Superior detection of faces in male infants at 2 months

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Abstract

Females generally attend more to social information than males; however, little is known about the early development of these sex differences. With eye tracking, we measured 2-month-olds' (*N*=101) social orienting to faces within 4-item image arrays. Infants, overall, were more likely to detect human faces compared to objects, suggesting a functional face detection system. Unexpectedly, males looked longer at human faces than females, and only males looked faster and longer at human faces compared to objects. Females, in contrast, looked less at human faces relative to animal faces and objects, appearing socially disinterested. Notably, this is the first report of a male face detection advantage at any age. These findings suggest a unique stage in early infant social development.

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Sex differences in social interest and sensitivity appear across multiple levels, including the brain, cognition, and behavior (Hines, 2011). Adult females are generally more socially attentive (Cárdenas, Harris, & Becker, 2013; Hall, Hutton, & Morgan, 2010), better at remembering faces (Rehnman & Helitz, 2007), and more empathetic than adult males (Christov-Moore et al., 2014). Compared to adult males, adult females are also faster, more accurate, and more automatic in their recognition of facial, vocal, and other nonverbal expressions (Kirkland, Peterson, Baker, Miller, & Pulos, 2013; McClure, 2000; Schirmer, Simpson, & Escoffier, 2007; Sokolov, Krüger, Enck, Krägeloh-Mann, & Pavlova, 2011).

Social competencies, like the ones listed above, are important from a young age. Such competencies are positively associated with children's interpersonal successes in both personal relationships and educational settings (Agostin & Bain, 1997; Connell & Prinz, 2002; Huitt & Dawson, 2011). Children with poor social skills often struggle with peer rejection, low levels of behavioral regulation, learning disabilities, and low achievement (Alexander, Entwisle, & Dauber, 1993; Kavale & Forness, 1996; McClelland, Morrison, & Holmes, 2000). These studies underscore the need to understand the genesis of individual differences in social abilities.

Many sex differences in sociability are present early in development. Within the first 3 days after birth, female neonates, compared to males, appear cuddlier (Benenson, Philippoussis, & Leeb, 1999), maintain eye contact longer (Hittelman & Dickes, 1979), and orient more to faces and voices (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000). In the first week after birth, female neonates also display more contagious crying, possibly an early marker of empathy (Sagi & Hoffman, 1976), and higher rates of neonatal imitation, a purported early social skill (Nagy, Kompagne, Orvos, & Pal, 2007). In later infancy, females continue to look longer at faces at 6 and 12 months of age (Gluckman & Johnson, 2013; Lutchmaya &

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Baron-Cohen, 2002), and maintain eye contact longer at 3 and 12 months (Leeb & Rejskind, 2004; Lutchmaya, Baron-Cohen, & Ragatt, 2002). Infants' early preferences for and engagement with social stimuli, such as faces, are theorized to be precursors for more complex social skills. For instance, looking at faces, eye contact, and imitation are proposed to lay the groundwork for the later development of joint attention, theory of mind, and more advanced communication (Charman et al., 2000).

Despite a large body of convergent evidence that reports a female advantage in social sensitivity in infancy (Simpson et al., 2016), a handful of studies report that, in some contexts, males exhibit greater social sensitivity than females. For example, a study of mother-infant interaction (i.e., face-to-face still-face paradigm) in 6-month-old infants reported that males, compared to females, displayed more positive expressions and vocalizations, spent more time in synchronous interactions, and looked longer towards their mothers; in contrast, females spent more time engaging with novel objects (Weinberg, Tronick, Cohn, & Olson, 1999). Another study reported that 6- to 8-month-old male infants looked longer at images of social groups than females, which suggests that males may be more attentive to social complexity (Benenson, Markovits, Muller, Challen, & Carder, 2007). In sum, these studies challenge the assumption that females consistently show advantages in social interest and sensitivity and highlight the need for further research on sex differences in early infancy, when social skills are swiftly emerging.

The first months after birth are a critical time in development. Infants at 2 months of age experience rapid developments in their visual attention (i.e., looking behaviors, typically defined by eye tracking measures or behaviorally coded live or from videos, based on where infants' eyes are oriented), including the onset of smooth pursuit tracking (i.e., continuously following an object without corrective saccades), attention towards internal features of patterns, and the ability

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to detect stimuli in the nasal visual field (Johnson, 1990). As infants' visual systems mature, their processing shifts from being primarily subcortical to more cortical (Morton & Johnson, 1991), accompanied by improvements in visual acuity and attentional control. In addition to developments in visual perception, at 2 months of age, faces are taking on new meaning, as social interactions are becoming more complex (Lavelli & Fogel, 2005). New social skills are forming, such as the emergence of social smiles (Wörmann, Holodynski, Kärtner, & Keller, 2012), growing sensitivity to social contingencies (Bigelow & Rochat, 2006; Soussignan, Nadel, Canet, & Gerardin, 2006), and increasing attention to the eye-region of faces (Jones & Klin, 2013). Already by 2 months of age, infants are faster to orient to and attend longer to silent dynamic social videos (e.g., people interacting), compared to nonsocial videos (e.g., high-contrast spinning shapes), potentially reflecting greater attention capture and holding for social, relative to nonsocial, stimuli (Maylott, Paukner, Ahn, & Simpson, 2020). At 2 months, infants also display improvements in facial identity recognition (Johnson, 1990), facial expression discrimination (Nelson, 1987), and face-voice cross-modal matching (Patterson & Werker, 2003). Additionally, 2-month-olds exhibit some adult-like face preferences (e.g., relying more on structural than contrast information; Kleiner & Banks, 1987), and display experience-driven face specialization (e.g., preferences for own-species' faces; Heron-Delaney, Wirth, & Pascalis, 2011; Simpson, Maylott, Mitsven, Zeng, & Jakobsen, 2020), as well as brain activation in core face perception regions, including the fusiform face area (Tzourio-Mazoyer et al., 2002). The wide-ranging physical, cognitive, and psychosocial advances at 2 months underscore the importance of studying this period of development.

Despite these remarkable perceptual and social changes at 2 months, infants' attention to social stimuli at this age is relatively unexplored (Shultz, Klin, & Jones, 2018). To our

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knowledge, few studies have examined 2-month-olds' social attention to faces (for a review of studies to date, see Table 1). The capacity to orient to a face in a complex visual environment is a critical early social skill, enabling infants to learn from socially relevant information in their environment (Capozzi & Ristic, 2018). With recent innovations, researchers can accurately track young infants' eye gaze with remote infrared eye tracking, allowing for more spatial and temporal precision than other methods (Oakes, 2012). Notably, 2 months is the earliest age, to date, in which modern eye tracking has been used (Jones & Klin, 2013; Sifre et al., 2018); thus, we are only beginning to understand infants' early visual abilities. Additionally, previous studies typically present only one or two images at a time, which may not approximate real-world demands on attention (Di Giorgio, et al., 2013; Gliga, Elsabbagh, Andravizou, & Johnson, 2009; Gluckman & Johnson, 2013; Jakobsen, et al., 2016). However, with modern eye tracking, it is now possible to present a greater number of stimuli at once, which enables researchers to examine how infants allocate their attention when confronted with numerous items. Therefore, contemporary eye tracking widens opportunities to further detect the nuances of infants' early skills. Detailing infants' looking behavior in these ways will provide a baseline of healthy social attention from which divergent trajectories may be identified (Telford et al., 2016), particularly in the first 2-3 months after birth, a period of rapid and significant neurodevelopment (Bradshaw et al., 2019).

Thus, we examined whether male and female 2-month-old infants demonstrate visual biases—privileged capture and holding of eye gaze—to human faces. In a free-viewing eye tracking task, infants observed a series of 4-item visual arrays (Figure 1), including our target of interest, human faces, and control images of non-face objects and chimpanzee faces. We predicted that 2-month-old infants would display overall attentional efficiency to human faces—

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faster orienting to and longer looking at human faces than non-face objects—and that these abilities would be modulated by infant sex (Gluckman & Johnson, 2013). Given that few studies have examined sex differences in social attention during the first year after birth, and no previous well-powered studies have examined sex differences in social attention at this age (2 months), we based our hypothesis on studies in older infants. Therefore, we predicted that females would be more socially attentive than males. In addition, although there's limited evidence of own-species bias (i.e., privileged processing of conspecifics relative to heterospecifics) before 6 months of age (Jakobsen et al., 2016; Scott & Fava, 2013), we hypothesized that a subtle own-species bias might be detectable using eye tracking, given its greater accuracy than manual coding (Gredebäck, Johnson, & von Hofsten, 2009; Oakes, 2012). We, therefore, predicted infants' greater attentional efficiency to human faces relative to chimpanzee faces.

Methods

The Institutional Review Board for Human Subject Research [Blinded for review] approved this study.

Participants

We recruited families with 2-month-old infants (N = 101; 44 females) from [Blinded for review] through community events (e.g., baby fairs, maternity centers) and advertisements (e.g., Facebook, flyers in public libraries). One or both parents spoke English. Families were invited to participate when their infant was 2 months (51-69 days) of age (M = 61.13 days, SD = 6.40 days). Infants were healthy, full-term (≥37 weeks of gestation, with the exception of two sets of twins, who were given a more lenient gestation of >35 weeks because twins are often born sooner than singletons), and had normal vision (see Supplementary Methods for detailed

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participant demographics). Data from a subsample of these infants (n = 55) were previously published as part of a larger longitudinal study, examining the influence of head and eye orientations on infants' face detection (Simpson, Maylott, Mitsven, Zeng, & Jakobsen, 2020). The additional infants in our current sample enabled us to move beyond group level effects to focus on individual differences in infancy, an underexplored area (Pérez-Edgar, Vallorani, Buss, & LoBue, 2020).

Materials

Infants viewed a series of 16 circular arrays, each with 4 images (see examples in Figure 1), in one of two semi-random orders, on a remote 58.4 cm monitor (51 cm in width by 28 cm in height) with integrated dark pupil eye tracking technology and a sampling rate of 300 Hz. We remotely tracked infants' eye gaze via corneal reflection using a Tobii TX300 eye tracker. Each array contained either a human face (n = 8 arrays) or a chimpanzee face (n = 8 arrays), and all arrays included three non-face objects.

Faces were upright with neutral expressions and visible, open eyes, as well as visible noses and mouths. Faces included males and females and were of various ages (e.g., young and old adults) and ancestries. The faces systematically varied in their attentional states, with half of the faces (8 arrays) oriented with direct-gaze (i.e., eye-contact) and half (8 arrays) with averted gaze (i.e., eyes/head oriented away at approximately 45°) to examine infants' attention to specific head and eye orientations (Simpson et al., 2020). While the inclusion of faces with averted gaze likely made the task more challenging, given infants' early preferences for eye-contact (Gliga & Csibra, 2007; Guellaï et al., 2020), it also made the faces more naturalistic, as infants often encounter people in their everyday lives who are not looking at them. We balanced these orientations across chimpanzee and human faces, such that half of each species oriented

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150 towards and half oriented away. Faces had little makeup or accessories. We counter-balanced
151 face locations across conditions (species, orientation), to ensure each face type was equally likely
152 to appear in all locations. The non-face images were common manufactured objects (i.e., chairs,
153 cars) and natural items (i.e., flowers).

154 Each colored image was 180 × 180 pixels (4.76 × 4.76 cm; 6.48 × 6.48°) and was equally
155 spaced in circular arrays, equidistant from the center. We collected images through internet
156 searches and positioned them into arrays using GNU Image Manipulation Program (GIMP;
157 https://www.gimp.org/) and Microsoft PowerPoint. To ensure novelty, each image appeared only
158 once. For all arrays, we chose heterogeneous images, instead of matching images on low-level
159 features, to retain the natural details of each stimulus (e.g., keeping images in color instead of
160 converting to grayscale; Hershler & Hochstein, 2005; Jakobsen et al., 2016). Additionally, we
161 used the Saliency Toolbox to analyze the arrays for differences in low-level salience—low-level
162 features, such as contrast or brightness—that may cause an image to stand out from the rest
163 (Gluckman & Johnson, 2013; Ho-Phuoc, Guyader, & Guérin-Dugué, 2010). This analysis
164 revealed that the non-face objects, not the faces, were the most salient images within each array,
165 for both human arrays ($t(15) = 5.61$, $p < .001$, $d = 2.12$) and chimpanzee arrays ($t(15) = 6.76$, $p <$
166 .001, $d = 2.75$). There were also no differences in low-level salience between the human and
167 chimpanzee faces, ($t(15) = .212$, $p = .835$). A binomial test indicated that the proportion of trials
168 in which the faces were the most salient images within the arrays (.03) was lower than the
169 expected proportion of observing a face (.25, since ¼ of images were faces; $p = .001$), indicating
170 that faces were the most salient images within the arrays significantly less often than chance.
171 Together, these finding suggest that any human face detection efficiency found with these stimuli
172 is unlikely to be due to low-level features of the images. However, we should interpret these

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findings cautiously given that the Saliency Toolbox is based on adult, and not infant, vision and low-level features may be particularly salient for young infants, especially newborns (Simion et al. 2007).

Procedure

We obtained caregivers' informed consent for infants' participation. We followed infant eye tracking best practices (Hessels, Andersson, Hooge, Nyström, & Kemner, 2015; Wass, Forssman, & Leppänen, 2014). Lighting was kept constant across infants, with overhead lights turned on, and all people (i.e., experimenters or additional family members) in the room were quiet and hidden from infants' view. We instructed caregivers not to speak or point to the screen during testing, and all test sessions were videotaped with two Sony HDR-PJ540 Full HD Handycam Camcorders to ensure these instructions were followed.

Testing took place when the infants were awake, alert, and calm. Infants who were sleepy or fussy were given a break to nap, feed, or be changed as needed. Infants sat on their caregiver's lap approximately 60 cm from the screen on which we presented the arrays (Figure 2A).

Before displaying the arrays, we calibrated each infant using five or more calibration points in Tobii Studio's preset locations. There were no sex differences in calibrations (for more information, see Supplementary Methods and Supplementary Results). After the calibration, a central cartoon (from Tobii Studio's standard set; e.g., bird, cat, school bus) and music attracted the infant's attention to the center of the screen for about 3 to 5 seconds before each array. Because we were interested in infants' initial looking behaviors, each array was displayed for only 10 seconds. Also, because of our interest in which images selectively captured infants' gaze compared to other images in the array, we chose this length of time to ensure that infants had enough time to look at some, but not all the images. In this passive-viewing task, infants were

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free to look anywhere on or off the screen while the arrays were displayed. Infants viewed up to 16 arrays in each test session. We considered a trial complete if an infant produced at least one fixation on one of the images in the array. A fixation was defined as occurring within a window of 35 pixels for at least 100 ms; the end of a fixation was marked by a saccade (either within the same AOI, to a different AOI, offscreen, or lost data). All fixations within each image were counted towards the total look duration measure. Beyond this requirement, there was no minimum fixation duration. An additional five infants were excluded from the sample due to no fixations (n = 3; 1 female), fussiness (n = 1; female), or inability to track gaze (n = 1; male). Infants completed an average of 12.38 trials (SD = 3.67, range 3-16).

In total, each test session lasted just under 4 minutes (without breaks, including calibration). Parents completed demographic questionnaires, including information on infants' date of birth, gestational age, and sex, as well as parents' education level, family income, and ethnicity. Families were compensated $50.

Measures

We measured three independent but related types of looking behavior (Cohen, 1972): (1) *Look latency* (eye gaze capture): the time from the start of the trial until the infants' first fixation on each image, theorized to reflect attention capture (Kosinski, 2008), (2) *Look duration* (eye gaze holding): the total time fixating on a stimulus, theorized to reflect both attention capture and holding (Bronson, 1991; Simpson et al., 2014a; 2014b), and (3) *Detection*: proportion of trials with at least one fixation on a stimulus, theorized to reflect attentional efficiency (Jakobsen et al., 2016). We created areas of interest (AOIs) around each individual picture (faces and objects) and extracted our measures from these regions (Figure 2B). The AOIs were 220 × 220 pixels (5.82 × 5.82 cm; 7.80 × 7.80°), drawn slightly larger than the image to account for measurement error,

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based on a previous study of Tobii TX300 accuracy ([Blinded for review]; for method, see Morgante et al., 2012). Our measures were extracted using Tobii Studio software (Tobii Technology, Sweden) with the Tobii (default) filter, which defines fixations as occurring within a window of 35 pixels for at least 100 ms. For look duration, if the infants looked at the array but not at a specific image, they were assigned a zero for look duration to that specific image; however, if there were no fixations on the array at all, we treated that trial as missing data. For look latency, an infant had to produce a fixation to the AOI, otherwise it was treated as missing data. Within each array, we computed an average for the non-face objects, as each array contained three objects.

Preliminary Analyses

Preliminary analyses revealed no sex differences in data quality, calibration, overall infant attentiveness, or infant/parent demographic variables (see Supplementary Materials). There were no statistically significant interaction effects between infant sex and eye/head orientations (direct vs. averted gaze) across the three dependent variables (*ps* > .05; for full results see Supplementary Results).

Analysis

We conducted two 2 × 2 mixed-design analyses of variance (ANOVAs) for each dependent variable—look latency, look duration, and detection—for six total ANOVAS. Each ANOVA included the between-subjects variable of infant sex (male, female). The first set of ANOVAs explored the repeated measures variable of image type (human faces, non-face objects) and the second set of ANOVAs explored the repeated measures variable of species (humans, chimpanzees). We used non-face objects from the chimpanzee arrays as the control objects when comparing objects to human faces, as to not violate the assumption of

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independence in the ANOVA (see Primary Data Analysis section in Supplementary Material for more information). We conducted *t*-tests to explore statistically significant interactions.

Data Availability

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Results

Look Latency

We measured how quickly infants looked at each type of image. We found no main effects of stimulus type (human face, non-face object; $F(1, 92) = .03$, $p = .859$) or infant sex ($F(1, 92) = .61$, $p = .633$). However, there was a stimulus type × infant sex interaction (Figure 3A; $F(1, 92) = 9.59$, $p = .003$, $\eta_p^2 = .09$). While female infants looked faster at non-face objects ($M = 2.85$ sec, $SD = 1.25$) than human faces ($M = 3.40$ sec, $SD = 1.95$; $t(40) = 2.03$, $p = .049$, $d = .45$), male infants looked faster at human faces ($M = 2.92$ sec, $SD = 1.68$) than non-face objects ($M = 3.58$ sec, $SD = 1.51$; $t(52) = 1.97$, $p = .022$, $d = .42$). We detected no difference in male and female look latency within human faces ($t(93) = 1.30$, $p = .196$); however, we did find that females were faster to look at non-face objects than males ($t(97) = 2.58$, $p = .011$, $d = .53$). There were no other statistically significant effects, $ps > .10$. See Supplementary Table 2 for details.

We found no main effect of species (human face, chimpanzee face; $ps > .05$) nor did we detect a species × infant sex interaction ($ps > .05$; Supplementary Table 1).

Look Duration

We measured how long infants looked at each type of image. We found no main effects of stimulus type (human face, non-face object; $F(1, 93) = .19$, $p = .664$) or infant sex ($F(1, 93) =$

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3.14, $p = .080$); however, there was a stimulus type × infant sex interaction (Figure 3B; $F(1,93) = 16.26$, $p < .001$, $\eta_p^2 = .15$). Male infants looked longer at human faces ($M = 1.05$ sec, $SD = .88$) than female infants ($M = .56$ sec, $SD = .51$; $t(95) = 3.19$, $p = .002$, $d = .68$). Further, male infants looked longer at human faces than non-face objects ($M = .73$ sec, $SD = .49$; $t(53) = 3.08$, $p = .003$, $d = .41$). In contrast, female infants looked longer at non-face objects ($M = .86$ sec, $SD = .65$) than human faces ($t(40) = 2.83$, $p = .007$, $d = .40$). There were no other statistically significant differences (see Supplementary Table 2 for details).

While we found no main effect of species (human face, chimpanzee face; $ps > .05$; Supplementary Table 1), there was a species × infant sex interaction ($F(1, 93) = 7.32$, $p = .008$, $\eta_p^2 = .07$). Although female infants looked longer at chimpanzee faces ($M = .91$ sec, $SD = .78$) than human faces ($M = .56$ sec, $SD = .51$; $t(39) = 2.86$, $p = .007$, $d = .52$), we detected no difference in look durations between chimpanzee faces and non-face objects ($t(42) = .39$, $p = .700$), meaning that female infants looked the most at chimpanzee faces and non-face objects and looked the least at human faces (Supplementary Figure 2). Male infants showed no difference in look duration across species ($ps > .05$; Supplementary Table 2); however, male infants looked longer at chimpanzee faces than non-face objects ($t(55) = 2.39$, $p = .020$, $d = .32$), suggesting that faces in general may hold male infants' gaze longer than objects.

Detection

We measured how likely infants were to look at each type of image. We found a main effect of stimulus type, in which infants, overall, were more likely to detect human faces than non-face objects (Supplementary Figure 1; $F(1, 99) = 6.83$, $p = .010$, $\eta_p^2 = .07$). We detected no main effect of infant sex ($F(1, 99) = .08$, $p = .782$) nor did we detect any stimulus type × infant sex interaction ($F(1, 99) = .04$, $p = .840$). For additional results, see Supplementary Table 2.

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Additionally, we found no main effect of species (human face, chimpanzee face; *ps* > .05) nor did we detect a species × infant sex interaction (*ps* > .05; Supplementary Table 1).

Discussion

Attending to social partners in infancy is a foundational early capacity that enables healthy social development (Capozzi & Ristic, 2018; Sclafani et al., 2016). However, social attention in the first months after birth, beyond the newborn period, has been largely unexplored. We addressed this gap by using eye tracking to measure whether 2-month-old infants rapidly detect and look longer at human faces compared to non-face objects and animal faces, when presented in four-item visual arrays. We found that infants, overall, were more likely to detect human faces compared to objects, suggesting a remarkably early functional face detection system. We also found a male advantage in face attention capture and holding at this age. The first months after birth may reflect a unique stage of early infant social development.

Contrary to previous reports of female advantages in social attention from birth to one year of age (Gluckman & Johnson, 2013; Leeb & Rejskind, 2004; Lutchmaya & Baron-Cohen, 2002; Lutchmaya, Baron-Cohen, & Raggatt, 2002), we found that male infants, but not female infants, looked faster and longer at human faces compared to non-face objects. Male infants also looked longer than female infants at human faces. Interestingly, female infants, unlike male infants, spent the *least* amount of time looking at human faces, attending more to chimpanzee faces and objects. For 2-month-old female infants, human faces did not appear to have the same attention holding qualities that they had for male infants. Further, these findings suggest that, not only do male infants attend more to human faces relative to other images, but female infants attend *less* to human faces relative to other images. Whether females are avoiding human faces

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or are simply *less* socially interested remains to be determined. Indeed, on the surface, social shyness can be difficult to disentangle from social disinterest (Coplan et al., 2004) or heightened nonsocial interest (Gale et al, 2019); yet, these distinct motivational differences need to be distinguished to improve social engagement (Koegel et al., 2014).

The present study is the first, to our knowledge, to document a male advantage in social attention at 2 months of age. In addition, we observed these sex differences in both attention capture—reflected by faster look latencies—and attention holding—reflected by longer look durations—suggesting male infants, at 2 months, have specialized processing of human faces across multiple interrelated attentional systems (Cohen, 1972). Our findings highlight the importance of studying social attention in the second month after birth—a period of rapid perceptual, cognitive, and social development (Bradshaw et al., 2019; Johnson, 1990; Lavelli & Fogel, 2005; Tzourio-Mazoyer et al., 2002)—and emphasize the significance of considering individual differences in infant attentional patterns to multi-image stimuli, even at this very young age (Maylott et al., 2020; Simpson et al., 2020; Wass & Smith, 2014).

Because our findings diverged from the more commonly reported female advantages in social attention, we examined a number of other factors that could potentially explain our findings (e.g., gestational age, birth weight; data quality, overall attentiveness); however, we found no sex differences in any other factors (see supplementary materials, including Supplementary Table 3). In sum, it seems unlikely that these factors can account for our findings. While caution is warranted given the quasi-experimental nature of the study, we nonetheless think our findings may reflect a true sex difference at 2 months of age.

One interpretation of our findings is that males may exhibit the same patterns in social attention that females display, but may do so later than females (Barbu, Cabanes, & Le Maner-

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Idrissi, 2011). In other words, the male advantage we found may reflect a deferred social preference. A similar finding has been reported in older children: Females engage in associative play (3-4 years), cooperative play (4-5 years), and social interactions with peers (5-6 years) systematically earlier than males of the same age; as females move on to develop other complex social skills, males display more associative play (4-5 years) and cooperative play (5-6 years) than females of the same age (Barbu et al., 2011). In our study, females may no longer display a strong social preference at 2 months as they did when they were newborns (Connellan et al., 2000) because they have already moved on to develop other advanced social abilities (e.g., attending more to dynamic or socially responsive faces). This pattern of development is also seen in emotion regulation, with female infants, from 3 to 4 month of age, and male infants at 6 months of age, displaying the same emotion regulation strategy, demonstrating more distress and negative emotions during a still face interaction with their caregiver (Mayes & Carter, 1990; Weinberg et al., 1999); while female infants at 6 months of age begin employing social avoidance (e.g., looking away from their caregiver) to regulate their emotions (Weinberg et al., 1999).

However, there are alternative or additional interpretations as well. For instance, during the initial months after birth, infants' social attention is theorized to be driven primarily by subcortical mechanisms that are automatic, rather than consciously controlled (Johnson, Dziurawiec, Ellis, & Morton, 1991; Johnson, Senju, & Tomalski, 2015; Morton & Johnson, 1991; Salley & Colombo, 2016). After the first months of life, infants' social attention shifts, becoming more cortically-based, and reflecting more endogenous social orienting. Johnson et al. (1991) theorized that, during this maturation from subcortical to cortical functioning, the pre-established, subcortical, automatic social attention may be disrupted, inhibiting automatic

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preferential social attention during this time, with social attention remaining lessened until attention to faces via more cortically controlled processes are strengthened. Our results may reflect this temporary disruption of social attention in female infants due to an earlier shift to more cortically-based attention, while male infants' attention may be less mature, still reflecting automatic, exogenous orienting to faces at 2 months.

Another potential interpretation of our findings is that males are more socially attentive than females at this age, not due to a trailing social or attentional trajectory, but because they have differential early experiences. Male infants' heightened social attention at 2 months may be, at least in part, due to differential interactions with caregivers (Fausto-Sterling, Coll, & Lamarre, 2012). For instance, caregivers attend to male neonates more than females at 3-weeks of age. Males receive more parental physical contact, stimulation, and gaze, while females receive comparably less attention (Moss, 1967). However, for male infants, this high rate of caregiver attention seems to decline with age. By 3 to 6 months of age, female infants are more often looked at, imitated, and spoken to by their caregiver than male infants (Lewis, 1972; Moss, 1967). By 2 months of age, male infants are receiving less parental attention than what they were accustomed to, and as a result, may be more attuned to disruptions in social contact. For example, in a mother-infant interaction paradigm (i.e., face-to-face still-face) at 6 months of age, males spent proportionately more time engaging with their mothers, and were more distressed when mothers stopped responding, often producing more intense negative responses and attempts to reengage their mothers in the social interaction (Weinberg et al., 1999). Furthermore, male infants' eye gaze towards social, relative to nonsocial, toys (e.g., dolls vs. cars) declines with age between 6 and 20 months, modulated by parental attitudes about gender norms (Liu, Escudero, Quattropani, & Robbins, 2020). Together, the current study and previous findings

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expose the developmental complexity of sex differences. An overarching female advantage may be an oversimplified view of early infant social development.

Considering disorders with disruptions in social development, such as autism spectrum disorder (ASD), which is four times more common in males than females (Constantino, 2017; Baron-Cohen et al., 2011; Jones & Klin, 2013), it is important to carefully document the different trajectories of males and females in infancy. While our findings of stronger social attention in males compared to females could signify a dysfunction or unhealthy pattern of attention in males, it may be adaptive for infants to develop different phenotypes that best suit their environments (Dufty et al., 2002). Drawing parallels between social disorders and the present findings, therefore, should be done with this limitation in mind.

The present study is limited by our testing of only one age group. Ideally, a longitudinal design would track infants' social attention from birth through the first year of life or beyond, to determine whether male infants are delayed in their social trajectories relative to females, or to see if these sex differences are stable with age. Unfortunately, eye tracking technology has not been successfully used, to our knowledge, in human infants younger than 2 months of age. Therefore, studies that precisely track newborns' attention to multiple concurrently presented stimuli remain difficult without further technological advancements. Nonetheless, researchers could follow infants beyond 2 months, to determine the developmental epochs in which male or female infants increase or decrease in social attentiveness. Additionally, we were limited in our analytic approach, and could not compare gaze behavior to images within each array without violating the assumption of independence. It should be noted that looking behavior to each item may vary based on the competing stimuli, as reported in adults (Simpson et al., 2014a; 2014b). Further, our stimuli, while including multiple images, were not dynamic or multimodal, which

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403 are qualities that also increase social attention (Kittler et al., 2020; Maylott et al., 2020). Our
404 stimuli were, therefore, less engaging. Social attentiveness in more varied, real-world contexts
405 will, therefore, be another important future direction.

406 Despite these limitations, this study makes novel contributions to the field of
407 developmental science. First and foremost, this is the first study to find greater attentiveness to
408 faces in males, challenging the widely-held view that females are more attentive to faces. It is
409 also one of only a few studies to use eye tracking in 2-month-old infants to measure attention to
410 multi-image visual stimuli (i.e., presenting more than two items at a time). The increased spatial
411 and temporal precision afforded by remote eye tracking offers a powerful way to unobtrusively
412 monitor early infant attention. This approach enabled us to find that, already by this early age,
413 infants, overall, show greater detection of human faces relative to objects. Our findings suggest
414 that, while infants overall may show an impressive early functional face detection system, male
415 infants appear to specialize in processing human faces. These findings might at first seem
416 surprising, and in contrast to findings at other ages; however, there are few other studies of face
417 detection at this age. More developmental studies during this important transitional age are
418 needed. Prospective research should utilize high-powered, longitudinal designs to better
419 understand the complex influences of sex and early experiences on individual differences in
420 social interest over the course of development.

421 As we look to the future, the goal of examining sex differences in social attention is not
422 simply to determine the causes of such differences, but to understand the malleability of these
423 capacities and the extent to which we can improve social competencies (Hines, 2020; Moore,
424 2012). Individual differences in infants' social interest have wide-ranging developmental
425 consequences, impacting not only social communication (Morales et al., 2000), but also

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opportunities for learning (Charman et al., 2000; De Klerk, Gliga, Charman, Johnson, & BASIS team, 2014). Early developmental plasticity may enable interventions to improve infants' social attention, with downstream consequences for later social skills (Kasari, Freeman, Paparella, 2006; Minar & Lewkowicz, 2018). Ultimately, as modern societies evolve to become more gender equitable, children's early experiences may help reduce any inborn differences in social development, allowing all children to reach their full potential.

For Review Only

References

Agostin, T. M., & Bain, S. K. (1997). Predicting early school success with developmental and social skills screeners. *Psychology in the Schools*, *34*(3), 219-228.

Alexander, K. L., Entwisle, D. R., & Dauber, S. L. (1993). First-grade classroom behavior: Its short-and long-term consequences for school performance. *Child Development*, *64*(3), 801-814.

Barbu, S., Cabanes, G., & Le Maner-Idrissi, G. (2011). Boys and girls on the playground: sex differences in social development are not stable across early childhood. *PloS ONE*, *6*(1), e16407.

Baron-Cohen, S., Lombardo, M. V., Auyeung, B., Ashwin, E., Chakrabarti, B., & Knickmeyer, R. (2011). Why are autism spectrum conditions more prevalent in males?. *PLoS biology*, *9*(6), e1001081.

Benenson, J. F., Markovits, H., Muller, I., Challen, A., & Carder, H. P. (2007). Explaining sex differences in infants' preferences for groups. I*nfant Behavior and Development*, *30*(4), 587-595.

Benenson, J. F., Philippoussis, M., & Leeb, R. (1999). Sex differences in neonates' cuddliness. *The Journal of Genetic Psychology*, *160*(3), 332-342.

Bigelow, A. E., & Rochat, P. (2006). Two-month-old infants' sensitivity to social contingency in mother–infant and stranger–infant interaction. *Infancy*, *9*(3), 313-325.

Bradshaw, J., Klin, A., Evans, L., Klaiman, C., Saulnier, C., & McCracken, C. (2019). Development of attention from birth to 5 months in infants at risk for autism spectrum disorder. *Development and Psychopathology*, 1-11.

For Review Only

Bronson, G. W. (1991). Infant differences in rate of visual encoding. *Child Development, 62*(1), 44-54.

Capozzi, F., & Ristic, J. (2018). How attention gates social interactions. *Annals of the New York Academy of Sciences*. Advance Online Publication. doi:

Cárdenas, R. A., Harris, L. J., & Becker, M. W. (2013). Sex differences in visual attention toward infant faces. *Evolution and Human Behavior*, *34*(4), 280-287.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation, and play as infancy precursors to language and theory of mind. *Cognitive Development*, *15*(4), 481-498.

Christov-Moore, L., Simpson, E. A., Coudé, G., Grigaityte, K., Iacoboni, M., & Ferrari, P. F. (2014). Empathy: Gender effects in brain and behavior. *Neuroscience & Biobehavioral Reviews*, *46*, 604-627.

Cohen, L. B. (1972). Attention-getting and attention-holding processes of infant visual preferences. *Child Development*, *43*(3), 869-879.

Connell, C. M., & Prinz, R. J. (2002). The impact of childcare and parent–child interactions on school readiness and social skills development for low-income African American children. *Journal of School Psychology*, *40*(2), 177-193.

Connellan, J., Baron-Cohen, S., Wheelwright, S., Batki, A., & Ahluwalia, J. (2000). Sex differences in human neonatal social perception. *Infant Behavior and Development*, *23*(1), 113-118.

Constantino, J. N. (2017). Taking stock of critical clues to understanding sex differences in the prevalence and recurrence of autism. *Autism*, *21*(6), 769-771.

For Review Only

Coplan, R. J., Prakash, K., O'Neil, K., & Armer, M. (2004). Do you" want" to play? Distinguishing between conflicted shyness and social disinterest in early childhood. *Developmental Psychology*, *40*(2), 244-258.

de Klerk, C. C., Gliga, T., Charman, T., Johnson, M. H., & BASIS team. (2014). Face engagement during infancy predicts later face recognition ability in younger siblings of children with autism. *Developmental Science*, *17*(4), 596-611.

Di Giorgio, E., Meary, D., Pascalis, O., & Simion, F. (2013). The face perception system becomes species-specific at 3 months: An eye-tracking study. *International Journal of Behavioral Development*, *37*(2), 95-99.

Dufty Jr, A. M., Clobert, J., & Møller, A. P. (2002). Hormones, developmental plasticity and adaptation. *Trends in Ecology & Evolution*, *17*(4), 190-196.

Fausto-Sterling, A., Coll, C. G., & Lamarre, M. (2012). Sexing the baby: Part 1–What do we really know about sex differentiation in the first three years of life? *Social Science & Medicine*, *74*(11), 1684-1692.

Gale, C. M., Eikeseth, S., & Klintwall, L. (2019). Children with autism show atypical preference for non-social stimuli. *Scientific Reports*, *9*(1), 1-10.

Gliga, T., & Csibra, G. (2007). Seeing the face through the eyes: a developmental perspective on face expertise. *Progress in Brain Research*, *164*, 323-339.

Gliga, T., Elsabbagh, M., Andravizou, A., & Johnson, M. (2009). Faces attract infants' attention in complex displays. *Infancy*, *14*(5), 550-562.

Gluckman, M., & Johnson, S. P. (2013). Attentional capture by social stimuli in young infants. *Frontiers in Psychology, 4*, 527.

For Review Only

Gredebäck, G., Johnson, S., & von Hofsten, C. (2009). Eye tracking in infancy research. *Developmental Neuropsychology*, *35*(1), 1-19.

Guellaï, B., Hausberger, M., Chopin, A., & Streri, A. (2020). Premises of social cognition: Newborns are sensitive to a direct versus a faraway gaze. *Scientific Reports*, *10*, 9796.

Hall, J. K., Hutton, S. B., & Morgan, M. J. (2010). Sex differences in scanning faces: Does attention to the eyes explain female superiority in facial expression recognition? *Cognition & Emotion*, *24*(4), 629-637.

Heron-Delaney, M., Wirth, S., & Pascalis, O. (2011). Infants' knowledge of their own species. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *366*(1571), 1753-1763.

Hershler, O., & Hochstein, S. (2005). At first sight: A high-level pop out effect for faces. *Vision Research, 45*(13), 1707-1724.

Hessels, R. S., Andersson, R., Hooge, I. T., Nyström, M., & Kemner, C. (2015). Consequences of eye color, positioning, and head movement for eye-tracking data quality in infant research. *Infancy*, *20*(6), 601-633.

Hines, M. (2011). Gender development and the human brain. *Annual Review of Neuroscience*, *34*, 69-88.

Hines, M. (2020). Neuroscience and Sex/Gender: Looking Back and Forward. *Journal of Neuroscience*, *40*(1), 37-43.

Hittelman, J. H., & Dickes, R. (1979). Sex differences in neonatal eye contact time. *Merrill-Palmer Quarterly of Behavior and Development*, *25*(3), 171-184.

For Review Only

519 Ho-Phuoc, T., Guyader, N., & Guérin-Dugué, A. (2010). A functional and statistical bottom-up
520 saliency model to reveal the relative contributions of low-level visual guiding factors.
521 *Cognitive Computation, 2*(4), 344-359.
522 Huitt, W., & Dawson, C. (2011). Social development: Why it is important and how to impact
523 it. *Educational Psychology Interactive*, 1-27.
524 Jakobsen, K. V., Umstead, L., & Simpson, E. A. (2016). Efficient human face detection in
525 infancy. *Developmental Psychobiology, 58*(1), 129-136.
526 Johnson, M. H. (1990). Cortical maturation and the development of visual attention in early
527 infancy. *Journal of Cognitive Neuroscience*, *2*(2), 81-95.
528 Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking
529 of face-like stimuli and its subsequent decline. *Cognition*, *40*(1-2), 1-19.
530 Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two-process theory of face processing:
531 modifications based on two decades of data from infants and adults. *Neuroscience &*
532 *Biobehavioral Reviews*, *50*, 169-179.
533 Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2–6-month-old infants
534 later diagnosed with autism. *Nature*, *504*(7480), 427-431.
535 Kasari, C., Freeman, S., & Paparella, T. (2006). Joint attention and symbolic play in young
536 children with autism: A randomized controlled intervention study. *Journal of Child*
537 *Psychology and Psychiatry*, *47*(6), 611-620.
538 Kavale, K. A., & Forness, S. R. (1996). Social skill deficits and learning disabilities: A meta-
539 analysis. *Journal of Learning Disabilities*, *29*(3), 226-237.

For Review Only

Kirkland, R. A., Peterson, E., Baker, C. A., Miller, S., & Pulos, S. (2013). Meta-analysis Reveals Adult Female Superiority in" Reading the Mind in the Eyes Test". *North American Journal of Psychology*, *15*(1), 121-146.

Kittler, P. M., Kim, S. Y., Flory, M. J., Phan, H. T. T., Karmel, B. Z., & Gardner, J. M. (2020). Effects of motion and audio-visual redundancy on upright and inverted face and feature preferences in 4-13-month old pre-and full-term NICU graduates. *Infant Behavior and Development*, *60*, 101439.

Kleiner, K. A., & Banks, M. S. (1987). Stimulus energy does not account for 2-month-olds' face preferences. *Journal Of Experimental Psychology: Human Perception And Performance*, *13*(4), 594-600.

Koegel, L. K., Singh, A. K., Koegel, R. L., Hollingsworth, J. R., & Bradshaw, J. (2014). Assessing and improving early social engagement in infants. *Journal of Positive Behavior Interventions*, *16*(2), 69-80.

Kosinski, R. J. (2008). A literature review on reaction time. *Clemson University, 10*.

Lavelli, M., & Fogel, A. (2005). Developmental changes in the relationship between the infant's attention and emotion during early face-to-face communication: the 2-month transition. *Developmental Psychology*, *41*(1), 265-280.

Leeb, R. T., & Rejskind, F. G. (2004). Here's looking at you, kid! A longitudinal study of perceived gender differences in mutual gaze behavior in young infants. *Sex Roles*, *50*(1-2), 1-14.

Lewis, M. (1972). State as an infant-environment interaction: An analysis of mother-infant interaction as a function of sex. *Merrill-Palmer Quarterly of Behavior and Development*, *18*(2), 95-121.

For Review Only

563 Liu, L., Escudero, P., Quattropani, C., & Robbins, R. A. (2020). Factors affecting infant toy
564 preferences: Age, gender, experience, motor development, and parental attitude. *Infancy*.
565 Advance Online Publication.
566 Lutchmaya, S., & Baron-Cohen, S. (2002). Human sex differences in social and non-social
567 looking preferences, at 12 months of age. *Infant Behavior and Development*, *25*(3), 319-
568 325.
569 Lutchmaya, S., Baron-Cohen, S., & Raggatt, P. (2002). Foetal testosterone and eye contact in 12-
570 month-old human infants. *Infant Behavior and Development*, *25*(3), 327-335.
571 Mayes, L. C., & Carter, A. S. (1990). Emerging social regulatory capacities as seen in the
572 still-face situation. *Child Development*, *61*(3), 754-763.
573 Maylott, S. E., Paukner, A., Ahn, Y. A., & Simpson, E. A. (2020). Human and monkey infant
574 attention to dynamic social and nonsocial stimuli. *Developmental Psychobiology*.
575 Advance Online Publication. https://doi.org/10.1002/dev.21979
576 McClelland, M. M., Morrison, F. J., & Holmes, D. L. (2000). Children at risk for early academic
577 problems: The role of learning-related social skills. *Early Childhood Research*
578 *Quarterly*, *15*(3), 307-329.
579 McClure, E. B. (2000). A meta-analytic review of sex differences in facial expression processing
580 and their development in infants, children, and adolescents. *Psychological*
581 *Bulletin*, *126*(3), 424-453.
582 Minar, N. J., & Lewkowicz, D. J. (2018). Overcoming the other-race effect in infancy with
583 multisensory redundancy: 10–12-month-olds discriminate dynamic other-race faces
584 producing speech. *Developmental Science*, *21*(4), e12604.

For Review Only

Moore, D. S. (2012). Sex differences in normal fetuses and infants: A commentary. *Child Development Perspectives*, *6*(4), 414-416.

Morales, M., Mundy, P., Delgado, C. E., Yale, M., Neal, R., & Schwartz, H. K. (2000). Gaze following, temperament, and language development in 6-month-olds: A replication and extension. *Infant Behavior and Development*, *23*(2), 231-236.

Morgante, J. D., Zolfaghari, R., & Johnson, S. P. (2012). A critical test of temporal and spatial accuracy of the Tobii T60XL eye tracker. *Infancy*, *17*(1), 9-32.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: a two-process theory of infant face recognition. *Psychological Review*, *98*(2), 164-181.

Moss, H. A. (1967). Sex, age, and state as determinants of mother-infant interaction. *Merrill-Palmer Quarterly of Behavior and Development*, *13*(1), 19-36.

Nagy, E., Kompagne, H., Orvos, H., & Pal, A. (2007). Gender-related differences in neonatal imitation. I*nfant and Child Development*, *16*(3), 267-276.

Nelson, C. A. (1987). The recognition of facial expressions in the first two years of life: Mechanisms of development. *Child Development*, 889-909.

Oakes, L. M. (2012). Advances in eye tracking in infancy research. *Infancy*, *17*(1), 1-8.

Patterson, M. L., & Werker, J. F. (2003). Two-month-old infants match phonetic information in lips and voice. *Developmental Science*, *6*(2), 191-196.

Pérez-Edgar, K., Vallorani, A., Buss, K. A., & LoBue, V. (2020). Individual differences in infancy research: Letting the baby stand out from the crowd. *Infancy*, *25*(4), 438-457.

Rehnman, J., & Herlitz, A. (2007). Women remember more faces than men do. *Acta Psychologica, 124*(3), 344-355.

For Review Only

607 Sagi, A., & Hoffman, M. L. (1976). Empathic distress in the newborn. *Developmental*
608 *Psychology*, *12*(2), 175-176.
609 Salley, B., & Colombo, J. (2016). Conceptualizing social attention in developmental
610 research. *Social Development*, *25*(4), 687-703.
611 Schirmer, A., Simpson, E., & Escoffier, N. (2007). Listen up! Processing of intensity change
612 differs for vocal and nonvocal sounds. *Brain Research*, *1176*, 103-112.
613 Sclafani, V., Del Rosso, L. A., Seil, S. K., Calonder, L. A., Madrid, J. E., Bone, K. J., ... &
614 Parker, K. J. (2016). Early predictors of impaired social functioning in male rhesus
615 macaques (*Macaca mulatta*). *PLoS ONE*, *11*(10), e0165401.
616 Scott, L. S., & Fava, E. (2013). The own-species face bias: A review of developmental and
617 comparative data. *Visual Cognition*, *21*(9-10), 1364-1391.
618 Shultz, S., Klin, A., & Jones, W. (2018). Neonatal transitions in social behavior and their
619 implications for autism. *Trends in Cognitive Sciences*, *22*(5), 452-469.
620 Sifre, R., Olson, L., Gillespie, S., Klin, A., Jones, W., & Shultz, S. (2018). A longitudinal
621 investigation of preferential attention to biological motion in 2-to 24-month-old infants.
622 *Scientific Reports*, *8*(1), 2527.
623 Simpson, E. A., Buchin, Z., Werner, K., Worrell, R., & Jakobsen, K. V. (2014a). Finding faces
624 among faces: Human faces are located more quickly and accurately than other primate
625 and mammal faces. *Attention, Perception, & Psychophysics*, *76*(8), 2175-2183.
626 Simpson, E. A., Husband, H. L., Yee, K., Fullerton, A., & Jakobsen, K. V. (2014b). Visual
627 search efficiency is greater for human faces compared to animal faces. *Experimental*
628 *Psychology*, *61*(6), 439.

For Review Only

629 Simion, F., Leo, I., Turati, C., Valenza, E., & Dalla Barba, B. (2007). How face specialization
630 emerges in the first months of life. Progress in brain research, 164, 169-185.
631 Simpson, E. A., Maylott, S. E., Mitsven, S. G., Zeng, G., & Jakobsen, K. V. (2020). Face
632 detection in 2-to 6-month-old infants is influenced by gaze direction and species.
633 *Developmental Science*, *23*(2), e12902.
634 Simpson, E. A., Nicolini, Y., Shetler, M., Suomi, S. J., Ferrari, P. F., & Paukner, A. (2016).
635 Experience-independent sex differences in newborn macaques: Females are more social
636 than males. *Scientific Reports*, *6*, 19669.
637 Sokolov, A. A., Krüger, S., Enck, P., Krägeloh-Mann, I., & Pavlova, M. A. (2011). Gender
638 affects body language reading. *Frontiers in Psychology*, *2*, 16.
639 Soussignan, R., Nadel, J., Canet, P., & Gerardin, P. (2006). Sensitivity to social contingency and
640 positive emotion in 2-month-olds. *Infancy*, *10*(2), 123-144.
641 Telford, E. J., Fletcher-Watson, S., Gillespie-Smith, K., Pataky, R., Sparrow, S., Murray, I. C., ...
642 & Boardman, J. P. (2016). Preterm birth is associated with atypical social orienting in
643 infancy detected using eye tracking. *Journal of Child Psychology and Psychiatry*, *57*(7),
644 861-868.
645 Tzourio-Mazoyer, N., De Schonen, S., Crivello, F., Reutter, B., Aujard, Y., & Mazoyer, B.
646 (2002). Neural correlates of woman face processing by 2-month-old
647 infants. *Neuroimage*, *15*(2), 454-461.
648 Wass, S. V., Forssman, L., & Leppänen, J. (2014). Robustness and precision: How data quality
649 may influence key dependent variables in infant eye-tracker analyses. *Infancy*, *19*(5),
650 427-460.

For Review Only

651 Wass, S. V., & Smith, T. J. (2014). Individual differences in infant oculomotor behavior during
652 the viewing of complex naturalistic scenes. *Infancy*, *19*(4), 352-384.
653 Weinberg, M. K., Tronick, E. Z., Cohn, J. F., & Olson, K. L. (1999). Gender differences in
654 emotional expressivity and self-regulation during early infancy. *Developmental*
655 *psychology*, *35*(1), 175.
656 Wörmann, V., Holodynski, M., Kärtner, J., & Keller, H. (2012). A cross-cultural comparison of
657 the development of the social smile: A longitudinal study of maternal and infant imitation
658 in 6-and 12-week-old infants. *Infant Behavior and Development*, *35*(3), 335-347.

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659 **Tables**
660

Modified Visual Search Paradigm

Citation	Ages (*n*)	Target Type	Color	Trials/(# Images in array)	Trial Dur.	Attn. Capture	Attn. Holding	Sex Diff.
Gluckman & Johnson, 2013	6mo (32)	Human Face, Animal Body	Color	up to 48 (6 items)	4 sec	Pos (Human Face > Animal > Object)	Pos (Human Face > Animal > Object)	F > M Attn. Holding
Jakobsen et al., 2016	6mo (23) 11mo (25)	Human, Mammal, or Primate Face	Color	up to 12 (25 items)	5 sec & 8 sec	Pos (Human > Primate & Mammal)	Pos (Human > Primate & Mammal)	Not reported
Di Giorgio et al., 2012	3mo (19) 6mo (12)	Human Face	Gray-scale	min. of 16 (4 or 6 items)	5 sec	Null (Face = Object)	Null for 3mo, Pos for 6mo (Face > Object)	Not reported
Elsabbagh et al., 2013	7mo (50) 14mo (48)	Human Face	Color	*M* = 11 (6 items)	15 sec	Pos (Human Face > Object)	Pos (Human face > Object)	Not reported
Gliga et al., 2009; Exp 1	6mos (16)	Human Face	Color	*M* = 11.1 (6 items)	12 sec	Pos (Human Face > Object)	Pos (Human face > Object)	Not reported
Kwon et al., 2016; Exp 2	4mo (22) 6mo (15) 8mo (16)	Human Face	Color	up to 12 (6 items)	5 sec	Null for 4mo, Pos for 6mo & 8mo (Human Face > Object)	Null for 4mo, Pos for 6mo & 8mo (Human Face > Object)	Not reported
Simpson et al., 2020	2mo (55) 4mo (58) 6mo (51)	Human Face, Chimp Face	Color	up to 16 (4 or 6 items)	8 sec & 10 sec	Not reported	Pos (Human Face > Chimp Face)	No sex diff. found

661
662 **Table 1**. Previous studies of face attention capture and holding (i.e., eye gaze capture and
663 holding) in infants. These studies used a modified visual search (e.g., passive-viewing with 4- to
664 25-item arrays) with typically developing human infants. Sample sizes (*n*) are reported next to
665 each age tested. All the studies reported here compared visual attention (eye gaze) to human and
666 animal faces and bodies (Target Types) to various non-face objects. Trials are the minimum,

667 maximum, or average number of arrays presented, and Images are the number of images (items)
668 per array. Trial duration is the length of each array presentation. Attention capture refers to the
669 latency to fixate on the target or the proportion or percentage of first looks to the target, out of
670 the total number of first looks to all items. Attention holding refers to the duration or the number
671 of fixations produced while looking at the target. Null represents null results, while "Pos" stands
672 for positive (statistically significant) results. The final column denotes if the study reported a sex
673 differences (F = female; M = male). Only one study reported a sex difference (top row).
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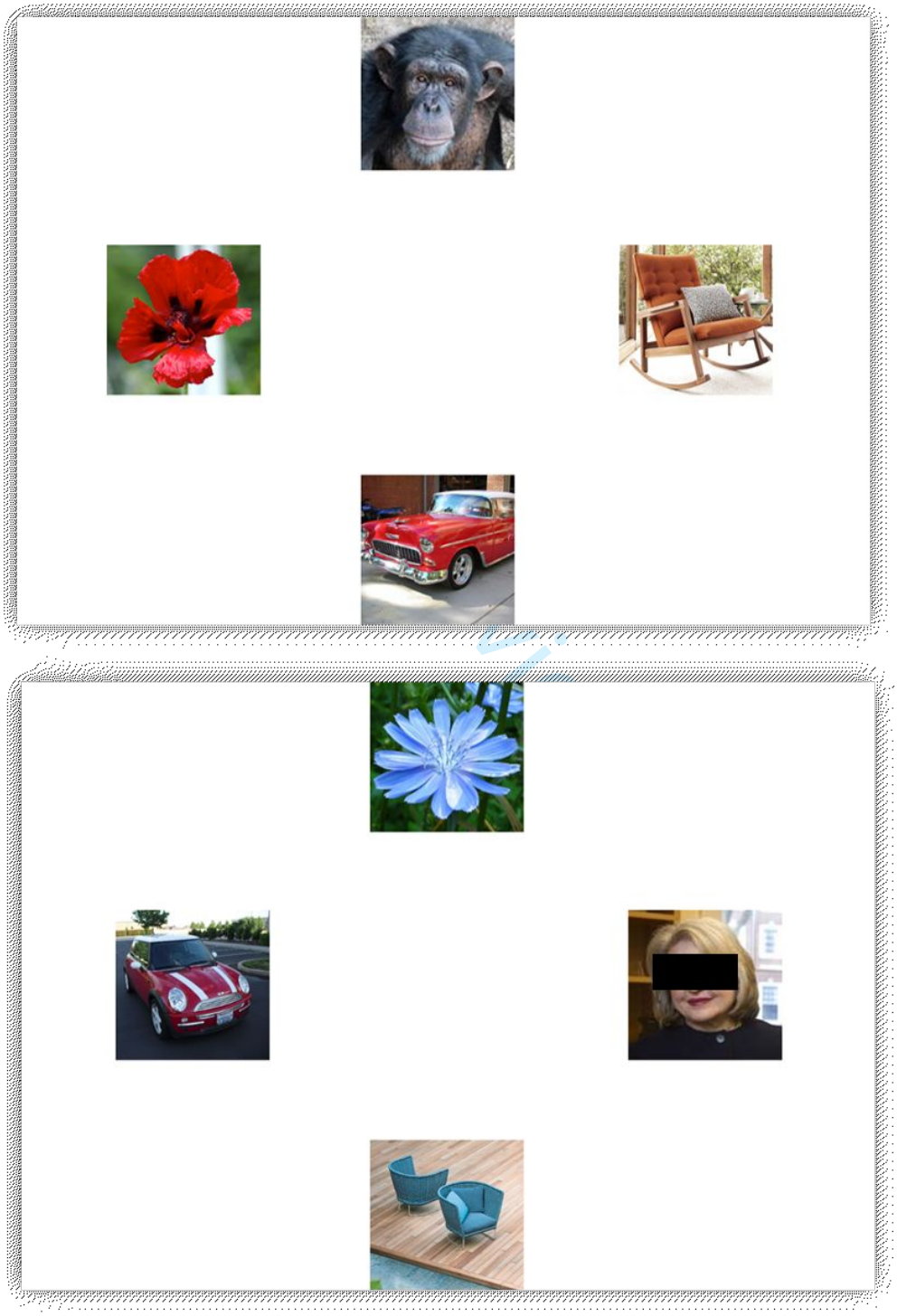
675 **Figures**



676

677 **Figure 1.** Sample chimpanzee (top) and human (bottom) arrays. The woman's face is obscured

678 since permission was not explicitly given to publish this image.

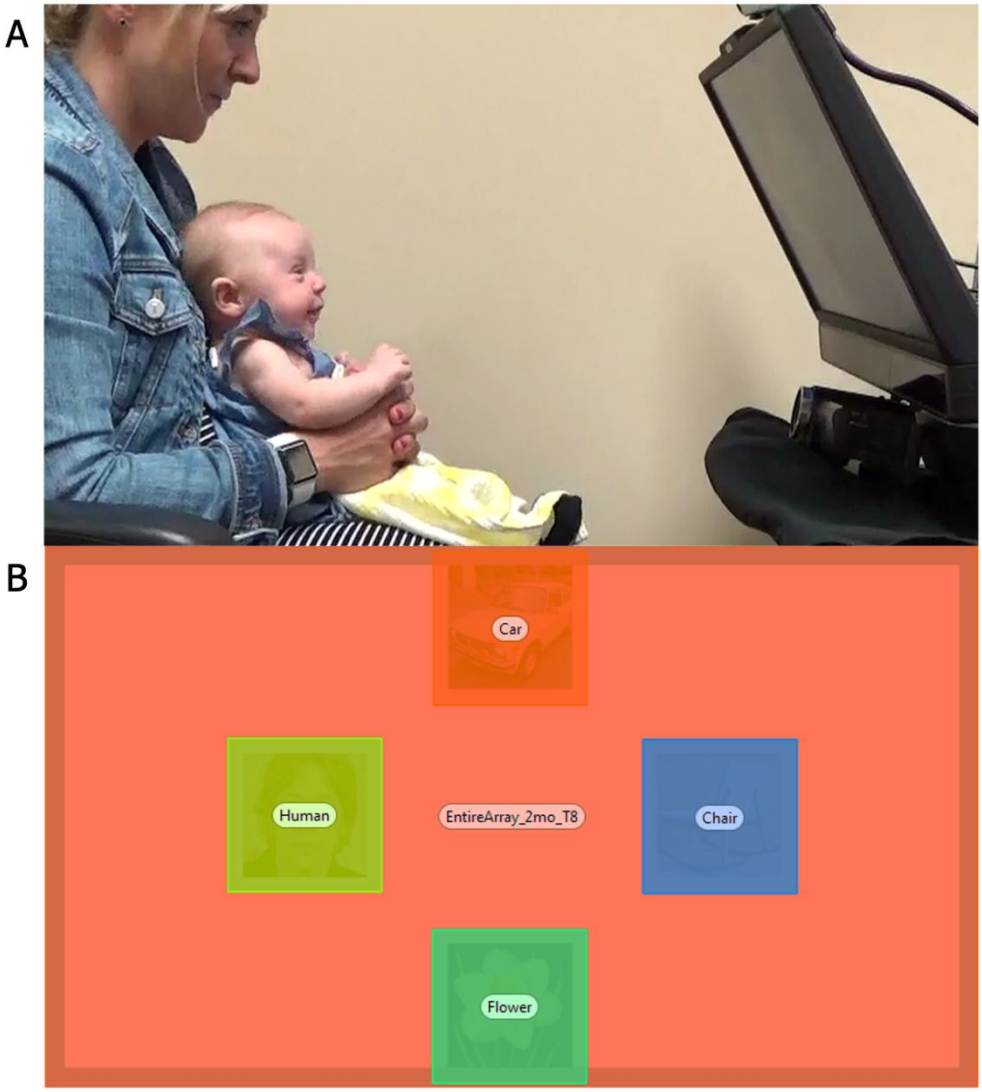


Figure 2. (A) Experimental set-up. Infants sat in their caregiver's lap at eye-level with the screen. Video cameras monitored the infant and caregiver. (B) Areas of interest (AOIs) around each image (faces and non-face objects). We extracted our dependent measures—look latency, look duration, and detection—from these regions.

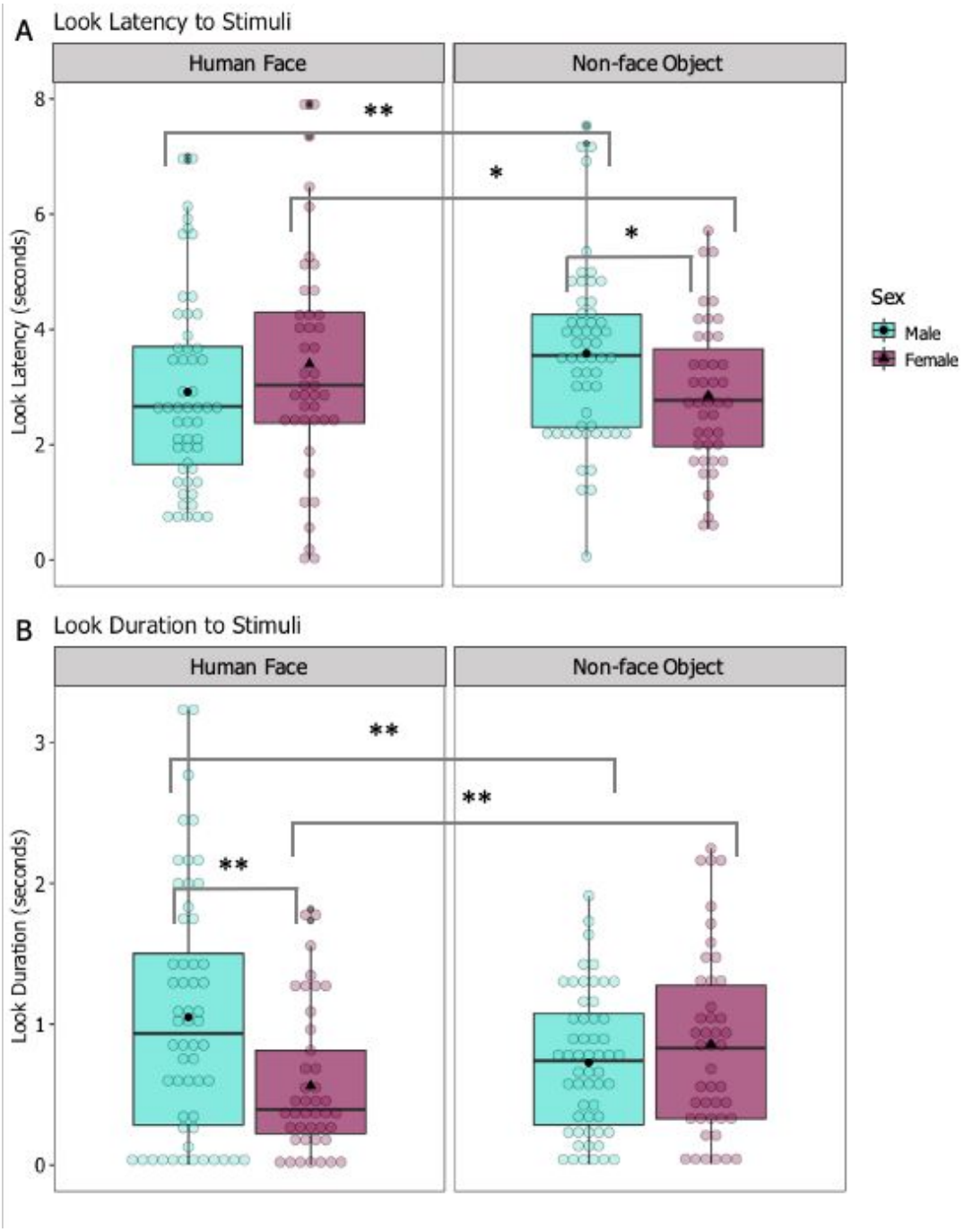


Figure 3. Male infants (light blue; circles) looked faster (A) and longer (B) to human faces (left column) than non-face objects (right column), and longer to human faces than female infants (dark purple; triangles). In contrast, female infants looked slower (A) and a shorter amount of time (B) to human faces compared to non-face objects, *ps < .05, **ps < .01. Boxes represent

689 the interquartile range, and whiskers represent error, which is measured as 1.5 times the
690 interquartile range. Horizontal lines within the boxes represent the medians, and points within
691 the boxes represent the means. Black points outside of the boxes represent outliers (for more
692 information see supplemental material). Colored circles represent raw data points, binned to
693 demonstrate the size of the sample, as well as the spread of the data.

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Supplementary Information Text

Supplementary Methods

Participants. Infants were 65% Caucasian, 17% Black or African-American, 1% American Indian/Alaska Native, Asian, Native Hawaiian or Pacific Islander, 1% Black or African-American and Asian, 1% Black or African-American and Caucasian, 5% American Indian/Alaska Native and Caucasian, 1% Asian and Caucasian, 1% Black or African-American, Caucasian, American Indian/Alaska Native, and Native Hawaiian or Pacific Islander, 1% Asian, Caucasian, and unknown, 2% American Indian/Alaska Native, Asian, Native Hawaiian or Pacific Islander, and unknown, and 5% unknown. More than half of the infants were Hispanic or Latino (59.4%). Parents (both mothers and fathers) had an average education level of a 2-year college degree. For mothers, 6% had a high school level education, 19% attended some college, 9% had a 2-year college education, 31% had a 4-year college education, and 35% had an advanced level of education. For fathers, 2% had less than a high school level education, 23% had a high school level education, 13% attended some college, 10% had a 2-year college education, 29% had a 4-year college education, and 23% had an advanced level of education. Parents had an average household income between $40,000 and $50,000 (USD). Four percent of parents had an income between $5,000-$9,999 a year, 4% had an income between $10,000-$19,000, 7% had an income between $20,000-$29,000, 10% had an income between $30,000-$39,000, 3% had an income between $40,000-$49,000, and 72% had an income over $50,000. In sum, our sample was racially, ethnically, educationally, and economically diverse for [city Blinded for review].

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Calibration. There is no agreed upon method for calibrating infants (Oakes, 2012), particularly very young infants who are notoriously difficult to calibrate (Aslin & McMurray, 2004; Oakes, 2010). Therefore, in the spirit of full transparency, we report all our methodological choices and make our data fully available for others to use different inclusion/exclusion criteria as they choose to improve replicability (Bakker & Wicherts, 2014; Davis-Kean & Ellis, 2019; Gennetian et al., 2020).

We calibrated each infant using at least five calibration points to Tobii Studio's preset locations. Infants looked at each dynamic, colored image as it flashed to at least five different locations on the black calibration screen. If we were unable to successfully calibrate an infant, the calibration was repeated, and if still unsuccessful, we used a calibration from another 2-month-old (n = 11 males; n = 12 females). Although not ideal, this is an approach that enables us to reduce the amount of missing data, due to the difficulty of obtaining eye tracking data from 2-month-old infants. Therefore, we retained all participants and followed best-practices for data disclosure (Carter & Luke, 2020), which may help reduce the Type 1 error rate (Bakker & Wicherts, 2014), and allow for more transparency, increasing study replicability (Gennetian, Tamis-LeMonda, & Frank, 2020). To ensure this approach did not negatively impact the quality of our data, these sessions with failed calibration were individually checked (i.e., looks were manually inspected and looking behaviors were coded, frame-by-frame, from video). Visual inspection of playback revealed high enough data quality for inclusion (i.e., infants' points of fixation were clearly within the target image areas of interest during playback). In a separate project we further compared infants with and without personalized calibrations, at this age and later ages, and found no differences accuracy ([Blinded for review]).

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Data Quality Analysis. As an additional check of data quality, for comparison's sake, we ran the main analyses comparing human faces to objects with only individually-calibrated infants (i.e., who had their own calibrations) and found the same results: For look latency, we found no main effects of stimulus type (human face, non-face object; ($F(1, 72) = 1.77$, $p = .187$) or infant sex ($F(1, 72) = .02$, $p = .888$). However, there was a statistically significant stimulus type × sex interaction ($F(1, 72) = 10.83$, $p = .002$, $\eta_p^2 = .13$). Look durations revealed no main effects of stimulus type ($F(1, 75) = .87$, $p = .355$) or infant sex ($F(1, 75) = .77$, $p = .384$); however, there was a stimulus type × infant sex interaction ($F(1, 75) = 5.24$, $p = .025$, $\eta_p^2 = .07$). Finally for detection, we found a main effect of stimulus type, in which infants were more likely to detect human faces than non-face objects ($F(1, 75) = 6.20$, $p = .015$, $\eta_p^2 = .08$). We detected neither a main effect of infant sex ($F(1, 75) = .03$, $p = .863$), nor any stimulus type × sex interaction ($F(1, 75) = .16$, $p = .691$). Given that these results are the same as the results with all of the infants included (even those without their own calibrations), we opted to include all infants.

Primary Data Analysis. Because we used chimpanzee face images and non-face object images from the chimpanzee arrays (control) to compare infant attention to human face images, we were unable to run an overall ANOVA in one analysis that included all of our variables (image type and species) because that would violate the independence assumption (Kenny & Judd, 1986). That is, both control variables were located in the same array, therefore, attention to one was not independent of attention to the other. Therefore, explored each of our variables of interest (image type and species) in separate ANOVAs for each dependent measure.

Preliminary Data Exploration, Preparation, and Analysis. Data were visualized using R version 3.4.4 and Rstudio version 1.1.423 and analyzed using IBM SPSS Statistics Version 24.

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Before running our main analyses, we examined descriptive statistics, and checked data for normalcy assumptions. Specifically, we assessed kurtosis and skewness of our continuous independent and dependent variables, visualizing the data with histograms.

Further, within each sex and between infants, we removed trials (a presentation of one array) in which an infant's looking (duration or latency) at each type of stimulus was more than 2.5 standard deviations from the group mean of each dependent variable. This resulted in the combined exclusion of less than 1% of the data (.007%). When we removed these outlier trials from one dependent variable, we retained inliers for the other two dependent variables for those trials. More specifically, for look duration, only four trials (1 male; 3 females) were removed from the human stimuli, only two trials (1 male; 1 female) were removed from the chimpanzee stimuli, and only two trials (2 males) were removed from the object stimuli. For look latency, one trial (1 male) was removed from the human stimuli, and two trials (1 male; 1 female) were removed from the object stimuli. There were no outliers in the detection measure. We also analyzed demographic data and found no sex differences (Table 1).

Supplemental Results

Data Quality. Using a multi-faceted approach, we explored whether there were differences in the data quality between male and female infants, an important factor to consider, when group differences are observed (Wass, Forssman, & Leppänen, 2014). We found no differences in data quality. First, we measured infants' overall attention to the screen—the total fixation duration (seconds) to any location on the screen across the full stimuli presentation. There were no differences in attention between males (M = 40.03, SD = 20.29) and females (M = 40.48, SD = 23.21; $t(99) = .103$, $p = .918$). Further, there were no differences in total looking to

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individual arrays between males (M = 5.46, SD = 2.29) and females (M = 5.49, SD = 2.65; t(99) = .08, p = .940). Next, we evaluated the average number of images an infant looked at per array. There were no differences in the number of images that males (M = 3.00, SD = 1.19) and females (M = 2.99, SD = 1.24) looked at within each of the arrays (t(99) = .004, p = .997). We also checked whether there were sex differences in the number of successful calibration points, but there were no differences between males (left eye: M = 5.28 points, SD = 2.31; right eye: M = 5.04, SD = 2.34) and females (left eye: M = 5.28 points, SD = 2.08; right eye: M = 5.56, SD = 2.09), left eye: t(76) = .003, p = .998; right eye: t(76) = 1.01, p = .318. Next, we examined the gaze sample percentage, which is calculated by dividing the number of eye tracking samples with usable gaze data that were correctly identified, by the number of attempts. 100% means that one or both eyes were found throughout the recording. 50% means that one eye or both eyes were found for half of the recording duration. Therefore, if the infants' eyes were not found (e.g., were off-screen) for a portion of the time the stimulus was displayed, it was reflected by a lower gaze sampling percentage. This gaze sampling percentage, therefore, reflects a combination of both time looking away and time looking but in which looks were not detected by the system (misses). The gaze sample percentage did not differ between males (M = 44.29%, SD = 26.60) and females (M = 39.27%, SD = 24.85), t(99) = .968, p = .335. Further, in a separate publication we further assessed the accuracy of our eye tracker data at this age and later ages using a previously established approach (Morgante et al., 2012), and found no sex differences (ps > .05; [Blinded for review]). Together, these findings suggest that the spatial and temporal quality of our eye tracking data appear to be comparable between male and female infants, and that the sex differences observed in the present study are unlikely to be due to differences in data quality between male and female infants.

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Face Stimulus Eye and Head Orientation. While not the primary focus of the current study, given that older infants appear sensitive to eye contact in studies of face detection (Simpson et al., 2020), we confirmed that there were no main effects of face or eye orientation (differing angles of the head and eyes, making eye-contact or not, for both human and chimpanzee faces), nor were there any orientation × sex interaction effects. Specifically, for the look latency human face and non-face object comparison, we found no effect of orientation ($F(3, 42) = .46$, $p = .713$) or orientation × sex ($F(3, 42) = 1.04$, $p = .387$). For the species look latency (human face and chimpanzee face) comparison, we found no effect of orientation ($F(3, 18) = .29$, $p = .832$), nor an orientation × sex interaction effect ($F(3, 18) = .62$, $p = .612$). For the look duration human face and non-face object comparison, we found no main effect of orientation ($F(3, 177) = .1.51$, $p = .213$), nor an orientation × sex interaction effect ($F(3, 177) = .39$, $p = .761$). For the look duration species comparison, we found no main effect of orientation ($F(3, 177) = .65$, $p = .586$), nor an orientation × sex interaction effect ($F(3, 177) = .48$, $p = .698$). For the detection measure comparing human face and non-face objects, we found no main effect of orientation ($F(3, 174) = 1.38$, $p = .252$), nor an orientation × sex interaction effect ($F(3, 174) = .12$, $p = .946$). For the detection measure comparing species, we found no main effect of orientation ($F(3, 174) = 2.51$, $p = .061$) nor an orientation × sex interaction effect ($F(3, 174) = .58$, $p = .628$). Given that we found no effect of eye or head orientation, we collapsed across these variables in our primary analyses.

Look Proportions. To further test our hypotheses, we ran an additional analysis examining the proportion of time infants spent looking at the stimuli (human faces, objects) in each array, out of the total time spent looking at that array. This enabled us to explore infants' relative attentiveness (gaze fixations) to the different stimuli, in addition to their absolute levels

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of attentiveness (e.g., Geeraerts et al., 2019; Pyykkö et al., 2019; Tummeltshammer & Amso, 2018; Yu & Smith, 2013). We found that infants overall looked longer at human faces than non-face objects ($F(1, 99) = 4.14$, $p = .045$, $\eta_p^2 = .04$), but this was qualified by a stimuli × sex interaction ($F(1, 99) = 4.79$, $p = .031$, $\eta_p^2 = .05$). Female infants showed no statistically significant difference in their looking proportions at human faces ($M = .13$, $SD = .11$) and objects ($M = .13$, $SD = .06$; $t(43) = .12$, $p = .908$), while male infants looked proportionally more at human faces ($M = .17$, $SD = .14$) than objects ($M = .12$, $SD = .06$; $t(56) = 2.97$, $p = .004$, $d = .47$). We also found that there was no effect of species (human, chimpanzee; $F(1, 99) = .01$, $p = .944$) or a species × sex interaction ($F(1, 99) = 2.55$, $p = .114$). These human and object findings directly parallel our look duration findings, and suggest that even when examining individual proportions, male infants show a social bias compared to female infants.

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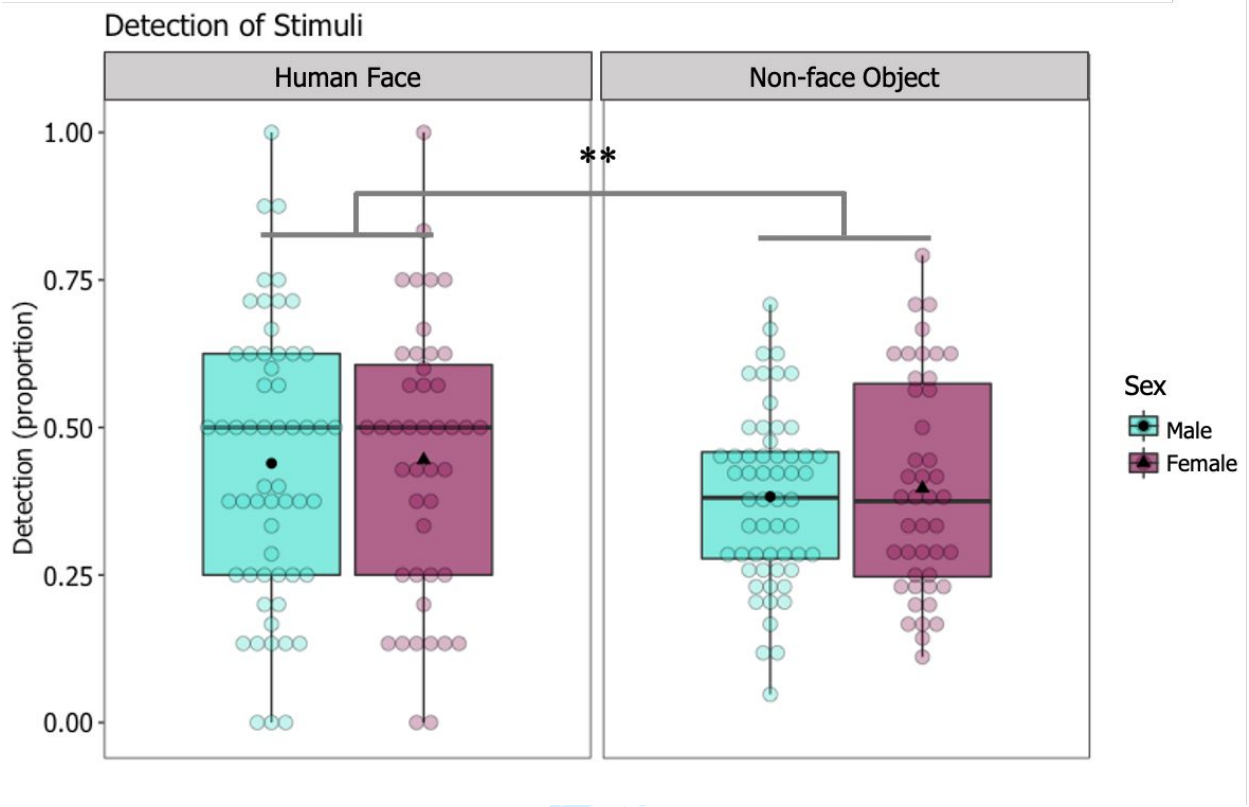

148

149 **Supplementary Figure 1.** Both male (light blue) and female (dark purple) infants were more

150 likely to detect human faces (left column) than non-face objects (right column), **ps < .01.

151 Boxes represent the interquartile range, and whiskers represent error, which is measured as 1.5

152 times the interquartile range. Horizontal lines within the boxes represent the medians, and black

153 points (circles and triangles) within the boxes represent the means (of males and females,

154 respectively). Colored circles represent raw data points, binned to demonstrate the size of the

155 sample, as well as the spread of the data.

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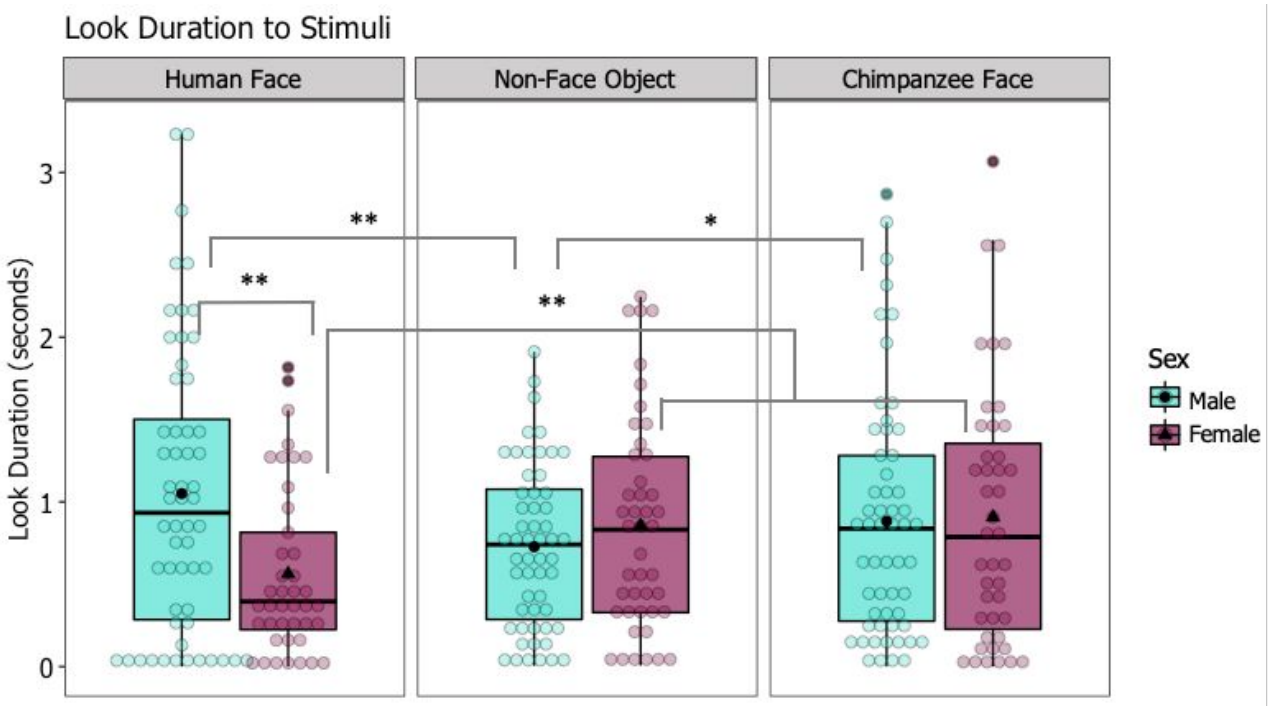

Supplementary Figure 2. Male (light blue) infants looked longer than females (dark purple) at human faces (left column). Male infants also looked longer at human faces than non-face objects (middle column), and they looked longer at chimpanzee faces (right column) than non-face objects. Female infants, in contrast, looked less at human faces relative to both non-face objects and chimpanzee faces. Boxes represent the interquartile range, and whiskers represent error, which is measured as 1.5 times the interquartile range. Horizontal lines within the boxes represent the medians, and points within the boxes represent the means. Black outlined points outside of the whiskers represent outliers. Colored circles represent raw data points, binned to demonstrate sample size and data spread. *ps < .05, **ps < .01.

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Look Latency				
ANOVA #1	***df***	***F***	***p***	η_p^2
Species (human, chimp)	1	.02	.899	<.001
Infant Sex (male, female)	1	.40	.529	.004
Species × Infant Sex	1	.90	.345	.010
Error	89	-	-	-
ANOVA #2				
Stimuli (human, objects)	1	.03	.859	<.001
Infant Sex (male, female)	1	.23	.633	.002
Stimuli × Infant Sex	1	9.59	.003	.094
Error	92	-	-	-

Look Duration				
ANOVA #3	***df***	***F***	***p***	η_p^2
Species (human, chimp)	1	.88	.351	.009
Infant Sex (male, female)	1	3.91	.051	.040
Species × Infant Sex	1	7.32	.008	.073
Error	93	-	-	-
ANOVA #4				
Stimuli (human, objects)	1	.19	.664	.002
Infant Sex (male, female)	1	3.14	.080	.033
Stimuli × Infant Sex	1	16.26	.000	.149
Error	93	-	-	-

Detection				
ANOVA #5	***df***	***F***	***p***	η_p^2
Species (human, chimp)	1	.03	.859	<.001
Infant Sex (male, female)	1	.00	.993	<.001
Species × Infant Sex	1	.04	.836	<.001
Error	99	-	-	-
ANOVA #6				
Stimuli (human, objects)	1	6.83	.010	.065
Infant Sex (male, female)	1	.08	.782	.001
Stimuli × Infant Sex	1	.94	.840	<.001
Error	99	-	-	-

Supplementary Table 1. ANOVAs for Look latency (top), Look duration (middle), and Detection (bottom).

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Look Latency

Independent Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human Faces	Male	2.92	1.68	1.30	93	.196	-
	Female	3.40	1.95				
Chimpanzee Faces	Male	3.29	1.94	.37	95	.716	-
	Female	3.15	1.84				
Non-Face Objects	Male	3.58	1.51	2.58	97	.011	.53
	Female	2.85	1.25				

Paired Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human – Chimp	Male	-.21	2.25	.68	50	.503	-
	Female	.28	2.69	.66	39	.516	-
Human – Non-Face Objects	Male	-.64	1.97	2.36	52	.022	.42
	Female	.71	2.27	2.03	40	.049	.45

Look Duration

Independent Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human Faces	Male	1.05	.88	3.19	95	.002	.68
	Female	.56	.51				
Chimpanzee Faces	Male	.88	.73	.15	97	.878	-
	Female	.91	.78				
Non-Face Objects	Male	.73	.49	1.13	97	.263	-
	Female	.86	.65				

Paired Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human – Chimp	Male	.17	1.01	1.24	54	.222	-
	Female	-.35	.77	2.86	39	.007	.52
Human – Non-Face Objects	Male	.28	.66	3.08	53	.003	.41
	Female	-.22	.51	2.83	40	.007	.40

Detection

Independent Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human Faces	Male	.44	.23	.12	99	.903	-
	Female	.45	.23				
Chimpanzee Faces	Male	.45	.22	.14	99	.887	-
	Female	.44	.22				
Non-Face Objects	Male	.38	.15	.42	99	.675	-
	Female	.40	.18				

Paired Samples Test

Stimuli	Sex	Mean	SD	*t*	df	*p*-value	Cohen's *d*
Human – Chimp	Male	-.01	.29	.29	56	.771	-
	Female	.00	.29	.02	43	.984	-
Human – Non-Face Objects	Male	.06	.20	2.13	56	.038	.29
	Female	.05	.20	1.61	43	.114	-

Supplementary Table 2. Follow-up independent and paired samples *t*-tests for Look latency (top), Look duration (middle), and Detection (bottom). Infants who were inattentive (i.e., did not produce any fixations to the images of interest) did not receive a response latency variable (i.e., were considered missing data); whereas inattention for Look duration was counted as zero seconds, so long as there was at least one fixation to the screen. Therefore, sample size in the analysis varied for Look latency. See data inclusion criteria for further details.

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Sex Differences in Additional Variables

	Sex	Mean	SD	*t*-value	*p*-value
Gestational Age	Male	38.99	1.50	.94	.350
	Female	39.28	1.61		
Birth Weight	Male	3263.54	438.47	.95	.344
	Female	3182.52	394.50		
Age at Visit	Male	61.16	7.31	.05	.962
	Female	61.10	4.98		
Father Education Level	Male	2.87	1.58	1.58	.117
	Female	3.37	1.51		
Mother Education Level	Male	3.50	1.33	1.77	.080
	Female	3.95	1.20		
Household Income	Male	5.10	1.48	.76	.452
	Female	5.33	1.39		
Number of People per Household	Male	3.32	1.51	.09	.931
	Female	3.30	1.43		

Supplementary Table 3. Descriptive statistics and paired samples *t* tests examining sex differences in demographic variables. Gestational age was documented in weeks, birthweight was measured in grams, and age at the visit was measured in days. Parental education level was assessed on a scale from 0 (less than a high school education) to 5 (advanced degree), household income was assessed on a scale from 0 (less than $5,000) to 6 (over $50,000), and number of people per household included any people living in the home with the infant (e.g., mother, father, siblings).

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References

Aslin, R. N., & McMurray, B. (2004). Automated corneal-reflection eye tracking in infancy: Methodological developments and applications to cognition. *Infancy*, *6*(2), 155-163.

Bakker, M., & Wicherts, J. M. (2014). Outlier removal and the relation with reporting errors and quality of psychological research. *PLoS One*, *9*(7), e103360.

Carter, B. T., & Luke, S. G. (2020). Best practices in eye tracking research. *International Journal of Psychophysiology*.

Davis-Kean, P. E., & Ellis, A. (2019). An overview of issues in infant and developmental research for the creation of robust and replicable science. *Infant Behavior and Development*, *57*, 101339.

Di Giorgio, E., Turati, C., Altoè, G., & Simion, F. (2012). Face detection in complex visual displays: An eye-tracking study with 3-and 6-month-old infants and adults. *Journal of Experimental Child Psychology*, *113*(1), 66-77.

Elsabbagh, M., Gliga, T., Pickles, A., Hudry, K., Charman, T., Johnson, M. H., & BASIS team. (2013). The development of face orienting mechanisms in infants at-risk for autism. *Behavioural Brain Research*, *251*, 147-154.

Geeraerts, S. B., Hessels, R. S., Van der Stigchel, S., Huijding, J., Endendijk, J. J., Van den Boomen, C., ... & Deković, M. (2019). Individual differences in visual attention and self-regulation: A multimethod longitudinal study from infancy to toddlerhood. *Journal of Experimental Child Psychology*, *180*, 104-112.

Gennetian, L. A., Tamis-LeMonda, C. S., & Frank, M. C. (2020). Advancing transparency and openness in child development research: Opportunities. *Child Development Perspectives*, *14*(1), 3-8.

For Review Only

Gliga, T., Elsabbagh, M., Andravizou, A., & Johnson, M. (2009). Faces attract infants' attention in complex displays. *Infancy*, *14*(5), 550-562.

Gluckman, M., & Johnson, S. P. (2013). Attentional capture by social stimuli in young infants. *Frontiers in Psychology*, *4*, 527.

Jakobsen, K. V., Umstead, L., & Simpson, E. A. (2016). Efficient human face detection in infancy. *Developmental Psychobiology*, *58*(1), 129-136.

Kenny, D. A., & Judd, C. M. (1986). Consequences of violating the independence assumption in analysis of variance. *Psychological Bulletin*, *99*(3), 422-431.

Kwon, M. K., Setoodehnia, M., Baek, J., Luck, S. J., & Oakes, L. M. (2016). The development of visual search in infancy: Attention to faces versus salience. *Developmental Psychology*, *52*(4), 537.

Morgante, J. D., Zolfaghari, R., & Johnson, S. P. (2012). A critical test of temporal and spatial accuracy of the Tobii T60XL eye tracker. *Infancy*, *17*(1), 9-32.

Oakes, L. M. (2010). Infancy guidelines for publishing eye-tracking data. *Infancy*, *15*(1), 1-5.

Oakes, L. M. (2012). Advances in eye tracking in infancy research. *Infancy*, *17*(1), 1-8.

Pyykkö, J., Forssman, L., Maleta, K., Ashorn, P., Ashorn, U., & Leppänen, J. M. (2019). Early development of visual attention in infants in rural Malawi. *Developmental Science*, *22*(5), e12761.

Simpson, E. A., Maylott, S. E., Mitsven, S. G., Zeng, G., & Jakobsen, K. V. (2020). Face detection in 2-to 6-month-old infants is influenced by gaze direction and species. *Developmental Science*, *23*(2), e12902.

Tummeltshammer, K., & Amso, D. (2018). Top-down contextual knowledge guides visual attention in infancy. *Developmental Science*, *21*(4), e12599.

For review Only

Wass, S. V., Forssman, L., & Leppänen, J. (2014). Robustness and precision: How data quality may influence key dependent variables in infant eye-tracker analyses. *Infancy*, *19*(5), 427-460.

Yu, C., & Smith, L. B. (2013). Joint attention without gaze following: Human infants and their parents coordinate visual attention to objects through eye-hand coordination. *PLoS ONE*, *8*(11), e79659.

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