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Shifting preferences for primate faces in neurotypical infants and infants later diagnosed with ASD

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Abstract

Infants look at others' faces to gather social information. Newborns look equally at human and monkey faces but prefer human faces by 1 month, helping them learn to communicate and interact with others. Infants later diagnosed with autism spectrum disorder (ASD) look at human faces less than neurotypical infants, which may underlie some deficits in social-communication later in life. Here, we asked whether infants later diagnosed with ASD differ in their preferences for both human and non-human primate faces compared to neurotypical infants over their first two years of life. We compare infants' relative looking times to human or monkey faces paired with non-face controls (Experiment 1) and infants' total looking times to pairs of human and monkey faces (Experiment 2). Across two experiments, we find that between 6 and 18 months, infants later diagnosed with ASD show a greater downturn (decrease after an initial increase) in looking at both primate faces than neurotypical infants. A decrease in attention to primate faces may partly underlie the social-communicative difficulties in children with ASD and could reveal how early perceptual experiences with faces affect development.

Lay Summary

Looking at faces helps infants learn to interact with others. Infants look equally at human and monkey faces at birth but prefer human faces by 1 month. Infants later diagnosed with ASD who show deficits in social-communication look at human faces less than neurotypical infants. We find that a downturn (decline after an initial increase) in attention to both human and monkey faces between 6 and 18 months may partly underlie the social-communicative difficulties in children with ASD.

Keywords

Face preference; human faces; monkey faces; infancy; eye tracking; autism spectrum disorder

Humans look at others' faces to gather social information—an ability thought to be crucial for the evolution of social-communicative abilities (e.g., Andrew, 1963). Learning to process

and identify faces begins early: infants look longer at faces and face-like patterns over non-face-like patterns prenatally (Reid et al., 2017) and shortly after birth (Farroni, Massaccesi, Pividori, & Johnson, 2004; Johnson, Dziurawiec, Ellis, & Morton, 1991; Macchi Cassia, Turati, & Simion, 2004; Simion, Macchi Cassia, Turati, & Valenza, 2001). This preference for faces is initially broad. Newborns look equally at human and monkey faces when they are equated for low-level visual properties (Di Giorgio, Leo, Pascalis, & Simion, 2012), but by 1 and 3 months, infants' preference becomes specific to human faces (Sanefuji, Wada, Yamamoto, Mohri, & Taniike, 2014), helping them learn from and communicate with the people around them (Brooks & Meltzoff, 2005; Cohn & Tronik, 1983; Csibra & Gergely, 2009, 2011; D'Entremont, Hains, & Muir, 1997; Gredebäck, Theuring, Hauf, & Kenward, 2008; Kelly et al., 2005; Pascalis, de Haan, Nelson, & de Schonen, 1998; Tronick, 1989; Vouloumanos, Druhen, Hauser, & Huizink, 2009)

Differential early processing of faces may underlie some of the social-communicative difficulties in people with autism spectrum disorder (ASD; American Psychiatric Association, 2013). Compared to neurotypical children, toddlers with ASD look less at faces, and those who look less at faces have more severe ASD symptoms and lower nonverbal functioning (Shic, Bradshaw, Klin, Scassellati, & Chawarska, 2011). Toddlers with ASD also process faces differently and have trouble recognizing human and non-human primate faces compared to their neurotypical peers (Chawarska & Shic, 2009; Chawarska & Volkmar, 2007; Chawarska, Volkmar, & Klin, 2010; Joseph & Tanaka, 2003). Though neurotypical 2-year-olds recognize and distinguish between different human faces, but not monkey faces, 2-year-olds with ASD recognize neither human nor monkey faces (Chawarska & Volkmar, 2007). And people with ASD begin to look less at faces in infancy. Compared to neurotypical infants, 6-month-olds later diagnosed with ASD look less at a speaker's face (Chawarska, Macari, & Shic, 2013; Shic, Macari, & Chawarska, 2014), and between 2 to 24 months, infants later diagnosed with ASD show a decline in looking at a speaker's eyes while neurotypical infants do not (Jones & Klin, 2013), with a steeper decline in looking correlating with more severe ASD symptoms at 36 months. Thus, not looking at faces in infancy may impair infants' ability to learn to communicate and interact with others.

Looking at faces is important for social-communicative abilities, and looking less at faces may underlie atypical social-communication. However, it remains unknown whether infants' looking at primate (human and monkey) faces changes over development and whether infants later diagnosed with ASD differ from neurotypical infants (infants not later diagnosed with ASD) in their preferences for primate faces. Previous studies have not examined whether neurotypical infants' preferences for faces over non-faces change beyond a few days after birth (Di Giorgio et al., 2012; Farroni et al., 2004; Johnson et al., 1991; Macchi Cassia et al., 2004; Simion et al., 2001) when they are becoming aware of even more complex social information (e.g., Hamlin, 2013; Liberman, Kinzler, & Woodward, 2014). Furthermore, prior studies have only examined changes in looking at human faces in infants later diagnosed with ASD and neurotypical infants (e.g., Chawarska et al., 2013; Jones & Klin, 2013). It is unclear whether differences in how infants later diagnosed with ASD process faces are specific to human faces, or whether they also look less at non-human primate faces across development. Though human and monkey faces are perceptually similar, monkey faces do not contain socially relevant information (Emery, 2000; Kobayashi

& Kohshima, 2001; Schmidt & Cohn, 2001; Senju & Csibra, 2008). If infants later diagnosed with ASD decline in their looking at both primate faces, it would suggest that differential processing is due to general perceptual properties of faces that are shared between human and monkey faces. In this paper, we consider two possibilities: that infants later diagnosed with ASD may lack a general perceptual bias for looking at faces, both human and monkey, or that they lack the social motivation to attend only to human faces.

Across two experiments in a prospective longitudinal study, we examined whether neurotypical infants (low- and high-risk infants not diagnosed with ASD) and infants later diagnosed with ASD differ in their preferences for primate faces and whether these preferences remain stable between 6 and 18 months. In Experiment 1, we measured infants' looking times to either a human or a monkey face compared to a phase-scrambled non-face at 6, 9, 12, and 18 months. In Experiment 2, we measured infants' looking times to pairs of human and monkey faces at 9, 12, and 18 months. These complimentary measures allowed us to examine 1) how infants' preference for either primate face over a non-face changed over time, and 2) how infants' total looking time to each primate face changed over time. All infants were evaluated for an ASD diagnosis at 24 months.

We predicted that neurotypical infants and infants later diagnosed with ASD would show different patterns of developmental change. Neurotypical infants' preference for the human face over the non-face (Experiment 1) and their total looking to the human face (Experiment 2) may remain stable over time. The strength of their preference for the monkey face over the non-face (Experiment 1) and their total looking to the monkey face (Experiment 2) may increase over time because older infants often become interested in novelty (Hunter & Ames, 1988; Kidd, Piantadosi, & Aslin, 2012, 2014).

In contrast, infants later diagnosed with ASD may decline in their preference for the human face (Experiment 1) and decline in their total looking to the human face (Experiment 2; Jones & Klin, 2013; Ozonoff et al., 2010). They may maintain or increase their preference for the monkey face (Experiment 1) and their total looking to the monkey face (Experiment 2) because monkey faces lack the social information of human faces (Emery, 2000; Kobayashi & Kohshima, 2001; Schmidt & Cohn, 2001; Senju & Csibra, 2008).

Experiment 1

Method

Participants—We tested 123 (58 female) full term 6-month-olds with at least one older sibling as a part of a larger prospective longitudinal study. The sample included 79 low-risk infants (35 female) with no immediate family members diagnosed with ASD, and 44 high-risk infants (23 female) with at least one older sibling diagnosed with ASD by a pediatrician or psychologist. Approximately 19% of infant siblings of children diagnosed with ASD will be diagnosed with ASD, compared to 1.7% in the general population (Center for Disease Control and Prevention, 2018; Ozonoff et al., 2011). Low-risk infants were recruited from maternity wards at local hospitals (New York, NY) and through parent fairs, flyers, and advertisements (Calgary, AB). High-risk infants were recruited through local pediatric clinics and ASD organizations. Infants were excluded if they presented with a neurological

disorder of known etiology, significant sensory or motor impairment, major physical abnormalities, and history of serious head injury and/or neurological disease.

The final sample of infants providing data for at least 50% of two or more test trials for at least two tested ages included 58 infants (27 female): 32 low-risk infants (16 female) and 26 high-risk infants (11 female). Infants were tested at 6 (low-risk: $M_{age} = 6.52$, $SD_{age} = .27$; high-risk: $M_{age} = 6.58$, $SD_{age} = .54$), 9 (low-risk: $M_{age} = 9.22$, $SD_{age} = .45$; high-risk: $M_{age} = 9.21$, $SD_{age} = .60$), 12 (low-risk: $M_{age} = 12.66$, $SD_{age} = .62$; high-risk: $M_{age} = 12.40$, $SD_{age} = .41$), and 18 months (low-risk: $M_{age} = 18.69$, $SD_{age} = .52$; high-risk: $M_{age} = 17.93$, $SD_{age} = 2.93$; see Table 1 for final sample sizes at each age).

Eye tracking data at each visit were excluded due to fussiness or inattention (6 months: 8 low-risk, 10 high-risk; 9 months: 7 low-risk, 3 high-risk; 12 months: 5 low-risk, 6 high-risk; 18 months: 3 low-risk, 8 high-risk), experimenter error (6 months: 1 high-risk; 9 months: 1 high-risk; 18 months: 1 high-risk), or inefficient data collection from the eye tracker (6 months: 40 low-risk, 13 high-risk; 9 months: 22 low-risk, 9 high-risk; 12 months: 20 low-risk, 5 high-risk; 18 months: 24 low-risk, 7 high-risk). Data were excluded for 9 infants who received a clinical best estimate diagnosis of atypical development without ASD at 24 months (6 low-risk, 3 high-risk). Parents gave informed consent on behalf of their infants and received \$20 as compensation for each visit. Parents also received a certificate and small toys or t-shirts. All procedures were approved independently by the University Committee on Activities Involving Human Subjects at New York University (IRB-FY 2016-170) and the Conjoint Health Research Ethics Board at the University of Calgary (REB15-1002).

Stimuli—Visual stimuli consisted of static gray scale photographs of four faces, two adult female humans and two adult female rhesus monkeys, as well as four non-faces. All visual displays were masked with an ellipse to occlude hair from the human faces and ears from both primate faces. The four non-face images contained the same pixels as the corresponding gray scale photograph (either adult female human or adult female rhesus monkey), but the pixels were scrambled by a Fourier transformation, so the image no longer resembled a face but was equated on luminance and contrast. Each 16.5 by 20 cm image was cropped to screen size and placed on a gray background using Adobe Photoshop (see Figure 1A).

Apparatus—Infants were seated upright in a high chair approximately 60 cm from a 29 cm x 47 cm screen in a sound-attenuated room. At a viewing distance of 60 cm, the stimulus scene measured 27.8° vertical and 43.1° horizontal visual angle. Gaze was measured with the SensoMotoric Instruments (SMI) RED or RED-m infrared eye tracker system (SensoMotoric Instruments GmbH, Tetlow, Germany; www.smivision.com/). The system recorded the pupil and corneal reflection, sampling at 60 or 120 Hz. Calibration and stimulus presentation were controlled by SMI IView X™ (Version 2.8, 2014) and Experiment Center™ (Version 3.4, 2014). Before beginning data collection, the eye tracking software obtained a 2-point calibration using a telescoping bulls-eye or an animated image of Elmo accompanied by infant friendly sounds to ensure that the eye tracker was correctly locating the infants' eyes. The calibration repeated if we did not obtain an accurate calibration. Prior to each test trial, infants' attention was drawn to the center of the screen

using a telescoping bulls-eye. The eye tracking software used a four-point validation at the end of the task to measure any change in the precision of the tracking after the initial calibration. The stimuli used for the validation were the same as the initial calibration.

Procedure—At 6, 9, 12, and 18 months, infants saw images of primate faces paired with their corresponding non-face. Each infant saw four trials in which one primate face (human or monkey) was shown side by side with its corresponding non-face separated by an 8.5 cm gap. Each trial lasted until the infant accumulated 10 s of looking time to either display or for a maximum of 20 s. The side of the screen on which the face and non-face appeared was counterbalanced. In the first trial, half of the infants saw a human face and its corresponding non-face, and the other half of the infants saw a monkey face and its corresponding non-face. In the first trial, half of the infants saw the primate face on the left side, and half saw it on the right side. The side of the screen on which each face appeared and the type of primate face, either human or monkey alternated.

Data Reduction and Analysis—Eye tracking data was processed using SMI BeGaze™ Eye tracking Analysis Software (Version 3.4, 2014). To assess infants' visual fixations to the primate faces and non-face, we defined an oval area of interest (AOI) for human faces, monkey faces, and their corresponding non-faces (all 324085 pixels). Looking time to each AOI was determined by total length of fixations in each AOI in each trial. The eye tracker calculated fixation lengths and locations by filtering raw looking data by predetermined criteria (80 ms, 100 pixels of dispersion) for each individual participant.

ASD Diagnosis—At 24 months, a licensed clinical psychologist with expertise in diagnosing and treating people with ASD evaluated all participants (high-risk and low-risk) for a clinical best estimate diagnosis for ASD using the Toddler Module of the Autism Diagnostic Observation Schedule (ADOS; Luyster et al., 2009). Fifteen infants (5 low-risk, 10 high-risk) met criteria for a clinical best estimate diagnosis of ASD. Forty-three infants (27 low-risk, 16 high-risk) were neurotypical and did not meet criteria for ASD or other language or cognitive delays.

Results

Overall preference for primate faces—First, we examined whether neurotypical infants and infants later diagnosed with ASD differed in their preference for either the human or the monkey face over the corresponding non-face at 6, 9, 12, and 18 months. We ran separate 2 (diagnostic group: neurotypical, ASD) x 2 (face type: human or monkey face, non-face) analysis of variances (ANOVAs) on infants' total looking time to each primate face and non-face at each age with diagnosis as a between-subjects factor and face type as a within-subjects factor. Tests of simple effects were corrected for multiple comparisons using the Bonferroni adjustment. ANOVAs were run in R using ez vers. 4.40 (Lawrence, 2016; R Core Team, 2013).

6 months. At 6 months, both neurotypical infants and infants later diagnosed with ASD looked longer at the human face compared to the human non-face ($F(1, 19) = 81.21, p < .001, \eta^2 = .66$). However, there was a significant diagnostic group by monkey face type

interaction ($F(1, 19) = 7.72, p = .01, \eta^2 = .23$) in which neurotypical infants looked longer at the monkey face ($M = 5228, SE = 454$) compared to the monkey non-face ($M = 2152, SE = 454, t(13) = 4.22, p = .001$), while infants later diagnosed with ASD looked equally at the monkey face ($M = 3626, SE = 582$) and monkey non-face ($M = 4060, SE = 582, t(6) = .42, p = .68$).

9 months.: At 9 months, both neurotypical infants and infants later diagnosed with ASD looked longer at the human face than the human non-face ($F(1, 38) = 46.84, p < .001, \eta^2 = .46$). Infants later diagnosed with ASD looked at both human face and human non-face slightly longer than neurotypical infants ($F(1, 38) = 3.43, p = .07, \eta^2 = .03$), though this effect is only marginally significant with a small effect size. Both groups also looked longer at the monkey face than the monkey non-face ($F(1, 38) = 21.38, p < .001, \eta^2 = .28$).

12 months.: At 12 months, both neurotypical infants and infants later diagnosed with ASD also looked longer at the human face than the human non-face ($F(1, 41) = 8.85, p = .01, \eta^2 = .13$) and looked longer at the monkey face than the monkey non-face ($F(1, 41) = 19.04, p < .001, \eta^2 = .25$).

18 months.: At 18 months, both groups looked equally at the human face and the human non-face ($F(1, 36) = .39, p = .53, \eta^2 = .01$), but looked marginally longer at the monkey face compared to the monkey non-face ($F(1, 36) = 3.51, p = .07, \eta^2 = .06$; see Table 1 and Figure 2).

Time course of preference for primate faces—Next, we used growth curve models to examine how preferences for either primate face over the non-face changed over time in neurotypical infants and infants later diagnosed with ASD. To quantify the strength of infants' preference for either primate face, we calculated a preference score by subtracting individual infants' looking time to either non-face from their looking time to the corresponding primate face. Positive scores reflect longer looking at the primate face over the non-face (see Figure 3).

We fit linear and quadratic growth curve models that included linear and/or quadratic effects of age, diagnostic group, face type, and their interactions as fixed effects and the intercept, linear and/or quadratic effects of age as random effects. Neurotypical infants and human preference score were coded as -1 , infants later diagnosed with ASD and monkey preference score were coded as 1 . The linear and quadratic effects of age were centered at 6 months. Adding the quadratic effect of age significantly improved the fit of the model ($-2LL = 40.0, p < .001$), so we report results of the quadratic growth curve model. (Note that in a quadratic growth curve model, the linear effect of age is interpreted as the instantaneous slope at time 0, which is at 6 months in this model; e.g., Grimm, Ram, & Hamagami, 2011). Growth curve models and graphs were created in R using nlme vers. 3.1-131.1 and ggplot2 vers. 2.1.0 (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2018; R Core Team, 2013; Wickham, 2009).

Fixed effects of the model suggest that neurotypical infants and infants later diagnosed with ASD showed different patterns of change between 6 and 18 months. Significant linear ($b =$

688, $SE = 2.62$, $t(216) = 2.62$, $p = .02$) and quadratic ($b = -28$, $SE = 10$, $t(216) = 2.64$, $p = .01$) interactions between the age and diagnostic group suggest that across face type, infants later diagnosed with ASD showed a greater downturn in their preference for primate faces over time compared to neurotypical infants ($b = -28$, $SE = 10$, $t(216) = 2.64$, $p = .01$): preference for primate faces in infants later diagnosed with ASD plateaued between 6 and 9 months then declined between 9 and 18 months, reaching preference scores close to 0 by 18 months. In contrast, neurotypical infants' preference for both primate faces decreased between 6 and 9 months, then remained relatively level between 9 and 18 months (see Figure 4 for model fit).

Across diagnostic groups, infants' preferences for either primate face also differed at 6 months and may have followed different trajectories over time. A significant linear interaction ($b = 477$, $SE = 204$, $t(216) = 2.33$, $p = .02$) and a marginal quadratic interaction ($b = -16$, $SE = 8$, $t(216) = 1.92$, $p = .06$) between age and face type suggest that infants may have shown a greater downturn in their preference for the monkey face compared to the human face over time ($b = -16$, $SE = 8$, $t(216) = 1.92$, $p = .06$). On average, infants' preference for the monkey face appeared to increase between 6 and 9 months, but declined between 9 and 18 months. In contrast, infants' preference for the human face appeared to decrease between 6 and 9 months, but leveled between 9 and 18 months more than their preference for the monkey face (see Table 2 for full model results).

Random effects of the model suggest that infants did not vary in their preference score of looking at either primate face over time, as adding the random linear ($-2LL = .20$, $p = .91$) and quadratic effects of age ($-2LL = 3.59$, $p = .31$) did not significantly improve the fit of the model. However, to ensure that our model is generalizable, we report results of the maximal model that includes random effects of the intercept, linear, and quadratic effects of age (Barr, Levy, Scheepers, & Tily, 2013).

Examining differences between risk groups—Because the neurotypical group included both low- and high-risk infants, we ran the same analyses as above to examine whether the low- and high-risk infants in the neurotypical group differed in their preferences for primate faces.

First, ANOVAs revealed that in both risk groups, neurotypical infants looked longer at the human and monkey faces over their corresponding non-faces at each age (all $ps < .04$). The only significant difference we found between the risk groups was at 12 months, when the high-risk neurotypical infants looked longer at monkey faces and monkey non-faces compared to low-risk neurotypical infants ($F(1,30) = 5.29$, $p = .03$, $\eta^2 = .05$). We found no significant interactions between risk group and face type at any age (all $ps > .13$; see Table 3 for means and standard deviations).

Second, we ran the same quadratic growth curve model to examine whether neurotypical low- and high-risk infants differed in their time course of preferences for primate faces. Low-risk infants and human preference score were coded as -1 , high-risk infants and monkey preference score were coded as 1 . The linear and quadratic effects of age were centered at 6 months. Again, adding the quadratic effect of age significantly improved the fit

the of the model ($-2LL = 36.00$ $p < .001$), so we report results of the quadratic growth curve model. Fixed effects of the model suggest that low- and high-risk neurotypical infants showed similar patterns of change between 6 and 18 months. We found no significant differences between face type or risk groups (all p s $> .28$; see Figure 5 and Table 4 for full model results). These results of the maximal model include random effects of the intercept, linear, and quadratic effects of age (Barr et al., 2013).

Experiment 2

Method

Participants—We tested 129 (59 female) full term 9-month-olds with at least one older sibling as a part of a larger prospective longitudinal study, a subset of whom participated in Experiment 1. The sample included 75 low-risk infants (34 female) and 54 high-risk infants (25 female). Infants were recruited and excluded following procedures of Experiment 1.

The final sample of infants providing data for at least 50% of two or more test trials for at least two tested ages included 31 infants (13 female): 18 low-risk infants (7 female) and 13 high-risk infants (6 female). Infants were tested at 9 (low-risk: $M_{age} = 9.15$, $SD_{age} = .56$; high-risk: $M_{age} = 9.43$, $SD_{age} = .46$), 12 (low-risk: $M_{age} = 12.56$, $SD_{age} = .31$; high-risk: $M_{age} = 12.35$, $SD_{age} = .41$), and 18 months (low-risk: $M_{age} = 18.56$, $SD_{age} = .32$; high-risk: $M_{age} = 18.49$, $SD_{age} = .43$; see Table 1 for final sample sizes at each age).

Eye tracking data at each visit was excluded due to fussiness or inattention (9 months: 8 low-risk, 5 high-risk; 12 months: 22 low-risk, 12 high-risk; 18 months: 10 low-risk, 10 high-risk), experimenter error (18 months: 1 low-risk), equipment error (18 months: 3 low-risk), or inefficient data collection from the eye tracker (9 months: 17 low-risk, 12 high-risk; 12 months: 10 low-risk, 6 high-risk; 18 months: 5 low-risk, 4 high-risk). Data were excluded for 9 infants who received a clinical best estimate diagnosis of atypical development without ASD at 24 months (6 low risk, 3 high risk). Parents gave informed consent and were compensated as in Experiment 1. All procedures were approved independently by the university IRBs (IRB-FY 2016-170 and REB15-1002).

Stimuli—Visual stimuli consisted of the same four faces as in Experiment 1: two adult female humans and two adult female rhesus monkeys (see Figure 1B).

Apparatus—Identical to Experiment 1.

Procedure—At 9, 12, and 18 months, infants saw images of human faces paired with monkey faces. Each infant saw four trials, in which one human face was shown side by side with a monkey face separated by an 8.5 cm gap. Each trial lasted until the infant accumulated 10 s of looking time to either display or for a maximum of 20 s. The side of the screen on which the human face and monkey face appeared was counterbalanced to avoid potential side biases. In the first trial, half of the infants saw the human face on the left side and the other half of the infants saw the human face on the right side. The side of the screen on which each face appeared alternated.

Data Reduction and Analysis—Eye tracking data was processed as in Experiment 1.

ASD Diagnosis—All infants were evaluated for an ASD diagnosis as in Experiment 1. Seven infants (4 low-risk, 3 high-risk) met criteria for a clinical best estimate diagnosis of ASD. Twenty-four infants were neurotypical (14 low-risk, 10 high-risk) and did not meet criteria for ASD or other language or cognitive delays.

Results

Time course of preference for primate faces—As in Experiment 1, we used a growth curve model to examine how looking time to either primate face changed over time in neurotypical infants and infants later diagnosed with ASD. However, unlike Experiment 1, we examined infants' engagement with different primate face by analyzing infants' total looking time to each primate face rather than calculating a preference score because the human and monkey faces were presented side by side, allowing us to examine how infants' total looking time to each primate face changed over time separately (see Table 1 and Figure 3 for means and standard deviations of infants looking times).

We fit linear and quadratic growth curve models that included linear and/or quadratic effects of age, diagnostic group, face type, and their interactions as fixed effects and the intercept, linear and/or quadratic effects of age as random effects. Neurotypical infants and human face were coded as -1 , infants later diagnosed with ASD and monkey face were coded as 1 . The linear and quadratic effects of age were centered at 9 months. Adding the quadratic effect of age significantly improved the fit of the model ($-2LL = 39.85$, $p < .001$), so we report results of the quadratic growth curve model. Growth curve models and graphs were created in R using nlme vers. 3.1-131.1 and ggplot2 vers. 2.1.0 (Pinheiro et al., 2018; R Core Team, 2013; Wickham, 2009).

As in Experiment 1, fixed effects of the model suggest that neurotypical infants and infants later diagnosed with ASD showed different patterns of change in their looking time to both primate faces between 9 and 18 months. Marginal linear ($b = 883$, $SE = 477$, $t(105) = 1.85$, $p = .07$) and quadratic ($b = -32$, $SE = 17$, $t(105) = 1.90$, $p = .06$) interactions between age and diagnostic group that just miss conventional significance criteria suggest that compared to neurotypical infants, infants later diagnosed with ASD showed a greater downturn in their looking at both primate faces ($b = -32$, $SE = 17$, $t(105) = 1.90$, $p = .06$). Specifically, infants later diagnosed with ASD appeared to increase their looking between 9 and 12 months and decrease their looking between 12 and 18 months. In contrast, neurotypical infants slightly decreased their looking between 9 and 12 months, but increased their looking between 12 and 18 months (see Figure 4).

Furthermore, a main effect of diagnostic group suggests that at 9 months, neurotypical infants looked longer at both primate faces compared to infants later diagnosed with ASD infants ($b = 2395$, $SE = 1125$, $t(29) = 2.13$, $p = .04$).

Random effects of the model suggest that individual infants significantly varied in their linear change in looking time to either primate face over time, as adding the random linear effect of age ($-2LL = 6.10$, $p < .05$) significantly improved the fit of the model, but adding

the random quadratic effect of age did not ($-2LL = 5.79, p = .12$). To ensure that our model is generalizable, we report results of the maximal model that includes random effects of the intercept, linear, and quadratic effects of age (Barr, Levy, Scheepers, & Tily, 2013; see Table 2 for full model results).

Examining differences between risk groups—As in Experiment 1, the neurotypical group included both low- and high-risk infants. We ran the same quadratic growth curve model as above to examine whether neurotypical low- and high-risk infants differed in their time course of preferences for primate faces. Low-risk infants and human preference score were coded as -1 , high-risk infants and monkey preference score were coded as 1 . The linear and quadratic effects of age were centered at 9 months. Again, adding the quadratic effect of age significantly improved the fit of the model ($-2LL = 31.64, p < .001$), so we report results of the quadratic growth curve model. We found no significant main effects or interactions between risk group, face type, and the linear and quadratic effects of age (see Figure 5, Table 3 for means, and Table 4 for full model results).

General Discussion

Across two experiments, our results show that neurotypical infants and infants later diagnosed with ASD differ in their looking at primate faces between 6 and 18 months. At 6 months, neurotypical infants prefer human and monkey faces over non-faces to similar degrees, while infants later diagnosed with ASD only prefer human faces to non-faces and do not prefer monkey faces to non-faces until 9 months (Experiment 1). Furthermore, compared to neurotypical infants, infants later diagnosed with ASD show a greater downturn in their preference for both primate faces compared to non-faces (Experiment 1) and in their total looking time to both primate faces (Experiment 2) between 6 and 18 months. Though the neurotypical group included both low- and high-risk infants, we found no differences between the risk groups' preferences for primate faces over time. Together these findings suggest that a decline in attention to primate faces after the first year of life may underlie some of the social and communicative deficits characteristic of children with ASD.

Infants' broad bias for faces over non-faces at birth (Farroni et al., 2004; Johnson et al., 1991; Macchi Cassia et al., 2004; Simion et al., 2001) seems to be maintained in neurotypical infants during their first year of life, looking longer at both human and monkey faces over non-faces between 6 and 12 months. Maintaining a preference for primate faces in infancy may be a broad mechanism for processing the perceptual information in human faces and perceptually similar monkey faces. However, at 18 months, we find that neurotypical infants look equally at human faces and non-faces and only marginally more at monkey faces than non-faces. Older infants may seek information from novel stimuli like non-faces to better understand and explore their environment (Mather, 2013; Roder, Bushnell, & Sassequille, 2000).

Infants later diagnosed with ASD, like neurotypical infants, prefer human faces to non-faces at 6 months, but a preference for monkey faces to non-faces is not observed until 9 months. Infants later diagnosed with ASD initially look equally at human faces compared to their neurotypical peers (Jones & Klin, 2013; Ozonoff et al., 2010), but may be delayed in looking

at monkey faces, which may reflect atypical perceptual biases for attending to non-human primate faces in general. Though neurotypical infants have a broad perceptual bias for faces of both human and non-human primates, infants later diagnosed with ASD only appear to show a narrower bias for the faces of humans at 6 months.

Though neurotypical infants, both low- and high-risk, maintain a preference for primate faces over non-faces over their first year, infants later diagnosed with ASD show a downturn in their preference for both primate faces. This downturn to both primates suggests that the decline in preference for human faces that has been previously documented (Jones & Klin, 2013; Ozonoff et al., 2010) may not be specific to human faces but may be a broader decline in preference for primate faces in general and may signal atypical social-communicative development. This may suggest that in infants later diagnosed with ASD, diminished attention to faces may not reflect a lack of social motivation to attend to human faces, but rather a broader lack of perceptual attention to primate faces. Humans and rhesus monkeys share over 90% of their genetic sequence, leading to many similarities in morphology including perceptual similarities between human and rhesus faces (Pascalis, Petit, Kim, & Campbell, 1999). For example, the eyes, nose, and mouth are located on the same plane in both human and monkey faces, unlike duck faces for example, which have a very different mouth shape and whose eyes are on different planes on either side of their head. Thus, it is possible that infants later diagnosed with ASD look less at faces compared to neurotypical infants (Jones & Klin, 2013; Ozonoff et al., 2010) because they are indifferent towards faces and, unlike neurotypical infants, they lack the perceptual bias that would draw their attention to faces in their environment. A decline in looking at primate faces in general after the first year may underlie face processing and social-communicative difficulties later in life (Dawson, Webb, & McPartland, 2005).

Across two experiments, our findings reveal that infants later diagnosed with ASD not only differ in their preference for human faces but also differ in their preference for other primate faces such as rhesus monkey faces between 6 and 18 months. Our findings also reveal differences between neurotypical infants' and infants later diagnosed with ASD's preferences for primate faces as early as 6 months, which is a year and a half before the current age of a reliable ASD diagnosis (e.g., Guthrie et al., 2013) and could inform intervention strategies targeting infants' attention to both human and non-human primate faces. Understanding how infants' preferences for primate faces changes across development could reveal how early perceptual experiences with faces may impact later social and communicative development.

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Figure 1.

Images of primate faces and non-faces. Static gray scale images of A) primate faces (adult female humans and adult female rhesus monkeys) presented with their corresponding non-faces (Experiment 1) and B) images of human and monkey faces presented side-by-side (Experiment 2). Each non-face contains the same pixels as its corresponding primate face scrambled by a Fourier transformation. Primate faces are equated for contrast and luminance.

Figure 2.

Mean looking times to each primate face and non-face by diagnostic group. Mean looking times (horizontal lines) to the human face and human non-face (“Non-Human”), and the monkey face and monkey non-face (“Non-Monkey”) in Experiment 1 at 6, 9, 12, and 18 months for neurotypical infants and infants later diagnosed with ASD. Circles represent individual infants’ mean looking times to each primate face and non-face. Yellow shading indicates an interaction between looking times of neurotypical infants and infants later diagnosed with ASD. * $p < .05$; † $p < .10$.

Figure 3.

Change in mean face preference score and mean looking time by diagnostic group. Mean face preference score for human and monkey faces relative to their corresponding non-faces in Experiment 1 (top panel) $\pm$ SEM (ribbon) and mean looking time in Experiment 2 (bottom panel) $\pm$ SEM (ribbon) for the human face (solid line) and monkey face (dashed line) at 6, 9, 12, and 18 months for neurotypical infants (left panel) and infants later diagnosed with ASD (right panel).

Figure 4.

Quadratic model fits for face preference score and mean looking time by diagnostic group. Quadratic model fits (lines) and observed means (circles) $\pm$ SEM (vertical lines) of face preference score across face type relative to their corresponding non-faces in Experiment 1 (top panel) and mean looking time (circles) $\pm$ SEM (vertical lines) in Experiment 2 (bottom panel) across face type at 6, 9, 12, and 18 months for neurotypical infants (left panel) and infants later diagnosed with ASD (right panel).

Figure 5.

Change in mean face preference score and mean looking time by risk group. Mean face preference score for human and monkey faces relative to their corresponding non-faces in Experiment 1 (top panel) $\pm$ SEM (ribbon) and mean looking time in Experiment 2 (bottom panel) $\pm$ SEM (ribbon) for the human face (solid line) and monkey face (dashed line) at 6, 9, 12, and 18 months for neurotypical low-risk (left panel) and neurotypical high-risk infants (right panel).

Table 1.

Means and standard deviations for infants' looking times in milliseconds to each primate face and corresponding non-face, and preference score for each primate face in Experiment 1, and looking times in milliseconds to each primate face in Experiment 2 at each age for neurotypical infants and infants later diagnosed with ASD.

	Experiment 1											
	6 months				9 months				12 months			
	Neurotypical n = 14				Neurotypical n = 29				Neurotypical n = 32			
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Human	5447	1372	5302	1193	4652	1214	5418	908	4311	1332	4308	1479
Non-face human	1898	1110	2261	759	2821	2822	2851	1121	3126	1175	3262	1112
Human preference score	3549	1781	3041	1015	1830	1833	2567	1761	1186	2108	1046	2261
Monkey	5253	1470	3651	2002	4777	1103	4732	1270	4810	1478	5059	1098
Non-face monkey	2177	1026	4058	2318	3220	1228	3041	823	3416	864	3461	881
Monkey preference score	3076	1863	-434	4007	1556	2043	1691	1806	1393	1973	1597	1922
	Experiment 2											
	9 months				12 months				18 months			
	Neurotypical n = 15				Neurotypical n = 19				Neurotypical n = 20			
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Human	3577	1262	3060	1865	2792	956	4174	830	3099	1176	3725	1311
Monkey	3852	1104	3763	2142	3833	1371	4476	702	4304	1263	4165	1058

Table 2.

Fixed effects of quadratic growth curve model for the linear and quadratic effects of age, diagnostic group, face type, and their interactions on infants' preference score in Experiment 1 and infants' looking times in Experiment 2.

	Experiment 1 DV: Preference Score				Experiment 2 DV: Looking Time			
	<i>b</i>	<i>SE</i>	<i>p</i>	95% CIs	<i>b</i>	<i>SE</i>	<i>p</i>	95% CIs
Intercept	2271.57	279.03	.00	1721.61 2821.54	4363.09	1125.19	.00	2132.04 6594.14
Age	-131.99	261.92	.61	-648.23 384.24	300.65	476.83	.53	-644.82 1246.12
Age ²	-0.73	10.44	.94	-21.31 19.86	-10.03	16.63	.55	-43.00 22.95
Diagnostic group	152.09	279.03	.59	-406.87 711.05	2395.24	1125.19	.04	93.96 4696.52
Face type	-439.94	235.09	.06	-903.30 23.42	423.84	788.84	.59	-1140.30 1987.97
Diagnostic group:Face type	-299.72	235.09	.20	-763.08 163.64	-767.89	788.84	.33	-2332.02 796.24
Age:Diagnostic group	688.14	261.92	.01	171.90 1204.38	882.80	476.83	.07	-62.67 1828.28
Age ² :Diagnostic group	-27.63	10.44	.01	-48.22 -7.05	-31.53	16.63	.06	-64.50 1.45
Age:Face type	477.41	204.06	.02	75.20 879.61	79.34	301.65	.79	-518.78 677.45
Age ² :Face type	-15.60	8.12	.06	-31.61 0.41	-2.25	10.86	.84	-23.77 19.28
Age:Diagnostic group:Face type	348.82	204.06	.09	-53.38 751.03	-324.56	301.65	.28	-922.67 273.55
Age ² :Diagnostic group:Face type	-11.64	8.12	.15	-27.65 4.36	10.80	10.86	.32	-10.73 32.32

Note. Age and Age² were centered at 6 months for Experiment 1 and 9 months for Experiment 2. Diagnostic group was coded as -1 = neurotypical, 1 = ASD. Face type was coded as -1 = human, 1 = monkey. Significant and marginal effects are in bold.

Table 3.

Means and standard deviations for infants' looking times in milliseconds to each primate face and corresponding non-face, and preference score for each primate face in Experiment 1, and looking times in milliseconds to each primate face in Experiment 2 at each age for neurotypical low-risk and high-risk infants.

	Experiment 1											
	6 months				9 months				12 months			
	Low Risk n = 8		High Risk n = 6		Low Risk n = 20		High Risk n = 9		Low Risk n = 19		High Risk n = 13	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Human	5192	1407	5787	1371	4476	1066	5043	1488	4080	1261	4651	1409
Non-face human	1713	1207	2145	1016	2859	875	2739	1313	3150	1291	3091	1031
Human preference score	3479	1755	3642	1978	1617	1640	2304	2238	930	2156	1560	2062
Monkey	5223	1624	5295	1388	4943	1072	4407	1143	4398	1564	5412	1147
Non-face monkey	1849	1144	2616	710	2994	1173	3723	1264	3386	911	3461	825
Monkey preference score	3374	2096	2679	1594	1949	1935	684	2117	1012	1986	1951	1890
	Experiment 2											
	9 months				12 months				18 months			
	Low Risk n = 10		High Risk n = 5		Low Risk n = 11		High Risk n = 8		Low Risk n = 11		High Risk n = 9	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Human	3581	1429	3571	1020	2743	943	2859	1036	2841	604	3414	1622
Monkey	3637	1210	4284	794	3717	1163	3993	1689	4226	1361	4400	1207

Table 4

Fixed effects of quadratic growth curve model for the linear and quadratic effects of age, risk group, face type, and their interactions on infants' preference score in Experiment 1 and infants' looking times in Experiment 2.

	Experiment 1 DV: Preference Score				Experiment 2 DV: Looking Time					
	<i>b</i>	<i>SE</i>	<i>p</i>	95% CIs	<i>b</i>	<i>SE</i>	<i>p</i>	95% CIs		
Intercept	2129.11	291.87	.00	552.61	5.61	2071.14	1190.39	.09	300.76	43.05
Age	-781.40	251.03	.00	-1277.24	-285.56	-557.01	468.01	.24	-1489.54	375.53
Age ²	25.61	9.80	.01	6.26	44.96	20.50	16.59	.22	-12.56	53.55
Risk group	12.84	291.87	.97	-576.60	602.29	13.65	1190.39	.99	-2455.07	2482.36
Face type	-175.36	252.22	.49	-673.53	322.81	622.53	844.27	.46	-1059.71	2304.77
Risk group:Face type	-133.90	252.22	.60	-632.07	364.28	-105.53	844.27	.90	-1787.77	1576.71
Age:Risk group	270.60	251.03	.28	-225.24	766.44	-29.92	468.01	.95	-962.45	902.62
Age ² :Risk group	-9.28	9.80	.34	-28.63	10.07	1.38	16.59	.93	-31.68	34.43
Age:Face type	155.83	222.41	.48	-283.47	595.14	171.46	322.79	.60	-471.71	814.64
Age ² :Face type	-5.07	8.68	.56	-22.21	12.07	-4.76	11.67	.68	-28.01	18.49
Age:Risk group:Face type	196.16	222.41	.38	-243.15	635.46	-121.97	322.79	.71	-765.15	521.20
Age ² :Risk group:Face type	-7.84	8.68	.37	-24.98	9.29	3.43	11.67	.77	-19.82	26.67

Note. Age and Age² were centered at 6 months for Experiment 1 and 9 months for Experiment 2. Risk group was coded as -1 = neurotypical low-risk, 1 = neurotypical high-risk. Face type was coded as -1 = human, 1 = monkey. Significant effects are in bold.