years--Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012. MMWR Surveill Summ, 65(3), 1–23. 10.15585/mmwr.ss6503a1

Connellan J, Baron-Cohen S, Wheelwright S, Batki A, & Ahluwalia J (2000). Sex differences in human neonatal social perception. Infant Behav Dev, 23(1), 113–118. 10.1016/S0163-6383(00)00032-1

Constantino JN, Kennon-McGill S, Weichselbaum C, Marrus N, Haider A, Glowinski AL, … Jones W (2017). Infant viewing of social scenes is under genetic control and atypical in autism. Nature, 547(7663), 340. 10.1038/NATURE22999 [PubMed: 28700580]

Dawson G, Meltzoff AN, Osterling J, Rinaldi J, & Brown E (1998). Children with Autism Fail to Orient to Naturally Occurring Social Stimuli. Journal of Autism and Developmental Disorders, 28(6), 479–485. 10.1023/A:1026043926488 [PubMed: 9932234]

Dean M, Harwood R, & Kasari C (2017). The art of camouflage: Gender differences in the social behaviors of girls and boys with autism spectrum disorder. Autism, 21(6), 678–689. 10.1177/1362361316671845 [PubMed: 27899709]

Dean Michelle, Kasari C, Shih W, Frankel F, Whitney R, Landa R, … Harwood R (2014). The peer relationships of girls with ASD at school: comparison to boys and girls with and without ASD. Journal of Child Psychology and Psychiatry, 55(11), 1218–1225. 10.1111/jcpp.12242 [PubMed: 25039696]

DeLoache JS, Simcock G, & Macari S (2007). Planes, trains, automobiles--and tea sets: Extremely intense interests in very young children. Developmental Psychology, 43(6), 1579–1586. 10.1037/0012-1649.43.6.1579 [PubMed: 18020834]

Dworzynski K, Ronald A, Bolton P, & Happe F (2012). How different are girls and boys above and below the diagnostic threshold for autism spectrum disorders? J Am Acad Child Adolesc Psychiatry, 51(8), 788–797. 10.1016/j.jaac.2012.05.018 [PubMed: 22840550]

Elliot C (2007). Differential Ability Scales (2nd ed.). San Antonio, TX: Harcourt Assessment.

Ferri SL, Abel T, & Brodkin ES (2018). Sex Differences in Autism Spectrum Disorder: a Review. Current Psychiatry Reports, 20(2), 9. 10.1007/s11920-018-0874-2 [PubMed: 29504047]

Fombonne E (2009). Epidemiology of pervasive developmental disorders. Pediatr Res, 65(6), 591–598. 10.1203/PDR.0b013e31819e7203 [PubMed: 19218885]

Frazier TW, Georgiades S, Bishop SL, & Hardan AY (2014). Behavioral and Cognitive Characteristics of Females and Males With Autism in the Simons Simplex Collection. Journal of the American Academy of Child & Adolescent Psychiatry, 53(3), 329–340.e3. 10.1016/J.JAAC.2013.12.004 [PubMed: 24565360]

Gluckman M, & Johnson SP (2013). Attentional capture by social stimuli in young infants. Front Psychol, 4, 527. 10.3389/fpsyg.2013.00527 [PubMed: 23966966]

Grossman RB, Zane E, Mertens J, & Mitchell T (2019). Facetime vs. Screentime: Gaze Patterns to Live and Video Social Stimuli in Adolescents with ASD. Scientific Reports, 9(1). 10.1038/s41598-019-49039-7

Halladay AK, Bishop S, Constantino JN, Daniels AM, Koenig K, Palmer K, … Szatmari P (2015). Sex and gender differences in autism spectrum disorder: summarizing evidence gaps and identifying emerging areas of priority. Mol Autism, 6, 36. 10.1186/s13229-015-0019-y [PubMed: 26075049]

Harrop C, Green J, & Hudry K (2017). Play complexity and toy engagement in preschoolers with autism spectrum disorder: Do girls and boys differ? Autism, 21(1), 37–50. 10.1177/1362361315622410 [PubMed: 26936930]

Harrop C, Jones D, Zheng S, Nowell S, Boyd BA, & Sasson NJ (2018a). Circumscribed interests and attention in autism: The role of biological sex. J Autism Dev Disord.

Harrop C, Jones D, Zheng S, Nowell S, Boyd BA, & Sasson NJ (2018b). Sex differences in social attention in autism. Autism Research.

Harrop Clare, Jones D, Zheng S, Nowell S, Schultz R, & Parish-Morris J (n.d.-a). Visual attention to faces in children with autism spectrum disorder: are there sex differences? 10.1186/s13229-019-0276-2

Harrop Clare, Jones D, Zheng S, Nowell S, Schultz R, & Parish-Morris J (2019). Visual attention to faces in children with autism spectrum disorder: are there sex differences? Molecular Autism, 10, 28. 10.1186/s13229-019-0276-2 [PubMed: 31297179]

Harrop Clare, Jones D, Zheng S, Nowell SW, Schultz RT, & Parish-Morris J (n.d.-b). Visual Attention to Faces in Children with Autism Spectrum Disorder: Are There Sex Differences? Molecular Autism.

Hiller RM, Young RL, & Weber N (2014). Sex differences in autism spectrum disorder based on DSM-5 criteria: evidence from clinician and teacher reporting. J Abnorm Child Psychol, 42(8), 1381–1393. 10.1007/s10802-014-9881-x [PubMed: 24882502]

Hiller RM, Young RL, & Weber N (2016). Sex differences in pre-diagnosis concerns for children later diagnosed with autism spectrum disorder. Autism, 20(1), 75–84. 10.1177/1362361314568899 [PubMed: 25717130]

Hines M, & Kaufman FR (1994). Androgen and the development of human sex-typical behavior: rough-and-tumble play and sex of preferred playmates in children with congenital adrenal hyperplasia (CAH). Child Development, 65(4), 1042–1053. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7956464 [PubMed: 7956464]

Hull L, Petrides KV, Allison C, Smith P, Baron-Cohen S, Lai M-C, & Mandy W (2017). "Putting on My Best Normal": Social Camouflaging in Adults with Autism Spectrum Conditions. Journal of Autism and Developmental Disorders, 47(8), 2519–2534. 10.1007/s10803-017-3166-5 [PubMed: 28527095]

Hunter J, Rivera-Arias O, Angelov A, Kim E, Fotheringham I, & Leal J (2014). Epidemiology of fragile X syndrome: A systematic review and meta-analysis. American Journal of Medical Genetics Part A, 164(7), 1648–1658.

Jacklin CN, DiPietro JA, & Maccoby EE (1984). Sex-typing behavior and sex-typing pressure in child/parent interaction. Archives of Sexual Behavior, 13(5), 413–425. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/6517683 [PubMed: 6517683]

Jacobs LA, Rachlin K, Erickson-Schroth L, & Janssen A (2014). Gender Dysphoria and Co-Occurring Autism Spectrum Disorders: Review, Case Examples, and Treatment Considerations. LGBT Health, 1(4), 277–282. 10.1089/lgbt.2013.0045 [PubMed: 26789856]

Jadva V, Hines M, & Golombok S (2010). Infants' Preferences for Toys, Colors, and Shapes: Sex Differences and Similarities. Archives of Sexual Behavior, 39(6), 1261–1273. 10.1007/s10508-010-9618-z [PubMed: 20232129]

Joseph RM, Tager-Flusberg H, & Lord C (2002). Cognitive profiles and social-communicative functioning in children with autism spectrum disorder. Journal of Child Psychology and Psychiatry, 43(6), 807–821. 10.1111/1469-7610.00092 [PubMed: 12236615]

Keysor CS, & Mazzocco MMM (2002). A developmental approach to understanding Fragile X syndrome in females. Microscopy Research and Technique, 57(3), 179–186. 10.1002/jemt.10070 [PubMed: 12112455]

Klin A, Danovitch JH, Merz AB, & Volkmar FR (2007). Circumscribed interests in higher functioning individuals with autism spectrum disorders: An exploratory study. Research and Practice for Persons with Severe Disabilities, 32(2), 89–100.

Klin A, Jones W, Schultz RT, Volkmar FR, & Cohen D (2002). Visual Fixation Patterns During Viewing of Naturalistic Social Situations as Predictors of Social Competence in Individuals With Autism. Archives of General Psychiatry, 59(9), 809. 10.1001/archpsyc.59.9.809 [PubMed: 12215080]

Lai MC, Lombardo MV, Auyeung B, Chakrabarti B, & Baron-Cohen S (2015). Sex/gender differences and autism: setting the scene for future research. J Am Acad Child Adolesc Psychiatry, 54(1), 11–24. 10.1016/j.jaac.2014.10.003 [PubMed: 25524786]

Lenth R, Singmann H, Love J, Buerkner P, & Herve M (2019). emmeans: Estimated Marginal Means. Retrieved from https://cran.r-project.org/web/packages/emmeans/index.html

Locke J, Anderson A, Frederick L, & Kasari C (2018). Understanding Friendship Sex Heterophily and Relational Characteristics to Optimize the Selection of Peer Models for Children with Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 48(12), 4010–4018. 10.1007/s10803-018-3662-2 [PubMed: 29982894]

Loomes R, Hull L, & Mandy WPL (2017). What Is the Male-to-Female Ratio in Autism Spectrum Disorder? A Systematic Review and Meta-Analysis. Journal of the American Academy of Child & Adolescent Psychiatry, 56(6), 466–474. 10.1016/j.jaac.2017.03.013 [PubMed: 28545751]

Lord C, Rutter ML, DiLavore PS, Risi S, Gotham K, & Bishop SL (2012). Autism Diagnostic Observation Schedule - Second Edition (ADOS-2). WPS.

Maccoby EE (1998). The Two Sexes: Growing Up Apart, Coming Together. Belknap Press of Harvard University Press. Retrieved from https://books.google.com/books?id=chtFzHfmBkMC

Murnen SK, Greenfield C, Younger A, & Boyd H (2016). Boys Act and Girls Appear: A Content Analysis of Gender Stereotypes Associated with Characters in Children's Popular Culture. Sex Roles, 74(1–2), 78–91. 10.1007/s11199-015-0558-x

Nowell SW, Jones DR, & Harrop C (2019). Circumscribed interests in autism: are there sex differences? Advances in Autism, AIA-09-2018-0032. 10.1108/AIA-09-2018-0032

Parish-Morris J, Liberman MY, Cieri C, Herrington JD, Yerys BE, Bateman L, … Schultz RT (2017). Linguistic camouflage in girls with autism spectrum disorder. Mol Autism, 8, 48. 10.1186/s13229-017-0164-6 [PubMed: 29021889]

Pike JJ, & Jennings NA (2005). The effects of commercials on children's perceptions of gender appropriate toy use. Sex Roles, 52(1–2), 83–91. 10.1007/s11199-005-1195-6

Reich SM, Black RW, & Foliaki T (2018). Constructing Difference: Lego® Set Narratives Promote Stereotypic Gender Roles and Play. Sex Roles, 79(5–6), 285–298. 10.1007/s11199-017-0868-2

Rutter M, Bailey A, & Lord C (2003). The Social Communication Questionnaire. United States of America: Western Psychological Services.

Rutter M, Le Couteur A, & Lord C (2003). ADI-R. Autism Diagnostic Interview Revised Los Angeles: Western Psychological Services.

Sasson NJ, & Touchstone EW (2014). Visual Attention to Competing Social and Object Images by Preschool Children with Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 44(3), 584–592. 10.1007/s10803-013-1910-z [PubMed: 23918441]

Sedgewick F, Hill V, Yates R, Pickering L, & Pellicano E (2016). Gender Differences in the Social Motivation and Friendship Experiences of Autistic and Non-autistic Adolescents. J Autism Dev Disord, 46(4), 1297–1306. 10.1007/s10803-015-2669-1 [PubMed: 26695137]

Serbin LA, Poulin-Dubois D, Colburne KA, Sen MG, & Eichstedt JA (2001). Gender stereotyping in infancy: Visual preferences for and knowledge of gender-stereotyped toys in the second year. International Journal of Behavioral Development, 25(1), 7–15. 10.1080/01650250042000078

Shell R, & Eisenberg N (1990). The Role of Peers' Gender in Children's Naturally Occurring Interest in Toys. International Journal of Behavioral Development, 13(3), 373–388. 10.1177/016502549001300309

Spinner L, Cameron L, & Calogero R (2018). Peer Toy Play as a Gateway to Children's Gender Flexibility: The Effect of (Counter)Stereotypic Portrayals of Peers in Children's Magazines. Sex Roles, 79(5–6), 314–328. 10.1007/s11199-017-0883-3 [PubMed: 30147223]

Strang JF, Meagher H, Kenworthy L, de Vries ALC, Menvielle E, Leibowitz S, … Anthony LG (2018). Initial Clinical Guidelines for Co-Occurring Autism Spectrum Disorder and Gender Dysphoria or Incongruence in Adolescents. Journal of Clinical Child and Adolescent Psychology, 47(1), 105–115. 10.1080/15374416.2016.1228462 [PubMed: 27775428]

Sutherland R, Hodge A, Bruck S, Costley D, & Klieve H (2017). Parent-reported differences between school-aged girls and boys on the autism spectrum. Autism, 1–10. 10.1177/1362361316668653

Team, R. S. (2015). RStudio: Integrated Development for R. Boston, MA: RStudio, Inc. Retrieved from http://www.rstudio.com/.

Todd BK, Fischer RA, Di Costa S, Roestorf A, Harbour K, Hardiman P, & Barry JA (2018). Sex differences in children's toy preferences: A systematic review, meta-regression, and meta-analysis. Infant and Child Development, 27(2). 10.1002/icd.2064

Van Wijngaarden-Cremers PJ, van Eeten E, Groen WB, Van Deurzen PA, Oosterling IJ, & Van der Gaag RJ (2014). Gender and age differences in the core triad of impairments in autism spectrum disorders: a systematic review and meta-analysis. J Autism Dev Disord, 44(3), 627–635. 10.1007/s10803-013-1913-9 [PubMed: 23989936]

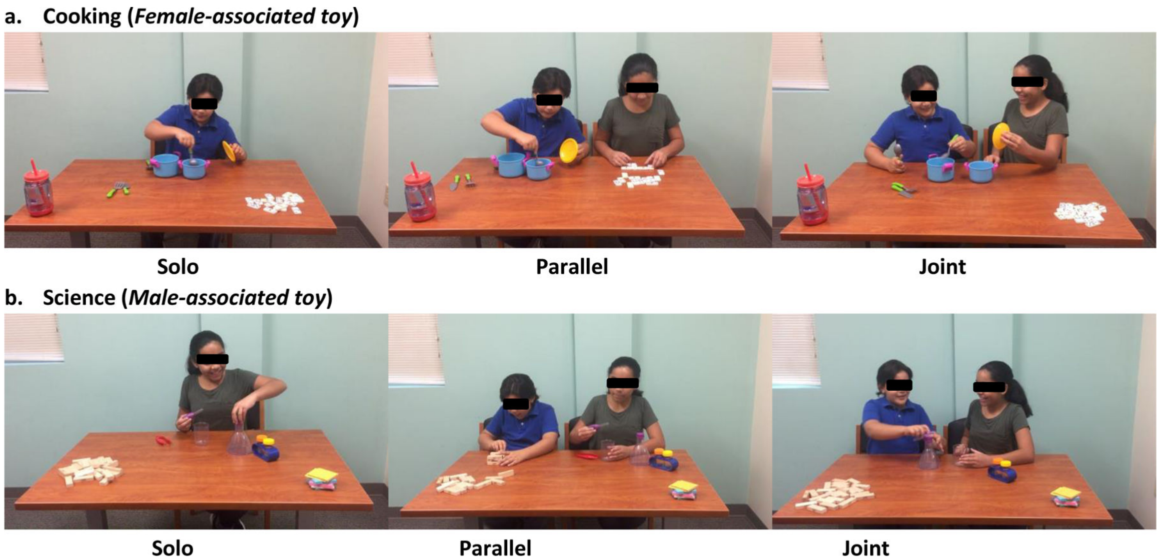

Figure 1.
Example Paradigm Stimuli
Toy Set 1 (gender of toy and sex of actor not congruent)

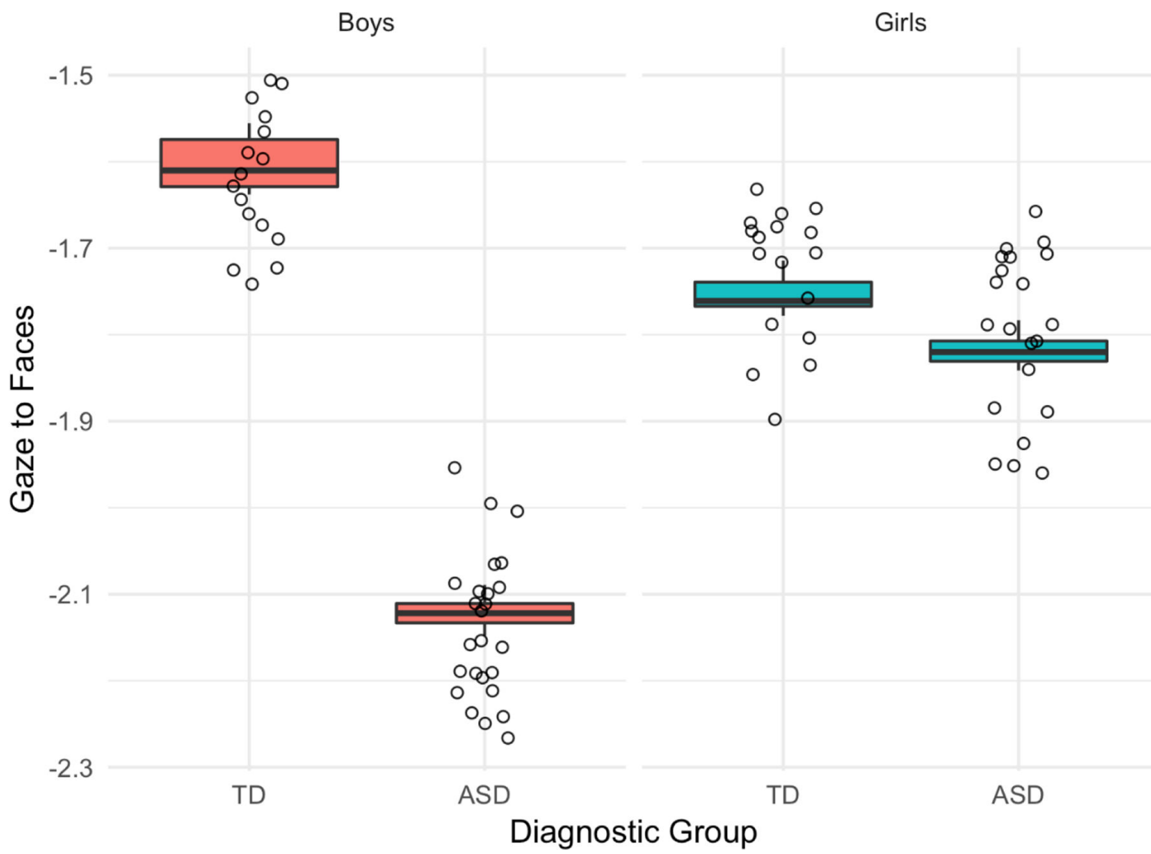

Figure 2. Gaze to Faces (Estimated Marginal Means) by Sex and Diagnosis.

After controlling for age and AE, GLM revealed a significant interactive effect of sex and diagnosis (Estimate: −.47, SE: .09, z = −5.36, $p < .0001$) on gaze to faces. TD boys looked longer to faces than ASD boys (OR: 1.68, SE: 0.12, z = 7.572, $p < .0001$). Within the ASD group, girls looked longer at faces than boys (OR: 1.38, SE: .08, z = 5.19, $p < .0001$). TD girls were significantly more likely to look at faces than ASD boys (OR: 1.46, SE: .10, z = 5.70, $p < .0001$), and ASD girls were less likely to look at faces than TD boys (OR: .82, SE: .05, z = −3.02, $p = .01$).

Figure 3. Gaze to Faces (Estimated Marginal Means) by Actor Sex and Toy Gender Association.
Children looked longer at faces when male actors were depicted playing with female-associated toys than when males were shown playing with male-associated toys (OR: 1.90, SE: .15, z = 7.89, $p < .0001$). Children looked longer at the faces of female actors playing with male-associated toys than when female actors were depicted playing with female-associated toys (OR: .67, SE: .06, z = −4.46, $p < .0001$). Children looked significantly longer at faces when male actors played with female-associated toys than when female actors played with male-associated toys (OR: 1.37, SE: .10, z = 4.30, $p = .0001$), suggesting that children paid more attention to incongruences between actor sex and toy gender-association when actors were male. Gaze to faces did not differ when males were shown playing with male-associated toys and females were shown playing with female-associated toys (OR: .93, SE: .09, z = −.72, $p = .89$), indicating less interest or surprise when actor sex and toy gender-association were congruent.

Table 1:

Sample Characteristics

	MALES		FEMALES	
	ASD (n = 25)	**TD Controls (n = 16)**	**ASD (n = 21)**	**TD Controls (n = 17)**
Age (years)	9.43 (.84)	7.67 (1.47)	8.40 (1.58)	7.92 (1.48)
Mental Age (years)	9.60 (2.62)	10.32 (3.45)	7.89 (2.38)	9.51 (2.00)
Race				
White	19	12	19	12
Black/African American	2	0	1	4
Asian	1	2	0	0
Mixed Race	3	2	1	1
Ethnicity				
Hispanic/Latino	5	3	2	0
Not Hispanic/Latino	20	13	19	17
SCQ Score	14.80 (5.79)	3.50 (2.58)	14.24 (5.26)	2.06 (2.77)
Basic Attention	82% (22%)	90% (13%)	85% (9%)	89% (8%)

Values indicate mean and SD