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Follow My Gaze: Face Race and Sex Influence Gaze-Cued Attention in Infancy

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Using the eye gaze of others to direct one's own attention develops during the first year of life and is thought to be an important skill for learning and social communication. However, it is currently unclear whether infants differentially attend to and encode objects cued by the eye gaze of individuals within familiar groups (e.g., own race, more familiar sex) relative to unfamiliar groups (e.g., other race, less familiar sex). During gaze cueing, but prior to the presentation of objects, 10-month-olds looked longer to the eyes of own-race faces relative to 5-month-olds and relative to the eyes of other-race faces. After gaze cueing, two objects were presented alongside the face and at both ages, infants looked longer to the uncued objects for faces from the more familiar-sex and longer to cued objects for the less familiar-sex faces. Finally, during the test phase, both 5- and 10-month-old infants looked longer to uncued objects relative to cued objects but only when the objects were cued by an own-race and familiar-sex individual. Results demonstrate that infants use face eye gaze differently when the cue comes from someone within a highly experienced group.

Infants use the eye gaze of others to direct their attention and learn about objects, events, and people in their environment (Triesch, Teuscher, Deák, & Carlson, 2006). Following the gaze of others is also thought to be fundamental for acquiring adult-like social skills (Frischen, Bayliss, & Tipper, 2007; Striano & Reid, 2006) as well as learning about objects within one's environment (Reid & Striano, 2005). During infancy, face processing biases, acquired through greater experience with some groups of people relative to others, begin to influence behavior (Kelly, Quinn, et al., 2007; Kelly et al., 2009; Vogel, Monesson, & Scott, 2012). However, it is currently unclear whether face processing biases, such as the other-race effect, influence infants' ability to discriminate gaze-cued versus uncued objects. This investigation is grounded in a recently proposed theoretical framework that

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suggests that face processing abilities tune and self-organize in response to salient people in the infant's environment (Scherf & Scott, 2012). According to this framework, we predict that the face processing biases that emerge early in infancy are functionally related to the developmental tasks of infancy (e.g., forming attachment relationships with caregivers, motor development, learning language and social communication skills). It is hypothesized that developmental tasks weight the influence of the primary caregiver and result in infants' increased sensitivity to faces that match their caregiver's characteristics.

Neonates are sensitive to gaze orientation (Farroni, Csibra, Simion, & Johnson, 2002) and follow eye movements (Farroni, Johnson, Brockbank, & Simion, 2000; Farroni, Massaccesi, Pividori, & Johnson, 2004; Hood, Willen, & Driver, 1998). By 4 months of age, infants show evidence of enhanced processing of eye gaze and exhibit discrimination of gaze-cued and uncued targets by looking longer to previously *uncued* objects (Hoehl, Wahl, & Pauen, 2013; Reid & Striano, 2005; Wahl, Michel, Pauen, & Hoehl, 2012). Face familiarity also influences the use of gaze cues to direct one's attention. For example, infants exhibit increased neural activity for objects that were *not* cued by the caregiver's eye gaze compared to objects that were previously gaze-cued (Hoehl, Wahl, Michel, & Striano, 2012). However, there were no neural differences between cued and uncued objects when cued by an unfamiliar face. In another investigation, 12- to 18-month-old infants displayed increased learning of a novel object label when the object was cued by the gaze of their caregiver relative to a stranger (Barry-Anwar, Burris, Graf Estes, & Rivera, 2017). Limited work with adults supports this hypothesis and finds faster response times to gaze shifts for own- relative to other-race faces (Pavan, Dalmaso, Galfano, & Castelli, 2011). Finally, discrimination of cued and uncued targets has not been found for non-human agents such as cars (Wahl et al., 2012) or robots (Okumura, Kanakogi, Kanda, Ishiguro, & Itakura, 2013) suggesting that infants are not simply following movement but are using gaze to allocate attention and better encode important events or features within their environment. However, the extent to which attention to eye gaze and subsequent object discrimination is influenced by the development of face biases, such as the own- and other-race or sex effects, is presently unknown.

Face biases develop between 3 and 12 months of age. These biases begin with looking preferences for own-race faces (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005; Kelly, Liu, et al., 2007). By 3 months of age, Caucasian infants only exposed to Caucasian faces (Kelly et al., 2005) and Chinese infants only exposed to Chinese faces (Kelly, Liu, et al., 2007) look longer at own-race faces when paired with other-races faces. In addition, Caucasian and African infants, exposed only to own-race faces, look longer toward own-race faces relative to other-race faces (Bar-Haim et al., 2006). Face biases for discriminating among faces also develops between 3 and 12 months of age during a process called perceptual narrowing or perceptual tuning (for reviews see: Pascalis et al., 2011; Scott, 2011a; Scherf & Scott, 2012; Scott & Fava, 2013; Scott, Pascalis, & Nelson, 2007). Perceptual narrowing/tuning is characterized by a decline in discrimination for faces within unfamiliar groups and stable or enhanced processing and discrimination for familiar-face groups, typically defined by the primary caregiver (s) (Rennels & Davis, 2008; Sugden, Mohamed-Ali, & Moulson, 2014). For example, from 6 to 9 months, infants' discrimination of other-race faces declines and by 9 months, they show more robust discrimination of faces within their own race relative to an unfamiliar race (Kelly, Quinn, et al., 2007; Kelly et al., 2009; Vogel et al., 2012).

The sex of infants' primary caregiver also results in an early bias for either male or female faces (for review see Ramsey, Langlois, & Marti, 2005). For example, 3-month-old infants raised by a female reliably prefer and differentiate among female faces (Barrera & Maurer, 1981; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002). Discrimination of male faces is not reliable until later in the first year of life (Righi, Westerlund, Congdon, Troller-Renfree, & Nelson, 2014), and preferences for male faces are only seen in infants raised primarily by fathers (Quinn et al., 2002). By 3 months of age, infants raised primarily by mothers not only prefer female faces, but they look significantly longer to *own-race* female faces in a spontaneous looking time paradigm (Fassbender, Teubert, & Lohaus, 2016; Quinn et al., 2008; Tham, Bremner, & Hay, 2015).

These previous findings suggest that infants develop preferences and perceptual discrimination biases for faces within the first year of life and that experiences with particular groups (i.e., female, own race) modulate these biases. Here, we extend these findings to examine the extent to which the development of face biases and perceptual narrowing/tuning impact the processing of gaze cues for faces within familiar compared to unfamiliar groups. Based on previous findings (Hoehl et al., 2013; Reid & Striano, 2005; Wahl et al., 2012), we hypothesized that attention to the direction of gaze should result in increased processing of the cued object and thus longer looking toward the uncued object during the paired comparison test phase. In addition, if the processing and discrimination of objects cued by gaze is influenced by early social experiences including greater experience with own-race faces or female/male faces, we expected to see increased discrimination of cued and uncued objects when cued by an own-race and familiar-sex individual. Furthermore, if attention to eye gaze is influenced by perceptual narrowing, we expected biased discrimination of cued and uncued objects for own race and familiar sex in 10- but not 5-month-old infants.

METHODS

All methods and procedures used in this study were reviewed and approved by the University Institutional Review Board.

Participants

The final sample size included 32 five-month-olds (M = 157.97 days, SD = 8.99; 21 females) and 30 ten-month-olds (M = 306.20 days SD = 10.58; 18 females). All infants were typically developing with no history of neurological damage or of premature birth. Primary caregivers received $10.00, and infants received a small toy for participation.

Primary caregivers were asked to complete a questionnaire which asked about racial and ethnic demographic information as well as the amount of time their infant spent with various individuals on a weekly basis. Fifty-six of 62 primary caregivers completed the questionnaire. Fifty infants were racially identified as White or Caucasian, one as Asian, one Black or African, one as American Indian/Alaskan Native White,[1]

[1]One parent identified as American Indian/Alaskan Native White and the second parent was identified as White. Parents of these infants reported their infant spent 100% of their time with own-race individuals, and for the purposes of the study's stimuli, Caucasian cueing faces were coded as own race for this infant.

and one as American Indian/Alaskan Native Black/African.[2] Three additional infants were ethnically identified as Hispanic or Latino and were either not racially identified or racially identified as White or Caucasian. Those who were not racially identified were classified as White or Caucasian based on their experience questionnaire (majority of time spent with White or Caucasian individual). Five additional parents did not complete the questionnaire but were included in the final sample. Infants whose parents did not complete the questionnaire were racially identified based on the experimenter's judgment and verbal conversation with the parents at the time of their visit to the laboratory. From these interactions, it was determined that one infant was racially identified as Black or African, one infant was racially identified as Asian, and the remaining three infants were racially identified as White or Caucasian.

Caregivers' answers from the demographic and experience questionnaire, as well as conversations with parents who did not complete the questionnaire, were used to determine each infants' own- and other-race face group as well as their familiar and less familiar-face-sex group. White or Caucasian faces were coded as own race for 58 infants, Black or African faces were coded as own race for two infants, and Asian faces were coded as own race for two infants. Female faces were coded as the more familiar sex for 57 infants, and male faces were coded as more familiar sex for five infants. A breakdown of the people and groups infants spent the majority of their time with is reported in Table 1. Overall, parents reported that their infants spent the majority of their time with own-race individuals and females. These findings are consistent with previously reported experiences for infants at this age (Rennels & Davis, 2008; Sugden et al., 2014).

Additional infants were recruited but excluded from the final sample if they failed to complete all of the test trials due to fussiness (5 m $n = 7$, 10 m $n = 7$) or if there was a computer-related error (5 m $n = 5$, 10 m $n = 1$). Finally, infants who were identified as being multiracial (5 m $n = 1$, 10 m $n = 2$) and spent equal time with both races were excluded from analyses as the design of the study did not allow for the own-race group to include two races.

TABLE 1
Frequency of Infants' Social Experiences

		5 months (SEM)	*10 months (SEM)*
Average percent of time on weekly basis	Mother	72.33 (4.54)	75.61 (4.32)
	Father	52.65 (4.12)	47.39 (3.35)
Proportion of individuals seen on a weekly basis	Female	65.04 (3.68)	64.32 (2.08)
	Male	34.93 (3.68)	35.31 (2.21)
	Own Race	96.92 (1.30)	94.87 (1.95)
	Other Race	3.08 (1.30)	5.13 (1.95)

Note. Mean time parents report infants spent on a weekly basis with their primary caregivers as well as proportion of female, male, own- and other-race individuals. No statistical differences were found across ages.

[2]This infant had two mothers who both racially identified as White or Caucasian; thus, White or Caucasian was coded as the infant's own race.

Stimuli

Videos

Videos of adults laterally shifting their eyes were created for the face stimuli (Figure 1a). Videos included adults who self-identified as male or female and either White/Caucasian, Black/African-American, or East-Asian/Asian-American. There were a total of six race-sex face groups for the video stimuli: White/Caucasian-female, White/Caucasian-male, Black/African-American-female, Black/African-American-male, East-Asian/Asian-American-female, and East-Asian/Asian-American-male. To control onset time and speed of eye movements across individuals, models were asked to visually track a rolling ball projected onto a wall. Videos of the eye movements were 2 sec in length presented at a visual angle width of 8.44° (8.2 cm) and height of 8.94° (8.68 cm). Five adults rated each video on friendliness and eye visibility with a 3-point scale. Ratings did not differ statistically across face race or sex. The two highest rated videos for each of the six face groups were included in the final stimulus set resulting in 12 videos of different individual adults.

Infants were randomly assigned to one of four counterbalance conditions. Each counterbalance condition included the two highest rated adults from each of the six race-sex face group (e.g., two different White/Caucasian-females, two different White/Caucasian-males, two different Black/African-American females etc.) resulting in 12

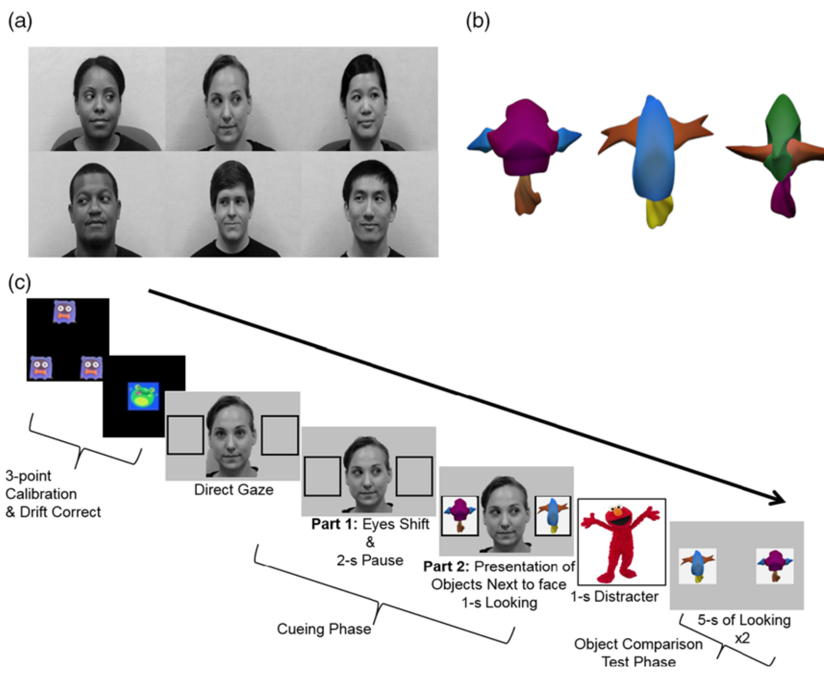

Figure 1 Experimental stimuli and an example trial. (a) Each race and sex face group was represented as still frames taken from the videos, capturing what infants saw after the adults had finished shifting their eye gaze. (b) The three objects are exemplars of the cued and uncued targets seen during the gaze-cueing phase and test phase. (c) Infants first completed a calibration task followed by a complete trial. Complete trials include a cueing phase and a test phase.

different trials seen by each infant. Each individual model was only presented once during the testing session. Within each race-sex face pair (i.e., within the African-American Male videos), one adult shifted their eye gaze to the left and the other adult shifted eye gaze to the right. Trial order was randomized across counterbalances (e.g., individual model A was presented first for infants in counterbalance 1 and was seen 8th for infants in counterbalance 2). Furthermore, across participants, each model's gaze direction was equally varied so each model was seen an equal number of times looking to the left and right.

Objects

Twenty-four computer-generated colored objects were used for the cued and uncued targets (Figure 1b). All objects were presented at a visual angle width of 10.14° (6.56 cm) and height of 7.1° (6.88 cm). Within each of the four counterbalance conditions, faces and objects were pseudo-randomly paired. Each object was only presented once, and the color and shape of the two paired objects differed within each trial.

Apparatus

An EyeLink 1000 arm-mount remote camera eye tracker (SR Research Ltd, Mississauga, Ontario, CA) was used to record infants' eye fixations while they saw faces and objects presented on a 17-inch LCD monitor. Fixation location and duration were recorded with an average accuracy of 0.5° and a sampling rate of 500 Hz using a 16mm lens and a 940nm infrared illuminator. Allowable head movement without accuracy reduction was approximately $22 \times 18 \times 20$ cm (horizontally $\times$ vertically $\times$ depth). The arm-mount gaze-tracking range was approximately 32° horizontally and 25° vertically. An eye track was recovered within 3 msec ($SD = 1.11$ msec) of losing the track; however, if data were missing due to excessive head movement or loss of head target sticker or pupil, it was recorded as an eye blink and removed.

Procedure

Infants were seated in a high chair (5-point harness) approximately 55 cm from the lens of the eye tracker while parents/guardians were seated behind their infant. A target sticker was placed on the forehead and allowed for tracking the infants' head position even when the pupil could not be captured (i.e., during blinks or sudden movements). Three randomly presented points, including a center/top point and left- and right-bottom corner points were used to calibrate the eye tracker for each infant. Following calibration and before each trial, infants completed a drift correct task in which an experimenter judged when the infant's eye fixation was as close to the target as possible. Calibration and drift correct targets were brightly colored cartoons sized 100×100 pixels that rotated to attract infant attention.

After calibration, infants completed 12 trials that included videos of 12 different adults. Each trial included a gaze-cueing phase (i.e., videos of adults' shift in eye gaze) followed by a paired object comparison test phase (Figure 1c). Trials began with an adult's face, with direct eye gaze, located in the middle of the screen. Gaze shifts began once infants fixated on the face for a minimum of 300 msec. The 300-msec criteria were included to ensure infants were looking at the faces at the start of the gaze shift, reducing the likelihood of infants missing the gaze-shifting event. Averted gaze was held for 2 sec before two objects simultaneously appeared one on either side of the face. Cued objects were those located on the congruent side of the directed gaze, and the uncued objects were on the incongruent side of the gaze. Objects remained on the screen with the face until infants accumulated 1 sec of looking toward the face or either presented object. Fixation time outside the areas of interest (AOIs; the face or objects) did not contribute to the 1 sec of accumulated looking. Gaze direction and location of cued objects were presented in a semirandom order with gaze direction changing at least every two trials. The race and sex of the adult faces were presented in a semirandom order such that one exemplar of each race-sex face category (e.g., Caucasian female) was presented in the first six trials. Twenty instrumental songs (e.g., steel drums, melodies of nursery rhymes) were randomly played with the face and objects to increase infant interest.

Following the gaze-cueing phase, a Distracter image (e.g., *Sesame Street* character, *Elmo*) appeared at the center of the screen while infants accumulated 1 sec of looking. Then, a blank screen with a fixation cross appeared and the object comparison test phase began (Figure 1c). The cued and uncued objects appeared side-by-side on the screen for two 5-sec (accumulated looking) presentations. Presenting objects side-by-side for a fixed amount of time has been previously used in visual-paired comparison tasks to assess perceptual discrimination capabilities during infancy (e.g., Hoehl et al., 2013; Reid & Striano, 2005; Scott, 2011b; Wahl et al., 2012). The object locations were randomized and switched between presentation one and presentation two.

Data processing and analyses

A heuristic filter was used to remove noise prior to the detection of saccades and fixations as well as reduce the frequency of false fixations being recorded during online data collection (for further details see Stampe, 1993). A saccade-pick algorithm was used to identify fixations, such that recorded eye samples that did not exceed the saccade thresholds for velocity (30 degrees/sec) or acceleration (8,000 degrees/sec squared), and was a movement of at least 15 degrees, were registered as fixations.

The total dwell time for the gaze-cueing phase and the object comparison test phase was analyzed. For all analyses, race of the cueing face was coded as own-race, other-race 1, and other-race 2 relative to the infant's identified race. Initial analyses revealed no differences between other-race 1 and other-race 2, and so, they were averaged together to form a single other-race category. Sex of the cueing face was coded as familiar sex and less familiar sex based on each infant's reported time spent with their mother and father.[3]

Areas of interest (AOI) during online data collection included the entire face or object image across the gaze-cueing and test phases. Offline data analysis included more specific areas of interest for the eyes and the mouth as well as the same AOIs for the entire object image. Each area of interest was hand drawn. An oval was drawn around each model's eyes and mouth. The tip of the nose was not included in either the eye or mouth area of interest. A rectangle approximately 30 pixels greater than the entire object image was used for the cued and uncued objects. The same area of

[3]Three infants had same-sex parents, thus making the sex not represented the unfamiliar sex.

interest was used for all the cued and uncued objects (10.08° width × 7.91° height). Accumulated looking during the gaze-cueing phase and test phase was recorded using timer triggers that began once a fixation crossed the area of interest boundary. The gaze-cueing phase was divided and analyzed into two separate parts (Part 1; Part 2). Part 1 of the gaze-cueing phase included dwell time during the 2-sec shift of the eyes *and* the 2-sec pause (face still present on the screen) following the completion of the eye shift, but prior to the appearance of the objects. Analyses compared dwell time to the eyes and mouth for Part 1. For Part 2 of the gaze-cueing phase, analyses focused on differences in dwell time to the cued and uncued objects, presented on either side of the model's head. For the test phase, only the objects were presented and so dwell time to the cued and uncued objects was analyzed (the two 5-sec side-by-side presentations were averaged for all test phase analyses).

RESULTS

Gaze-cueing phase

Part 1: Eyes shift and 2-sec pause

A 4-factor 2 × 2 × 2 × 2 mixed measures MANOVA was used to investigate differences in looking time to the eyes and mouth during the gaze-cueing event. Within-subject factors included the cueing face race (other race, own race), the cueing face sex (familiar sex, less familiar sex), and the display region of interest (cueing face eyes and cueing face mouth). Infant age (5 months, 10 months) was the between-subjects factor.

A significant main effect of region of interest was found, $F(1, 60) = 88.45$, $p < .001$, $\eta^2 = .596$. Infants looked significantly longer to the cueing face eyes ($M = 1087.11$ msec, $SD = 611.76$) compared to the mouth ($M = 158.59$ msec, $SD = 273.46$). In addition to this main effect, there was a significant 2-way interaction between the race of the cueing face and infant age, $F(1, 60) = 5.80$, $p = .019$, $\eta^2 = .088$. This interaction was driven by longer looking toward own-race trials at 10 months ($M = 784.28$ msec, $SD = 312.41$) compared to 5 months ($M = 480.67$ msec, $SD = 307.23$), $t(60) = -3.86$, $p < .001$.

A significant interaction between race, region of interest, and age was also found $F(1, 60) = 8.53$, $p = .005$, $\eta^2 = .124$ (Figure 2). Follow-up two-tailed independent tests revealed that 10-month-old infants looked longer toward the eyes ($M = 1382.68$ msec, $SD = 772.57$) of own-race cueing faces than 5-month-old infants ($M = 855.79$ msec, $SD = 637.58$), $t(60) = -2.94$, $p = .005$. Ten-month-olds looked longer toward other-race mouths ($M = 236.13$ msec, $SD = 333.69$) relative to 5-month-olds ($M = 106.79$ msec, $SD = 143.58$), $t(60) = -1.99$, $p = .05$, and 10-month-olds looking longer toward the eyes of own-race faces ($M = 1382.68$ msec, $SD = 772.57$) compared to the eyes of other-race faces ($M = 1134.71$ msec, $SD = 591.12$), $t(29) = 2.36$, $p = .025$. Looking longer toward the eyes of own-race compared to other-race faces was not present for 5-month-old infants.

Part 2: Presentation of objects next to faces

A 4-factor 2 × 2 × 2 × 2 mixed measures MANOVA was used to investigate differences in looking time to the cued and uncued object during the second part of the

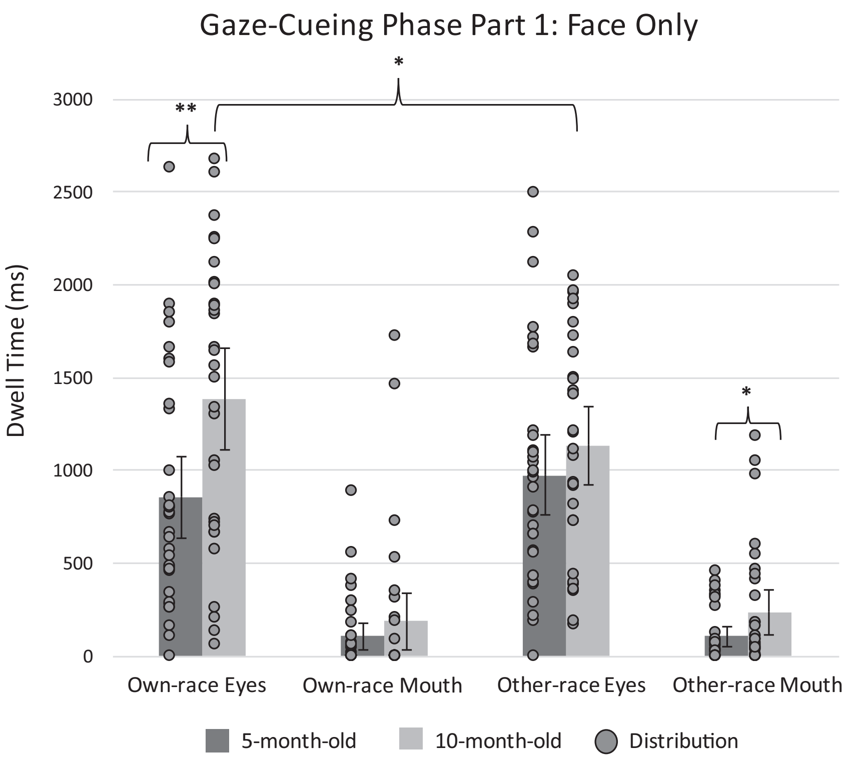

Figure 2 Mean dwell time (msec) during the gaze-cueing phase, Part 1 eye gaze shift and 2-sec pause. Dwell time to the cueing face eyes and mouth, for own- and other-race faces (collapsed across sex of the face). Comparisons made between infant ages. Error bars represent 95% confidence intervals, and each of the black and gray dots represents a subject mean. Significant differences are indicated with asterisks (** indicates $p < .01$ and * indicates $p < .05$).

gaze-cueing phase. Within-subject factors included the cueing face race (own race, other race), the cueing face sex (familiar sex, less familiar sex), and the display region of interest (cued object, uncued object). Infant age (5 months, 10 months) was the between-subjects factor.

A significant interaction was found between gaze-cueing face sex and object $F(1, 60) = 8.63$, $p = .005$, $\eta^2 = .126$ (Figure 3). Follow-up analyses revealed longer looking toward the uncued object ($M = 303.41$ msec, $SD = 166.16$) compared to the cued object ($M = 242.44$ msec, $SD = 136.27$) when cued by familiar-sex faces, $t(61) = -2.14$, $p = .036$. In contrast, infants looked longer toward the cued object ($M = 311.79$ msec, $SD = 152.24$) compared to the uncued object ($M = 249.47$ msec, $SD = 138.77$) when the cueing faces were of a less familiar sex $t(61) = 2.26$, $p = .027$. Furthermore, infants looked longer toward cued objects when cued by faces of the less familiar sex ($M = 311.79$ msec, $SD = 152.24$) compared to the familiar sex ($M = 242.44$ msec, $SD = 136.27$) $t(61) = -3.11$, $p = .003$. However, dwell time for the uncued object was significantly longer for familiar-sex faces ($M = 303.411$ msec, $SD = 166.16$) compared to less familiar-sex faces ($M = 249.47$ msec, $SD = 138.77$), $t(61) = 2.17$, $p = .034$.

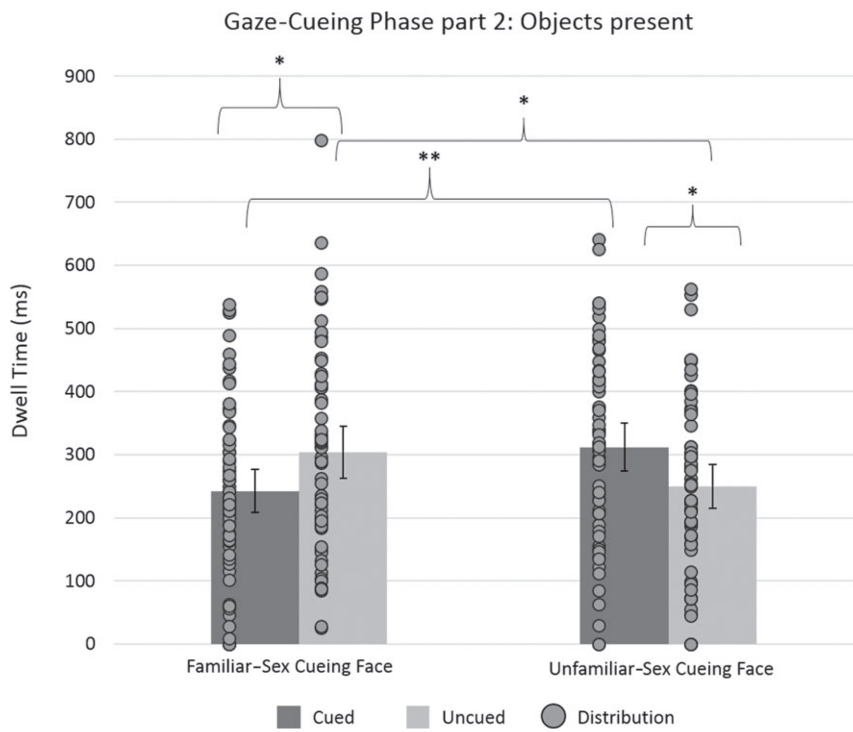

Figure 3 Mean dwell time (msec) during the gaze-cueing phase Part 2, presentation of objects next to the faces. Dwell time to the cued and uncued object, for familiar-sex and unfamiliar-sex faces (collapsed across race of the face and infant age). Error bars represent 95% confidence intervals, and each of the black and gray dots represents a subject mean. Significant differences are indicated with asterisks (** indicates $p < .01$ and * indicates $p < .05$).

Object comparison test phase

A 4-factor $2 \times 2 \times 2 \times 2$ mixed measures MANOVA was used to investigate differences in looking time to the cued and uncued object during the object test presentations. Within-subject factors included cueing face race (other race, own race), cueing face sex (familiar sex, less familiar sex), and object type (cued, uncued). Infant age (5 months, 10 months) was the between-subjects factor. Based on a priori hypotheses related to looking time to cued versus uncued objects (see Reid & Striano, 2005), follow-up tests of significant interactions only examined looking to cued versus uncued objects within conditions.

Analyses revealed no significant main effects. However, there was a significant interaction between cueing face sex and object type, $F(1, 60) = 4.45$, $p = .039$, $\eta^2 = .069$ (see Figure 4). Follow-up paired comparisons suggest that this interaction was driven by significantly longer dwell time to the uncued ($M = 2578.54$ msec, $SD = 280.02$) compared to the cued ($M = 2385.47$ msec, $SD = 273.67$) object after being cued by familiar-sex faces, $t(61) = -2.82$, $p = .006$. This effect was not found after cueing by less familiar-sex faces.

A significant interaction between cueing face race, cueing face sex, and object type $F(1, 60) = 8.62$, $p = .005$, $\eta^2 = .126$ was also found. This interaction was driven by

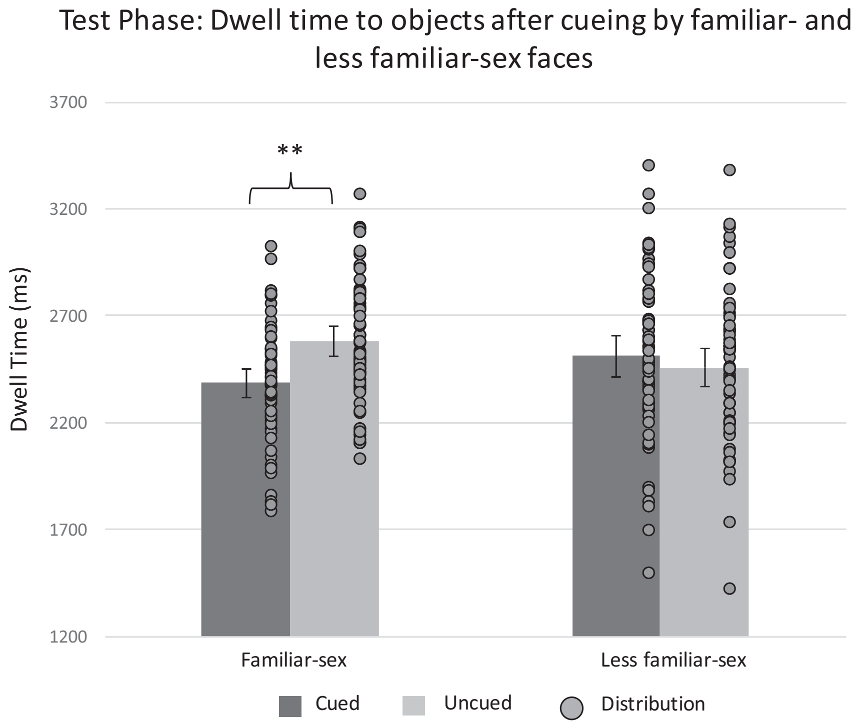

Figure 4 Mean dwell time (msec) to cued and uncued objects during the test phase after the gaze-cueing phase with familiar- and less familiar-sex faces. Error bars represent 95% confidence intervals, and each of the black and gray dots represents a subject mean. Significant differences are indicated with asterisks (** indicates p < .01).

longer dwell time to the uncued (M = 2668.70 msec, SD = 390.38) compared to the cued object (M = 2270.03 msec, SD = 399.40) when cued by the gaze of an own-race and familiar-sex face, $t(61) = -4.10$, p = .001 (see Figure 5).

This three-way interaction is qualified by a significant four-way interaction between cueing face race, cueing face sex, object type, and infant age, $F(1, 60) = 6.77$, p = .012, η^2 = .101. Five-month-old infants displayed longer dwell time toward uncued (M = 2735.13 msec, SD = 419.18) versus cued (M = 2190.40 msec, SD = 457.49) objects when the cueing faces were of an own race and from the familiar sex, $t(31) = -3.63$, p = .001. For 10-month-old infants, there was also longer looking to the uncued (M = 2597.83 msec, SD = 350.25) relative to the cued (M = 2354.97 msec, SD = 311.99) object for own-race familiar-sex faces, $t(29) = -2.06$, p = .048. Although not significant, the difference in looking between cued and uncued objects was greater in 5-month-olds relative to 10-month-olds.

DISCUSSION

The present investigation aimed to determine the extent to which extensive early experience with some groups of people (e.g., own-race and familiar-sex individuals) influence infants' processing of social cues such as attending to eye gaze and encoding

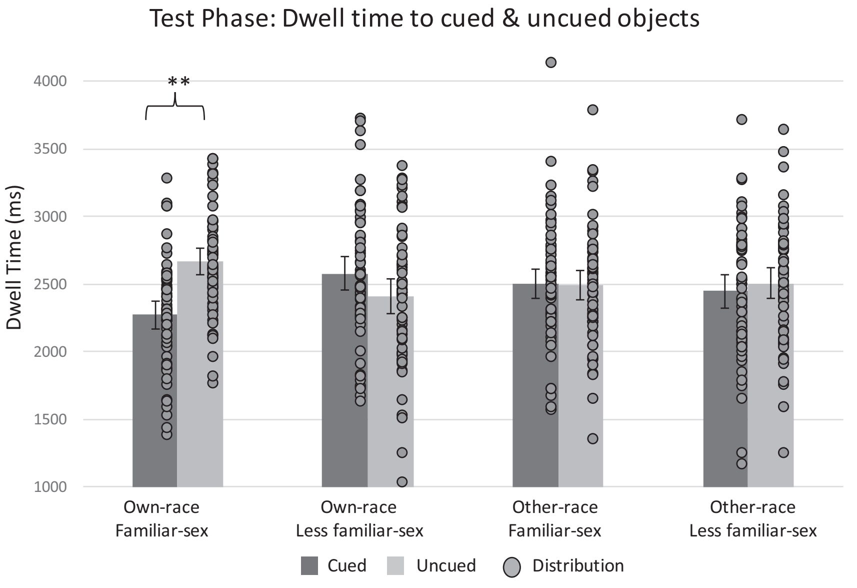

Figure 5 Mean dwell time (msec) to cued and uncued objects during the test phase after one of the objects was cued by an own- or other-race familiar- or less familiar-sex face. Error bars represent 95% confidence intervals, and each of the black and gray dots represents a subject mean. Significant differences are indicated with asterisks (** indicates $p < .01$).

gaze-cued objects. Based on previous findings (Hoehl et al., 2013; Reid & Striano, 2005; Wahl et al., 2012), it was hypothesized that attention to gaze would result in increased encoding of the gaze-cued object and thus longer looking toward the uncued object during a later paired comparison test phase. However, we also expected that experience-based face biases, such as the other-race and familiar-sex effects, would impact discrimination of cued and uncued objects.

Here, we found increased dwell time to the uncued compared to the cued object, but *only* when cued by the gaze of an own-race *and* familiar-sex face. These findings support previous results (Grossmann, Missana, Friederici, & Ghazanfar, 2012; Hillairet de Boisferon et al., 2015; Lewkowicz & Ghazanfar, 2006; Vogel et al., 2012) that suggest that face processing biases extend beyond the task of face discrimination and are present when infants use gaze cues.

Unlike previous reports of perceptual narrowing, we found few differences between 5- and 10-month-old infants. The present results indicate that 5- and 10-month-olds are similarly influenced by the race and sex of the cueing face and appear to exhibit greater attention to faces within familiar race and sex groups. However, there is one notable difference between the two ages (see Figure 2): When infants saw the eyes laterally shift followed by a 2-sec pause, 10-month-old infants looked significantly longer toward the eyes of own-race cueing faces compared 5-month-old infants. Additionally, 10-month-old infants' dwell time toward the eyes of own-race cueing faces was significantly longer than it was for the eyes of other-race cueing faces and this difference was not present for 5-month-olds. These findings suggest that for this task, 10-month-old infants differentially attend to the eyes of own- versus other-race faces relative to 5-month-olds. The present findings also support previously reported changes in visual fixations for own- compared to other-race faces that occur between 6 and 9 months of age (Liu et al., 2011; Wheeler et al., 2011; Xiao, Quinn, Pascalis, & Lee, 2014; Xiao, Xiao, Quinn, Anzures, & Lee, 2013).

The absence of a differential looking toward the eyes of own- and other-race faces in 5-month-old infants is consistent with the typically reported behavioral pattern of perceptual narrowing (e.g., Kelly et al., 2007; Kelly et al., 2009; Pascalis, de Haan, & Nelson, 2002; Scott & Monesson, 2009; Vogel et al., 2012), but should be interpreted cautiously. Longer looking toward the eyes of own-race faces at 10 months compared to 5 months is also consistent with previous eye-tracking studies (Wheeler et al., 2011; Xiao et al., 2013) and suggests that from 5 to 10 months of age, infants increase their attention to the eyes for own-race but not other-race faces. We hypothesize that increased attention to the eyes for own-race faces may be driven by changes in infants' developmental goals (Scherf & Scott, 2012). Processing communication cues, developing a secure attachment with a caregiver, motor development, and learning language may impact attention to face features relevant for that task/goal. These attention differences are expected to change with development and during important transition periods (e.g., learning to sit, Cashon, Ha, Allen, & Barna, 2013).

In Part 2, after the eye gaze shifted, the objects appeared on either side of the cueing face. For this part of the gaze-cueing phase, infants at both ages looked longer toward uncued objects when cued by familiar-sex faces and looked longer toward cued objects when cued by less familiar-sex faces (see Figure 3). This finding suggests that when cued by a familiar-sex face, infants quickly and efficiently encoded the cued object and shifted their attention to the uncued object. However, for objects cued by a less familiar-sex face, infants may have needed additional time to encode the cued object, resulting in longer looking to the cued object. No differences were found for objects cued by own- and other-race faces, and no sex differences were found during the earlier face-only part of the cueing phase. Based on these findings, differential processing of cueing face race occurred during Part 1 (when only the faces were on the screen) and differential processing of cueing face sex were not found until Part 2 (when both the face and the objects were on the screen). These findings suggest temporal processing differences between face race and sex; however, the current design and results do not allow us to make strong conclusions. Future work examining timing differences between different face biases across development will be important for better understanding these results.

The findings during the test phase (only the cued and uncued objects on the screen) clearly suggest that infants look longer toward the uncued object relative to the cued object when cued by an own-race and familiar-sex face (Figure 5). This result was somewhat surprising given the lack of clear corresponding dwell time differences during the gaze-cueing phase. However, the combination of looking in Part 1 (faces only) and Part 2 (faces with objects) may have contributed to these object discrimination differences. In addition, the colorful nature of the stimuli, the proximity of the stimuli to the face, and the fast 1-sec trials may have led infants to process the objects using peripheral vision during the cueing phase. Previous studies using similar procedural timing also did not find longer looking toward the cued compared to the uncued object during gaze cueing despite finding longer looking to the uncued object at test (Hoehl et al., 2013; Reid & Striano, 2005; Wahl et al., 2012). One previous infant investigation suggested that infants' differential processing of cued and uncued objects may be a result of covert, rather than overt, attention during gaze cueing (Reid, Striano, Kaufman, & Johnson, 2004). Extending the duration of the gaze-cueing phase, presenting the objects on either side of the face from the start of the cueing phase, placing the objects outside of the range that can be perceived with peripheral vision, and controlling for object color (i.e., keeping color constant for cued and uncued objects) are potential variations to the current task that may capture encoding differences across face groups and across development. These are all important factors to consider when determining whether the development of face biases influence encoding or retrieval (or both). However, equally important is to compare encoding/retrieval across overt (foveal) versus covert (peripheral) tasks.

The present dwell time differences between the uncued and the cued objects, during the test phase, are consistent with past reports that find infants look longer at the uncued versus cued objects after watching a gaze- (Hoehl et al., 2013; Okumura et al., 2013; Reid & Striano, 2005; Theuring, Gredebäck, & Hauf, 2007; Wahl et al., 2012) or spatial-cueing event (Markant & Amso, 2013; Markant, Oakes, & Amso, 2015). Our results suggest that group familiarity is critically important for infants' processing of eye gaze and discrimination of gaze-cued objects. However, the mechanisms underlying longer looking to *uncued* objects are not well understood. Prior gaze-cueing studies suggest longer looking to the uncued object is reflective of a novelty preference. Infants better encode the gaze-cued object during a cueing event, making the uncued object more novel at test (Reid & Striano, 2005). However, it is also possible that longer looking toward the uncued object may be driven by effects related to inhibition of return, such that attention is selectively directed to items in the uncued location due to suppression at the cued location (for review Klein, 2000). Using spatial-cueing tasks, prior results find faster looking to previously uncued locations, indicating inhibition of return, and resulting in increased attention to objects or faces in uncued compared to cued locations (Markant & Amso, 2013; Markant et al., 2015). In the present investigation, presence of a cued and uncued target during the gaze-cueing phase makes it difficult to determine to extent to which infants' selective attention toward the uncued target location resulted in longer looking toward the same object at test.

Here, we find increased discrimination of cued and uncued objects after cueing by a person of a familiar race and sex. However, it is not clear whether these effects can be characterized as perceptual learning. Perceptual learning has been defined as long-lasting perceptual changes from one's environment that results in an improved ability to respond to the environment (Goldstone, 1998). Previous cueing studies demonstrate learning when infants anticipate the location and type of object that will appear within a scene (Wu, Gopnik, Richardson, & Kirkham, 2011; Wu & Kirkham, 2010). In addition, relative to nonsocial cues, social cues, such as direct gaze and smiling, increase generalization of learning (Wu, Tummeltshammer, Gliga, & Kirkham, 2014). In the current study, the test phase findings indicate that infants stored a sufficient amount of perceptual information following gaze cueing by own-race and familiar-sex individuals to discriminate between cued and uncued objects. It is possible that in Part 1 of the gaze-cueing phase (prior to the presentation of objects), the direct gaze from faces of familiar race and sex increased and biased attention throughout the task.

We find no evidence of discrimination of the cued and uncued objects when the cueing face is from an other-race or the less familiar-sex group. This lack of discrimination may be due to several factors, including the task used. We predict that increasing the duration of the cueing event for faces within less familiar groups will result in increased discrimination of the cued and uncued objects. Regardless of the factors that contribute to a lack of discrimination seen here, the present results suggest that during the first months of life, infants quickly fine-tune their processing (including but not limited to attention, perception, and conceptual processing) to the sex and race of familiar people within their environment.

One recent hypothesis (Picci & Scherf, 2016; Scherf & Scott, 2012) suggests that the characteristics (age, sex, gender) of the primary caregiver drive face biases beginning in infancy and continuing through development. According to this hypothesis, infants prefer to look at, better discriminate, and show increased learning from faces that match the characteristics of the primary caregiver. This caregiver bias is also long lasting. Picci and Scherf (2016) found that among prepubescent children ages 6–8 years, face recognition biases were dominated by caregiver biases. These children were better at recognizing adult faces than peer faces or adolescent faces. Here, we extend support for the caregiver bias by showing that infants exhibit increased discrimination of gaze-cued objects when they are cued by a person who matches the race and sex of the reported primary caregiver. Additional support for this hypothesis comes from studies finding that by 3 months, infants prefer to look at faces which match the sex (Hillairet de Boisferon, Uttley, Quinn, Lee, & Pascalis, 2014; Quinn et al., 2002) as well as race (Fassbender et al., 2016; Liu, Xiao, Quinn, et al., 2015; Liu, Xiao, Xiao, et al., 2015 Quinn et al., 2008); of their primary caregiver. Based on these findings, as well as a previously reported effect suggesting that early face learning in infancy continues to impact childhood (Hadley, Pickron, & Scott, 2015), we also predict that the current effects will be long lasting and likely contribute to pervasive adult face biases, such as faster gaze following for own-race faces (Pavan et al., 2011) and the other-race effect (for review Meissner & Brigham, 2001).

Two investigations that extensively tracked and recorded infant experience with people suggest that as a group, infants tend to spend more time with female and own-race individuals who are approximately the same age as the mother (Rennels & Davis, 2008; Sugden et al., 2014). These previous reports further support the presence of a caregiver bias. In one small study, infants who were raised by their fathers were found to prefer to look at male faces over female faces, whereas infants primarily raised by mothers preferred to look at female faces (Quinn et al., 2002). Although infants (presumably spending more time with females) gradually learn to differentiate among male faces by 7 months of age (Fagan, 1976; Righi et al., 2014), they maintain a female face processing bias at the neural level until at least 7 months of age (Righi et al., 2014). Finally, a recent study investigating face–voice multisensory matching indicates that by 9 months of age, infants reliably match female, but not male voices to faces (Hillairet de Boisferon et al., 2015). Although these studies exemplify the extensive work on developmental face processing and learning based on the sex of faces, investigators have only recently begun to combine sex and race groups into their designs (Kim, Johnson, & Johnson, 2015; Tham et al., 2015). Differences for own-race *and* familiar-sex faces in infancy has been shown in 3- to 4-month-old infants who exhibit increased face discrimination for own-race female, but not own-race male or other-race female and male faces in the context of a habituation/dishabituation task (Tham et al., 2015). The present study expands this work and provides evidence that infants' use gaze is influenced by the intersection of race and sex during the first year of life. These findings also support a recent hypothesis (Pascalis et al., 2014) that face biases are present across various forms of communication including eye gaze following.

One limitation of the present work is the small number of infants whose primary caregiver was not White or Caucasian ($n = 4$) and infants who were reported as spending more time with a male caregiver compared to a female caregiver ($n = 5$). Although not expected, it is possible that the effects reported here would differ if our sample was non-Caucasian or raised primarily by males. Moreover, the complex nature of family makeup (e.g., mixed race and/or same sex households, extended family members in the home) and experiences (e.g., daycare or non-family member care experiences) pose significant challenges for accurately measuring experience. Although our questionnaire allowed us to determine the characteristics of the individuals infants spend the most time with, a better measure would include actual observations of infant experiences and interactions in order to measure quantity and quality of experiences (similar to Sugden et al., 2014).

In the present study, we coded the face conditions based on parent-reported experience. Despite the small number of infants who had greater experience with males than females, our findings suggest that experience drives the development of face biases for race and sex. We predict that the processing bias between male and female own-race faces is driven by a combination of two experience-dependent factors. First, infants tend to be exposed to a greater number of people who match the race, age, and sex of the primarily caregiver. Second, the face-to-face experiences infants have with their primary caregiver are both quantitatively and qualitatively different than the experience they have with other individuals, including other family members. These quantitative and qualitative differences may differentially weight the characteristics of the primary caregiver and lead to increased attention, encoding, and learning from faces that match these characteristics. If confirmed with future work, this finding has implications that span education and clinical practice. For example, if future findings confirm that individuals pay more attention to and learn more from people who match the characteristics of the primary caregiver, both clinical and educational intervention programs may be more effective when administered by individuals who match the characteristics of the student/client/patient's primary caregiver.

Further work is also needed to examine conditions that enhance processing of gaze-cued targets from unfamiliar groups of people. Studies examining the effects of face experience suggest that learning at the level of the individual promotes later differentiation and neural processing of faces within unfamiliar groups (Pascalis et al., 2005; Scott & Monesson, 2009, 2010). For example, infants trained with faces paired with individual-level labels, relative to category-level labels or no label, more effectively differentiated monkey faces at 9 months of age (Scott & Monesson, 2009). Furthermore, individual-level labels (but not category-level labels or exposure with no labels) also led to increased neural differentiation of upright relative to inverted faces (Scott & Monesson, 2010). We predict that individually labeling faces from within unfamiliar groups during infancy will enhance attention to eye gaze resulting in increased discrimination of cued versus uncued objects. However, it is also possible that this training will not be able to completely overcome caregiver biases given infants' extensive experience with their primary caregiver.

In sum, the results from the present investigation improve our understanding of the factors that influence infant attention to eye gaze and encoding of gaze-cued objects. At both 5 and 10 months of age, infants successfully discriminated an uncued from a cued object when the cueing face is of the more familiar sex *and* own race. These infant findings are the first to show that attention to eye gaze and discrimination of gaze-cued objects are influenced by experience and person characteristics such as race and sex. The present report suggests that infants can harness their increased perceptual sensitivity to familiar person characteristics (here race and sex) to process visual information effectively. The current study's main question and findings provide an important contribution to both the face processing and gaze-cueing literature and suggest that research investigating perception, attention, and learning from faces may be important for both educators and clinicians to consider.

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