Received: 1 April 2022 | Revised: 23 September 2022 | Accepted: 20 November 2022

DOI: 10.1002/dev.22362

Developmental Psychobiology WILEY

RESEARCH ARTICLE

Face race and sex impact visual fixation strategies for upright and inverted faces in 3- to 6-year-old children

Julia Farrell[1] | **Stefania Conte**[2] | **Ryan Barry-Anwar**[1] | **Lisa S. Scott**[1]

[1]Department of Psychology, University of Florida, Gainesville, Florida, USA

[2]Department of Psychology, University of South Carolina, Columbia, South Carolina, USA

Correspondence
Lisa S. Scott, Department of Psychology, University of Florida, PO Box 112250, Gainesville, FL 32611, USA.
Email: lscott@ufl.edu

Abstract

Everyday face experience tends to be biased, such that infants and young children interact more often with own-race and female faces leading to differential processing of faces within these groups relative to others. In the present study, visual fixation strategies were recorded using eye tracking to determine the extent to which face race and sex/gender impact a key index of face processing in 3- to 6-year-old children ($n = 47$). Children viewed male and female upright and inverted White and Asian faces while visual fixations were recorded. Face orientation was found to have robust effects on children's visual fixations, such that children exhibited shorter first fixation and average fixation durations and a greater number of fixations for inverted compared to upright face trials. First fixations to the eye region were also greater for upright compared to inverted faces. Fewer fixations and longer duration fixations were found for trials with male compared to female faces and for upright compared to inverted unfamiliar-race faces, but not familiar-race faces. These findings demonstrate evidence of differential fixation strategies toward different types of faces in 3- to 6-year-old children, illustrating the importance of experience in the development of visual attention to faces.

KEYWORDS

children, eye tracking, face processing, inversion effect, other-race effect (ORE), visual attention, visual orienting

1 | INTRODUCTION

The ability to process and recognize faces is important for social interactions throughout life. In the first year of life, infants use faces as a tool for learning about the visual and auditory world, building a foundation for complex social interactions. However, learning from faces during development is limited to the people infants interact with most, including their primary caregivers (Rennels & Davis, 2008; Sugden et al., 2014). Extensive experience with a few individuals in the first years of life is thought to lead to enhanced face processing for faces within these highly familiar groups, including faces of the same race and sex/gender as the primary caregivers (e.g., Liu et al., 2011; Quinn et al., 2002, 2019; Ramsey et al., 2005; Ramsey-Rennels & Langlois, 2006; Righi et al., 2014; Sangrigoli & de Schonen, 2004; Tham et al., 2017; Xiao et al., 2013). However, extensive experience with some groups of people relative to others is also thought to contribute to face processing biases and result in impaired recognition, identification, and discrimination of faces from unfamiliar groups (for reviews, see Markant & Scott, 2018; Scherf & Scott, 2012; Scott et al., 2007).

One theoretical account (Scherf & Scott, 2012) proposes that the mechanisms of developmental change for face processing include both continuities and discontinuities driven by relevant experience and developmental tasks or goals (e.g., language development, the formation of an attachment relationship, or the increase in same age friendships). In infancy, face processing is enhanced for faces that share features or characteristics with the primary caregiver. However, the extent to which these experience-dependent caregiver biases continue to impact face processing in childhood is not known. The current investigation seeks to understand whether race and sex/gender experience-dependent face processing biases found in infancy are also present during childhood.

The other- or own-race effect (ORE) refers to a processing bias toward faces within one's own race compared to faces within a different race (for reviews, see Bothwell et al., 1989; Meissner & Brigham, 2001). The ORE emerges during the first year of life and is driven by experience with the faces developing infants see and interact with the most (Ge et al., 2009; Lee et al., 2017; Lindsay et al., 1991; Markant & Scott, 2018; Scherf & Scott, 2012). Thus, face biases based on race are driven by faces within one's environment, which may not be the same as one's "own" race (Scherf & Scott, 2012). For example, Korean adults who were adopted into White families as children showed increased recognition for White than Korean faces, but Korean adults raised in Korea exhibited better recognition of Korean faces (Sangrigoli et al., 2005). Similarly, Asian children who had been adopted into White families as infants equally recognized White and Asian faces (de Heering et al., 2010). These findings suggest that meaningful experience plays a salient role in the development of face processing biases.

Previous work in adults (for review, see Kawakami et al., 2018) and infants (e.g., Gaither et al., 2012; Liu et al., 2011; Wheeler et al., 2011) has shown differences in visual attention when viewing own- compared to other-race faces. For example, using eye tracking, adults were shown to attend more to the eyes of own-race faces and more to the nose and mouth of other-race faces (Goldinger et al., 2009; Kawakami et al., 2018). Adults also more actively scan own-race compared to other-race faces as indexed by fewer and longer fixations and more frequent saccades (Goldinger et al., 2009; Wu et al., 2012). For adult face recognition, only one to two fixations are required for accurate recognition performance and these fixations are typically located between the eyes (Hsiao & Cottrell, 2008). However, small differences in first fixation location have been reported when both Asian and White adults viewed faces from multiple races (Or et al., 2015). In addition, varying the first fixation may impact recognition. For example, both White and Black adults show better recognition for Black faces when guiding the first fixation to the tip of the nose compared to between the eyes. However, for White faces better recognition was shown after guiding the first fixation to a point between the eyes compared to the tip of the nose (Hills et al., 2013b). These findings suggest that the first fixation to a face may impact subsequent recognition and that face experience may play an important role in first fixation location. Based on previous adult work, the first fixation may be an important driver of attentional and perceptual processing and may impact recognition. However, to date, no studies have examined the first fixation during face processing in childhood.

In children, face processing biases related to race are also present (Anzures et al., 2013; e.g., Golarai et al., 2021; Pezdek, 2003; Tham et al., 2017). Eye-tracking work has shown cultural differences in visual fixations between English and Chinese 7- to 12-year-old children such that English children preferentially fixated the eye region and Chinese children fixated the nose region of both White English and Chinese faces (Kelly et al., 2011). Similarly, the proportion fixation duration to the eye region of Chinese faces was decreased relative to White faces in Chinese 4- to 7-year-old children and adults (Hu et al., 2014).

Although experience-dependent face processing biases related to race appear to be quite robust, race biases do not occur in vacuum. Other face characteristics, including sex/gender (Pickron et al., 2017), age (Heron-Delaney et al., 2017; Wiese, 2012), and emotion (Malsert et al., 2020; Vogel et al., 2012), may interact with face race and result in multifaceted processing differences. For instance, at 3–4 months of age an own-race advantage was present for female, but not male faces, but at 8–9 months of age an own-race advantage was present for both male and female faces (Tham et al., 2015). In addition, 12-month-old infants did not show evidence of forming category representations by sex/gender for other-race faces (Damon et al., 2022). Finally, 5- to 6-year-olds raised in a multiracial population exhibited an own-race recognition effect for male faces, but recognized female faces equally from multiple race groups (Tham et al., 2017). These findings suggest, as predicted by Scherf and Scott (2012), that different attributes of faces, including face race and face sex, may interact and lead to discontinuous, qualitative changes in face processing throughout development.

Face processing biases related to sex/gender have been extensively investigated during infancy. Infants typically show a preference for looking at female faces (Lee et al., 2013; Quinn et al., 2002, 2019; Ramsey-Rennels & Langlois, 2006) and this preference is thought to be driven by experience with primarily female faces during the first year of life (Rennels & Davis, 2008). This experience-based explanation is also supported by work that showed infants who were primarily cared for by a male caregiver exhibited a looking preference for male faces (Quinn et al., 2002). Sex/gender face biases have also been shown in adolescents (e.g., Picci & Scherf, 2016) and adults (e.g., Herlitz & Lovén, 2013; Motta-Mena et al., 2016; Wright & Sladden, 2003). However, at some point during development a bias toward faces of the same sex as an infant's primary caregiver (e.g., Quinn et al., 2002) gives way to an own-gender bias in adulthood (most notably for females) (e.g., Herlitz & Lovén, 2013; Motta-Mena et al., 2016; Wright & Sladden, 2003). Children show preferences for same-gender friendships throughout early childhood (LaFreniere et al., 1984), which may contribute to the shift from a caregiver bias to a peer face processing bias (Picci & Scherf, 2016). However, the developmental timing of this shift and its interaction with race processing biases is largely unknown.

One way to examine the development and interaction of multiple face processing biases is to use a task that has been widely used as an index of expert processing in adults. The upright versus inverted faces task measures aspects of holistic and expert processing as shown by impaired processing of inverted faces relative to upright faces while controlling for low-level perceptual features (Farah et al., 1995; Freire et al., 2000; Mardo et al., 2018). This marker of enhanced face processing develops across the first several years of life (e.g., de Haan et al., 2003; Kato & Konishi, 2013; Sangrigoli & de Schonen, 2004; Schwarzer, 2000; Turati et al., 2004; Valentine, 1988; Xu & Tanaka, 2013; Yin, 1969) and is impacted by experience (for review, see Cashon & Holt, 2015). Using an inversion task, 5- to 8-year-olds recognized upright faces better than inverted faces across multiple species (i.e., human and nonhuman primate faces; Pascalis et al., 2001). Similarly, 3- to 5-year-old children were better at recognizing a previously learned upright compared to inverted face (Sangrigoli & de Schonen, 2004). However, an “inverted inversion effect” has also been reported such that 2- to 4-year-old children were quicker to identify a target face in the inverted than the upright orientation, suggesting an early reliance on featural processing (Brace et al., 2001). Moreover, after being habituated to a face and then asked to remember the learned face when paired with a novel face, children showed greater recognition deficits between inverted compared to upright own-race faces than between inverted compared to upright other-race faces (Sangrigoli & de Schonen, 2004).

Eye-tracking has also been used to examine differences between upright and inverted faces. Adults tend to primarily fixate the nose and mouth regions of inverted faces and the eyes of upright faces (Xu & Tanaka, 2013), and the upper half of both upright and inverted faces (Barton et al., 2006; Man & Hills, 2016). In adults, directing the first fixation to the eyes for both upright and inverted faces decreases the recognition advantage for upright compared to inverted faces relative to directing the first fixation to the mouth (Hills et al., 2013a). Infants, however, disproportionately scan the eye region regardless of face orientation (Oakes & Ellis, 2013). These findings suggest that infants and adults exhibit different fixation strategies when viewing upright and inverted faces and these strategies are malleable in adults.

1.1 | The current investigation

Both face processing biases (race, gender/sex) and inversion effects develop across the first years of life and are thought to be experience dependent (for reviews, see Cashon & Holt, 2015; Scherf & Scott, 2012). However, our understanding of the developmental trajectory of face processing biases is limited due to the lack of work examining early childhood. In the present investigation, the primary research goal is to examine how face race and sex/gender impact young children’s face processing. To this end, the present investigation uses multiple measures of visual fixations (first fixation duration, first fixation location, average fixation duration, and fixation number) to examine the extent to which 3- to 6-year-old children differentially fixate and attend to upright and inverted faces that vary by race and gender/sex.

Using measures of visual fixations allows for making inferences about several aspects of visual attention, including visual orienting, attention shifting, and efficiency (e.g., Arizpe et al., 2012; Kato & Konishi, 2013; Schlesinger et al., 2007). Here, aspects of visual orienting were examined with first fixation duration and the proportion of first fixations to each interest area (left eye, right eye, nose, or mouth). Measures of first fixations have previously been used to examine visual orienting, and the location and duration of the first fixation can provide useful information about attention to faces (Arizpe et al., 2012; Hsiao & Cottrell, 2008). Left and right eyes were analyzed separately due to previous reports suggesting that both adults (Butler et al., 2005; Guo et al., 2012) and children (5 years and older: Aljuhanay et al., 2010; Balas & Moulson, 2011) demonstrate a gaze bias toward the left side of faces, suggesting right hemispheric specialization for face processing.

Further, average fixation duration has been used to measure how efficiently information is gathered from a face (Kato & Konishi, 2013), while fixation number is thought to reflect shifts in attention (Schlesinger et al., 2007). These measures will be used to index fixation strategies and to examine the extent to which differences in face race and sex/gender impact visual fixations as well as the face inversion effect.

2 | MATERIALS AND METHODS

All methods and procedures used in this study were reviewed and approved by the University Institutional Review Board. Data collection for this study occurred between March 15, 2017 and November 15, 2019.

2.1 | Participants

Forty-nine child participants were recruited for this study via an existing database of parents who agreed to be contacted for research. Parents of all children gave written informed consent before participating, and all children who were able gave verbal assent. Parents were paid $10 for participation and children were given a small toy. Of the 49 children recruited, two were not included in the final sample due to equipment failure ($n = 1$) or equal exposure to both races used as stimuli in this study ($n = 1$).

The final sample consisted of 47 children ages 3–6 years old (mean age = 4.37 years, 26 females). This sample size is based on previous reports examining children’s face processing (e.g., Pascalis et al., 2001; Picozzi et al., 2009; Sangrigoli & de Schonen, 2004). All participants were typically developing, right-handed, had no history of neurological problems, and had normal or corrected to normal vision. Of the final sample, 38 children racially identified as White (80.8%), five identified as Asian and White (10.6%), two identified as Asian (4.2%), one identified as White and Pacific Islander/Hawaiian (2.1%), and one identified as White and American Indian/Alaska Native (2.1%). Three of the children who had racially identified as White also ethnically identified as Hispanic or Latinx (6.4%).

Prior to visiting the laboratory, caregivers were asked to complete a questionnaire regarding prior experience (i.e., with whom the child spends the majority of their time) and demographic information (Table 1). Caregivers’ responses were used to determine each child’s most familiar race (the race with which they have had the most experience). Of the 47 primary caregivers, 41 completed the questionnaire. For those children whose parents did not complete the questionnaire, the child’s own race was classified as their most familiar race ($n = 6$; Asian = 1; White = 5). In the final sample, 41 children were coded with White faces as their most familiar race (87.2%),

TABLE 1 Participant demographics

	Participant age (years)				
	3	4	5	6	Total
N	20	12	12	3	47
Sex					
Male	7	5	8	1	21
Female	13	7	4	2	26
Race					
White	17	9	9	1	36
Asian	0	1	1	0	2
White and Asian	2	2	1	0	5
White and Hispanic	1	0	0	2	3
White and Pacific Islander/Hawaiian	0	0	1	0	1
Primary caregiver					
Mother	9	8	7	2	26
Father	2	1	0	0	3
Both equally	7	3	2	0	12
No response	2	0	3	1	6
Combined Family Income per year					
<$45,000	0	1	2	0	3
$45,000–$75,000	5	2	1	0	8
>$75,000	11	9	6	2	28
Does not wish to disclose/No response	4	0	3	1	8
Parents' highest level of education					
Doctoral degree (at least one parent)	6	4	4	0	14
Master's degree (at least one parent)	9	7	3	1	20
4-year college degree or professional degree (at least one parent)	3	1	1	1	6
High school graduate (at least one parent)	0	0	1	0	1
No response	2	0	3	1	6
Participant's siblings					
Older (at least one)	4	0	0	0	4
Younger (at least one)	7	11	7	1	26
Both older and younger	4	1	5	2	12
None	5	0	0	0	5

and six (12.8%) were coded with Asian faces as their most familiar race.

The questionnaire was also used to determine the participant's primary caregiver, based on percentage of time spent with each caregiver in an average week. Almost all primary caregivers were the biological parent of the child ($n = 1$ adoptive or surrogate parent). The majority of children's parents indicated that their mother was the primary caregiver ($n = 26$) or that both a mother and a father spent equal time with the child ($n = 12$). A small percentage ($n = 3$) of the parents noted that the father spent more time with the child in an ordinary week. As noted, there were six participants whose caregiver did not complete the questionnaire and therefore we do not have data regarding caregiving experience. Other information from the experience questionnaire is presented in Table 1.

2.2 | Stimuli

Stimuli included static images of four White and Asian female or male faces. White faces were selected from the NimStim face stimulus set (Tottenham et al., 2009), and Asian faces were from the CUHK Face Sketch database (Wang & Tang, 2009). Both face sets have data related to validity and reliability of the stimuli and models with neutral expressions were selected based on these reports. All faces were shown from

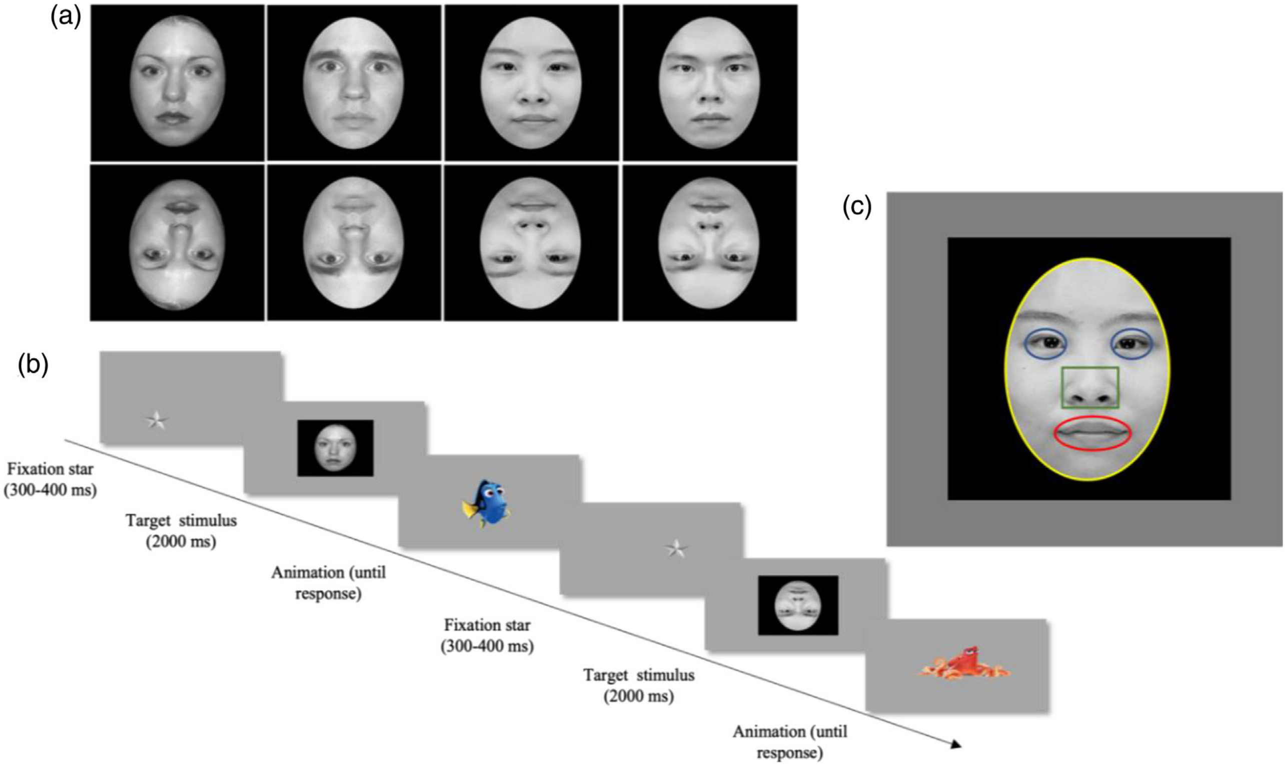

FIGURE 1 Stimuli, design, and areas of interest (AOIs). (a) Example stimuli used for this task include upright and inverted White and Asian, male, and female faces. White faces were from NimStim face stimulus set (Tottenham et al., 2009), and Asian faces were from the CUHK Face Sketch database (Wang & Tang, 2009). Due to publication limitations, the NimStim face examples above were not the faces used in the task. (b) Example of two individual trials, including the randomly varied fixation star prior to the trial and the attention-getting animation that appeared after the trial. Children pressed a key on a keyboard if they "found Dory." (c) Example AOIs for one face. AOIs were created around the face (yellow), the eyes (blue), the nose (green), and the mouth (red).

the front and were unfamiliar to the participants. The four photos used were either a White male, White female, Asian male, or Asian female. One photo of each type was presented as an upright photo, and one of each type was inverted by rotating the face 180 degrees, creating a total of eight face conditions (Figure 1a). All photos were cropped in a standard oval to remove any hair or surrounding external features, converted to grayscale, and equated (within a range) for luminance and contrast using the SHINE toolbox (Willenbockel et al., 2010). These changes to the face stimuli were designed to discourage reliance on any salient external features and control for differences related to low-level visual features within and across races. The faces were then placed on a black square using Adobe Photoshop. Each stimulus was 15.5 cm × 15.5 cm on the screen and subtended a visual angle of 14.72 degrees (14° 43′ 0.19″) horizontally and vertically when viewed from a distance of 60 cm. Stimuli were presented using SR Research Experiment Builder (SR Research Ltd, Mississauga, Ontario, CA) on a 17-inch ViewSonic monitor.

2.3 | Apparatus

Participants sat in a height-adjustable chair approximately 60 cm away from the 17-inch ViewSonic LED flat-screen monitor with the following features: 160° (H) 160° (V) viewing angle, 1000:1 contrast ratio, 5 ms response time, 1280 × 1024 resolution, and 250 cd/m^2 brightness. An EyeLink 1000 Plus Remote camera eye tracker (SR Research Ltd, Mississauga, Ontario, CA) was placed at the bottom of the screen to record visual fixations during free exploration of the stimuli. The SR EyeLink 1000 Plus eye-tracking system uses a real-time and timing-sensitive operating system, allowing for low variability. The eye-tracking camera recorded the reflection of an infrared light source on the cornea relative to the pupil at a frequency of 1000 Hz. Fixation location and duration were recorded during free exploration of the stimuli with an average accuracy of 0.5° using a 16-mm lens and a 940-nm infrared illuminator. Each fixation was defined by a threshold of 100 ms in a dispersion region of 1 degree of visual angle. A target sticker was placed on the participant's forehead to track their head position if the pupil could not be captured (i.e., during blinks), with a 1 ms blink recovery time, and allowed for free movement during the task.

2.4 | Procedure

Participants and a caregiver came into the laboratory and children first completed an electroencephalogram task (not reported here). Participants then completed the eye-tracking task that was presented as a "Finding Dory" game. During the eye-tracking task, the child sat in a height-adjustable chair in front of a computer screen, while a caregiver sat in a chair behind the child. Two experimenters were present throughout the task; one experimenter controlled the task and eye tracker, while the other experimenter sat next to the child and redirected their attention to the screen as needed.

The eye tracker was first calibrated to focus on the participant's right pupil by asking the child to follow colorful moving targets that appeared at three locations on the screen in a random order. The right eye was chosen to be in line with previous reports (e.g., Oakes & Ellis, 2013) and for consistency. The Eyelink HV3 calibration type was used, with the three calibration points forming a triangle on the top middle, bottom left, and bottom right corners of the screen (SR Research, Mississauga, Ontario, Canada). The calibrated area within this triangle fully covered the size of the face stimuli. A fixation at a calibration target was judged as correct if the spatial pattern of recorded gaze location corresponded with the pattern of calibration targets being presented. Calibration accuracy was validated by examining errors between the participant's measured fixation location and the target location. Calibration and validation were repeated if the deviation was greater than 1°.

After successful calibration, the task began. Before each trial, a drift check was performed to ensure continued calibration accuracy. Children fixated on a randomly positioned grayscale star on the screen for approximately 300–400 ms, while the experimenter pressed a key to check that the fixation data matched the target location, triggering the presentation of the stimuli when the participant looked at the screen. A within-subject design was used such that each child was exposed to eight trial types corresponding to the eight experimental conditions: race (familiar, unfamiliar), sex (male, female), and orientation (upright, inverted). Stimuli were presented centrally, in a pseudorandom order, with the constraint that the same face could not appear twice in a row. Stimuli were presented until the child fixated the face for 2000 ms. After 2000 ms of accumulated fixation time to the face, the face disappeared, one of several animated characters from the movie "Finding Dory" appeared, and children were asked to press the space bar when they "found" Dory. Children were given a sticker to add to a sticker book every time they correctly identified Dory. The game was intended to encourage attentiveness throughout the task. After the response, the next trial began with a randomly positioned star (described above). Fixation data (e.g., average fixation duration; fixation number) were collected until the 2000 ms threshold of accumulated fixation time to the face was reached. Children completed an average of 44 trials (range = 20–55 trials, $SD = 8.85$), with an average total trial duration of 5.05 s (range = 2.19–12.93 s, $SD = 1.39$ s).

2.5 | Data processing

To analyze participants' visual fixations, five areas of interest (AOIs) were defined for each face: the whole face, left eye, right eye, nose, and mouth. When the eyes were taken together, the three internal AOIs (eyes, nose, and mouth) were equal in size and each covered 8% of the total area of the face, together covering 24% of the face (Figure 1c). Based on previous reports, fixations to the left and right eyes were analyzed separately (Arizpe et al., 2012; Barton et al., 2006). Trials were only included in final analyses if there was at least one fixation onto any of the internal interest areas. If the participant fixated only on the "whole face" AOI, but never onto any of the internal AOIs, the trial was excluded. After excluding 103 trials for which participants did not fixate on an internal AOI, there was a total of 1899 trials included in the analyses, or an average of 40 trials per participant (range = 18–53, $SD = 8.92$). Of the 103 excluded trials, there was no difference between face race (57 familiar race trials excluded; 46 unfamiliar) or sex (57 male trials excluded; 46 female). Participants were more likely not to fixate an internal AOI for upright (95 trials excluded) compared to inverted (eight trials excluded) faces. There was also no relation between participant age and the number of trials excluded due to lack of internal AOI fixations ($r = .015$, $p = .31$).

Utilizing the fixation data from each trial, four dependent variables were chosen to examine both visual orienting and attention. To measure visual orienting, the first fixation onto an interest area was recorded. For each trial, the first fixation was defined as the first fixation onto an internal AOI; fixations toward any other area on the screen prior to fixating on an internal AOI were removed. First fixation duration was calculated by averaging the duration of the first fixation onto an AOI for each condition within each participant. First fixation location was calculated as a proportion by dividing the number of trials per condition where a participant first fixated on each AOI by the total number of trials for that condition for each participant (see Bindemann et al., 2009).

In addition, the number of fixations for each trial was counted and the duration of all fixations was averaged for each condition within participants. These averages spanned the total trial duration that varied across participants. Fixation number and average fixation duration were analyzed separately because increases or decreases in total fixation duration may be related to either (a) longer fixation durations or (b) a greater number of fixations (e.g., Elhamiasl et al., 2022). By measuring both, information about visual strategy use and attention can be inferred.

Prior to analysis, outliers were identified and removed. The means and standard deviations were calculated separately for each of the four dependent measures, and any values that were 3 or more standard deviations away from the mean were removed. Any participant with one or more condition identified as an outlier was removed from that analysis. An average of 3.8 participants were removed from each analysis, leaving a range of 41–47 participants for each analysis. The number of participants included in each analysis are reported in the results section.

2.6 | Statistical analyses

Separate 2 (face sex: male or female) × 2 (face race: familiar or unfamiliar) × 2 (face orientation: upright or inverted) repeated-measures

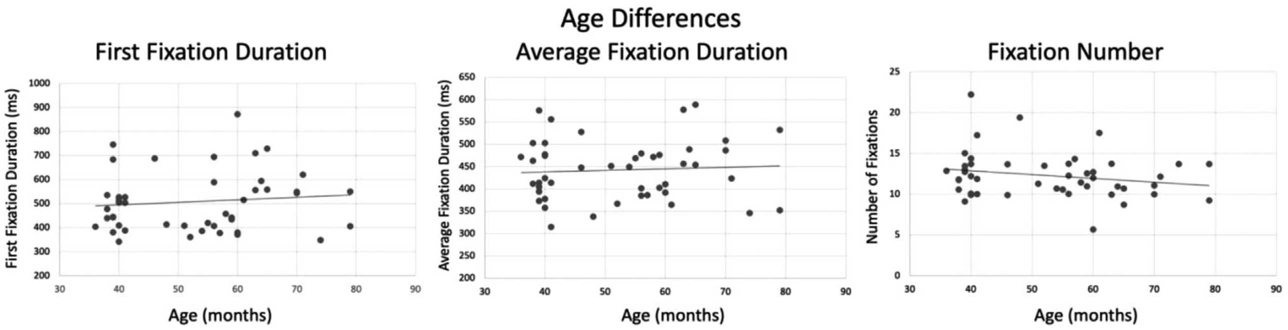

FIGURE 2 Scatterplot of each dependent variable by age, collapsed across conditions. No significant age differences were present for first fixation duration (left), average fixation duration (middle), or fixation number (right) (*rs* = .06–.21, *ps* = .16–.68).

ANOVAs were run for first fixation duration, average fixation duration, and fixation number. For first fixation location, the four predetermined interest areas (left eye, right eye, nose, and mouth) were also used as a repeated measures independent variable, resulting in a 2 (face race: familiar, unfamiliar) × 2 (face sex: male, female) × 2 (face orientation: upright, inverted) × 4 (AOI: left eye, right eye, nose, mouth) repeated-measures ANOVA.

Results were Bonferroni corrected for multiple comparisons for each analysis, and any significant interactions were followed up using Bonferroni-corrected paired comparisons. Both corrected (p_c) and uncorrected (p_u) values are reported.

3 | RESULTS

3.1 | Age differences

Age was included in the analyses as a continuous variable, measured in months, and age differences were examined using Pearson's *r* correlations. No significant correlations with age were found for first fixation duration, average fixation duration, or fixation number (*rs* = .06–.21, *ps* = .16–.68) (Figure 2). Difference scores were then calculated for each face group (i.e., upright–inverted, female–male, and familiar race–unfamiliar race) to determine whether age differentially impacts fixations across conditions. No significant condition differences with age were present (*rs* = .013–.16, *ps* = .274–.931). Given the lack of significant changes across age, all subsequent analyses were collapsed across age.

3.2 | First fixation duration

Forty-one participants were included in the first fixation duration analysis after six participants were marked as outliers ($M \geq 3$ *SDs*) and removed. A significant main effect of face orientation (upright, inverted) was found ($F(1,40) = 11.349$, $p = .002$, $\eta^2 = .221$), such that there were longer first fixations to upright ($M = 524.024$, $SEM = 22.199$) than inverted ($M = 443.677$, $SEM = 18.457$) faces (Figure 3a).

3.3 | First fixation location

There were no outliers for first fixation location and so all 47 participants were included in the analysis. There was a significant main effect of AOI ($F(3, 44) = 30.676$, $p < .001$, $\eta^2 = .425$). Follow-up tests revealed that the highest proportion of first looks was toward the nose ($M = 0.431$, $SEM = 0.022$) compared to the right eye ($M = 0.141$, $SEM = 0.016$), left eye ($M = 0.220$, $SEM = 0.020$), and mouth ($M = 0.208$, $SEM = 0.015$) (all uncorrected $ps < .001$, all corrected $ps < .01$), as well as a greater proportion of first looks to the mouth than the right eye ($p_u = .008$, $p_c = .048$). There were no differences between the left and right eye ($p_u = .016$, $p_c = .096$), or between the left eye and the mouth ($p_u = .660$, $p_c = 1.00$) (Figure 3b).

The main effect of AOI was qualified by a significant interaction between AOI and face orientation ($F(3, 44) = 39.883$, $p < .001$, $\eta^2 = .498$). Follow-up tests revealed significant differences in first fixation locations between upright and inverted faces for every AOI, with a greater proportion of first looks to the left and right eye for upright compared to inverted faces (uncorrected $ps < .001$, corrected $ps < .01$), and a greater proportion of first looks to the nose and mouth for inverted compared to upright faces (uncorrected $ps < .001$, corrected $ps < .01$) (Figure 3c). Follow-up tests also revealed that for upright faces, the majority of first looks were to the eyes (right eye: $M = 0.228$, $SEM = 0.030$; left eye: $M = 0.355$, $SEM = 0.034$) and nose ($M = 0.325$, $SEM = 0.030$), with a significantly lower proportion of first looks to the mouth than the other three AOIs (uncorrected $ps < .001$, corrected $ps < .01$), and no differences between the eyes or nose. For inverted faces, most first looks were to the nose ($M = 0.538$, $SEM = 0.027$) and mouth ($M = 0.325$, $SEM = 0.029$), with a greater proportion of first looks to the nose than all three other AOIs (uncorrected $ps < .001$, corrected $ps < .01$), and a greater proportion of first looks to the mouth than either eye (uncorrected $ps < .001$, corrected $ps < .01$), but no difference between the eyes ($p_u = .056$, $p_c = .896$) (Figure 3d).

3.4 | Average fixation duration

Forty-four participants were included in the average fixation duration analysis after three participants were identified as outliers ($M \geq 3$ *SDs*)

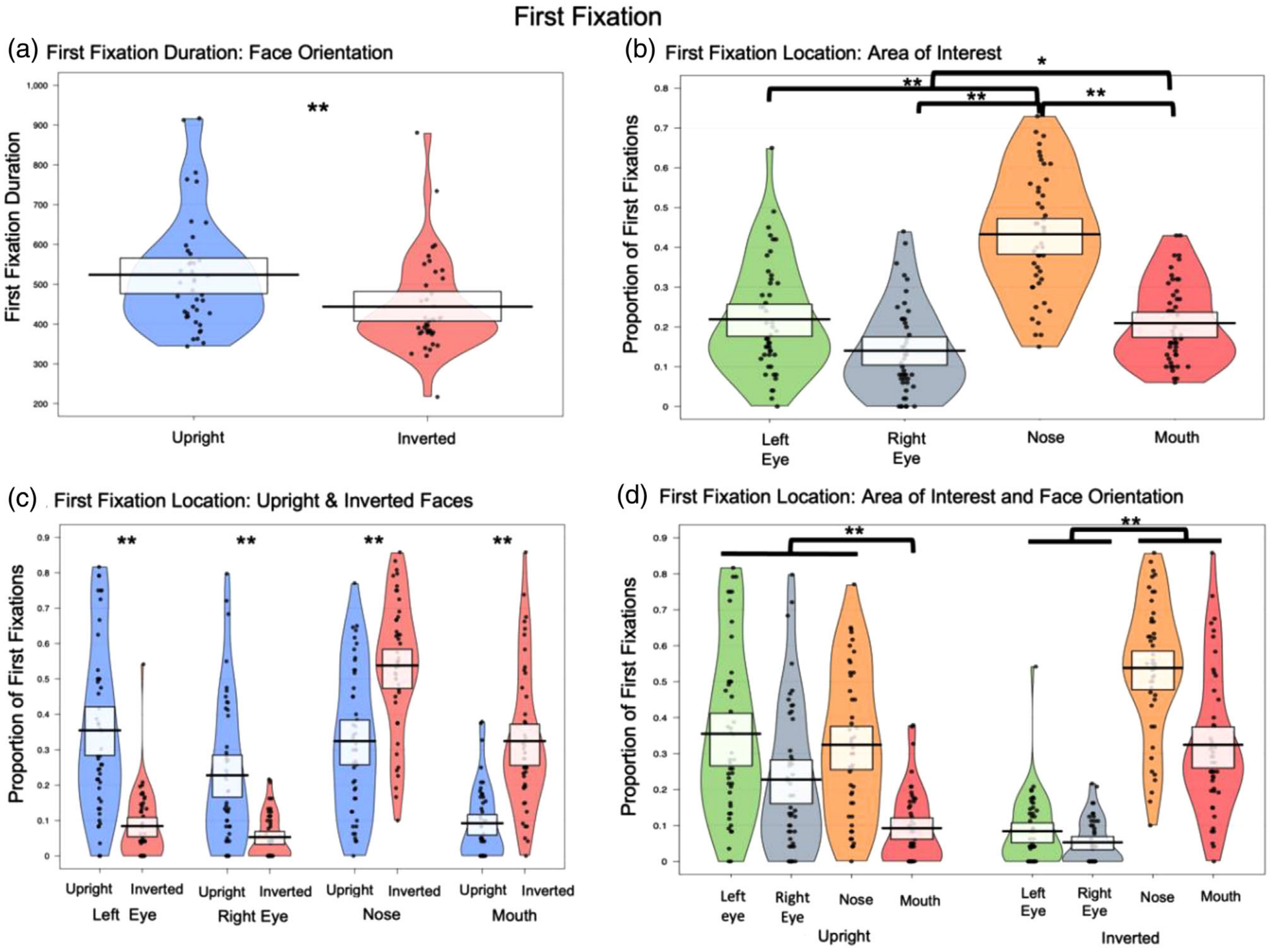

FIGURE 3 Differences in first fixation duration (a) and proportion of first looks to each AOI (b–d). Within each bar, each participant's mean proportion of first looks to that AOI is marked with a dot, the black line represents the overall mean for that AOI, and the white box represents the 95% confidence interval. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. (a) Collapsing across face race and sex, there were longer first fixations to upright than inverted faces. (b) Collapsing across all face types, the majority of the first looks were to the nose, and there were no differences between the proportions of first looks to the eyes or mouth except for more first looks to the mouth than the right eye. (c) Comparing upright and inverted faces (averaged across face race and sex), there was a greater proportion of first looks to the eyes in upright compared to inverted faces, and a greater proportion of first looks to the nose and mouth in inverted compared to upright faces. (d) Looking at the pattern of first fixations between upright and inverted faces, we see mostly first looks to the eyes and nose in upright faces and the nose and mouth in inverted faces.

and removed. Like for first fixation duration, a significant main effect of face orientation (upright, inverted) was found ($F(1,43) = 18.333$, $p < .001$, $\eta^2 = .299$), such that there were longer average fixation durations to upright ($M = 447.913$, $SEM = 10.076$) than inverted ($M = 425.332$, $SEM = 9.581$) faces (Figure 4a).

This main effect of face orientation was qualified by an interaction between face orientation and race ($F(1,43) = 4.131$, $p = .048$, $\eta^2 = .088$), and follow-up tests revealed greater fixation durations toward upright ($M = 454.408$, $SEM = 11.14$) than inverted ($M = 421.498$, $SEM = 10.4$) unfamiliar-race faces ($p_u < .001$, $p_c < .01$), but no significant differences between upright and inverted familiar-race faces ($p_u = .093$, $p_c = .372$), upright familiar-race compared to unfamiliar-race faces ($p_u = .038$, $p_c = .152$), or inverted familiar-race compared to unfamiliar-race faces ($p_u = .276$, $p_c = 1.00$) (Figure 4a).

There was also a main effect of face sex (male, female) ($F(1,43) = 6.752$, $p = .013$, $\eta^2 = .136$), such that there were longer average fixation durations to male ($M = 442.692$, $SEM = 9.541$) than female ($M = 430.553$, $SEM = 9.965$) faces (Figure 4a).

3.5 | Fixation number

Forty-two participants were included in the fixation number analysis after five participants were marked as outliers ($M \geq 3$ SDs) and removed. A main effect of face orientation (upright, inverted) was found ($F(1,41) = 5.107$, $p = .029$, $\eta^2 = .111$), such that there were more fixations to inverted ($M = 11.884$, $SEM = 0.330$) than upright ($M = 11.352$, $SEM = 0.290$) faces (Figure 4b).

The main effect of orientation was qualified by a significant interaction between orientation and race ($F(1,41) = 10.242$, $p = .003$, $\eta^2 = .200$). Follow-up tests revealed more fixations to upright familiar-race ($M = 11.792$, $SEM = 0.356$) than upright unfamiliar-race

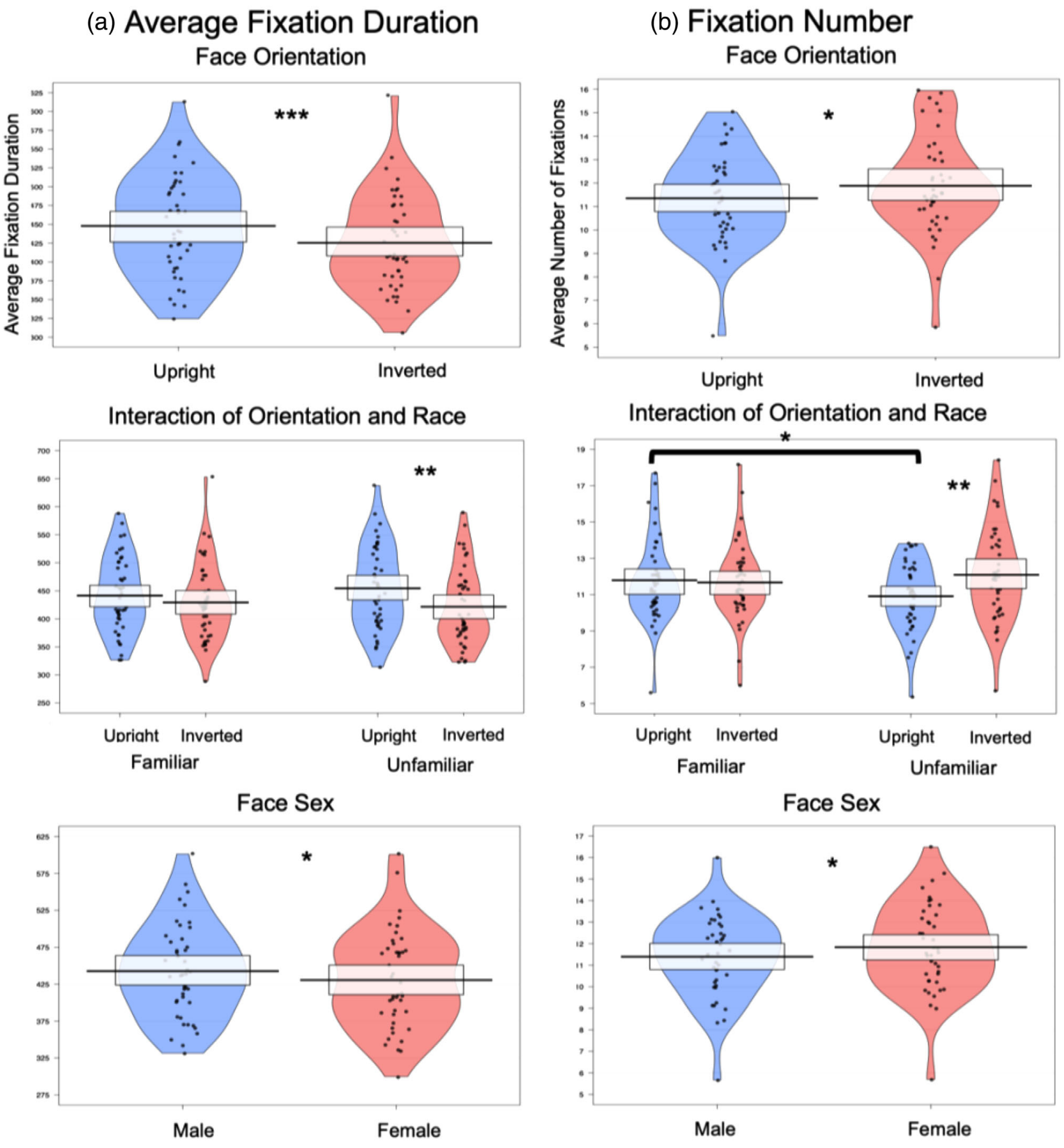

FIGURE 4 Differences in the average fixation duration (ms) and number of fixations based on face type. (a) Collapsing across face race and sex, there were longer fixation durations for upright compared to inverted faces (top). This is qualified by race, with longer fixations for upright unfamiliar-race faces compared to inverted unfamiliar-race faces, but no difference between upright and inverted familiar-race faces (middle). There were also longer fixation durations for male compared to female faces when collapsing across orientation and race (bottom). (b) Collapsing across face race and sex, there was a greater number of fixations to inverted faces compared to upright faces (top). This was qualified by race, with more fixations to familiar-race than unfamiliar-race upright faces, but no differences between familiar- and unfamiliar-inverted faces, as well as more fixations to inverted than upright unfamiliar-race faces, but no differences between upright and inverted familiar-race faces (middle). There were also more fixations to female than male faces when collapsing across face race and orientation (bottom). Within each bar, each participant's mean is marked with a dot, the black line represents the overall mean, and the white box represents the 95% confidence interval. *$p < .05$, **$p < .01$, ***$p < .001$

($M = 10.912$, $SEM = 0.290$) faces ($p_u = .003$, $p_c = .012$), but no difference between inverted familiar- and unfamiliar-race faces ($p_u = .270$, $p_c = 1.00$) (Figure 4b).

Follow-up tests also revealed more fixations to inverted ($M = 12.095$, $SEM = 0.396$) than upright ($M = 10.912$, $SEM = 0.290$) unfamiliar-race faces ($p_u = .002$, $p_c = .008$), but no difference between inverted and upright familiar-race faces ($p_u = .851$, $p_c = 1.00$) (Figure 4b).

There was also a main effect of face sex/gender (male, female) ($F(1,41) = 4.881$, $p = .033$, $\eta^2 = .106$), such that there were more fixations for female ($M = 11.840$, $SEM = 0.318$) than male ($M = 11.396$, $SEM = 0.291$) faces (Figure 4b).

4 | DISCUSSION

Face processing biases (e.g., race, gender/sex) develop and change across the first years of life and are thought to be experience dependent (Scherf & Scott, 2012). However, our understanding of the developmental trajectory of face processing biases is limited due to the lack of work examining early childhood. The primary aim of this investigation was to examine how face race and sex/gender impacts a key index of face processing, the inversion effect, using eye tracking in 3- to 6-year-old children. This work has several important findings. First, there was no evidence of age differences for first fixation duration, average fixation duration, or fixation number. Second, the first fixation location differed and was longer in duration for inverted compared to upright faces. Third, average fixation durations were longer for upright compared to inverted unfamiliar-race face trials and for male compared to female face trials. Finally, the fixation number was greater for upright familiar-race compared to unfamiliar-race face trials and for female compared to male face trials. These findings highlight the visual strategies children use when viewing faces and the results can be interpreted within a developmental framework highlighting the presence of both continuities and discontinuities based on experience and task goals (Scherf & Scott, 2012).

The present results showed no age-related differences for visual fixations while children, from 3 to 6 years of age, viewed upright and inverted faces that varied by race and sex/gender. These findings may suggest that the current measures of visual fixations and the inversion effect are mature by 3 years of age. However, it is also possible that future work with more participants at each age, or using longitudinal samples, could show significant age-related differences. Several other studies have also reported no age-related differences for the inversion effect after 12 months of age (for review, see Cashon & Holt, 2015).

In the current study, the first fixation was typically directed to the eyes and nose of upright faces and to the nose and mouth of inverted faces (see Figure 3d). However, across upright and inverted faces, there was also a greater proportion of first fixations toward the nose than toward the eyes or mouth. Further, there were no differences in first fixations toward the left compared to the right eye, suggesting the left side face bias present in adults (e.g., Butler et al., 2005) may not be present, for the first fixation, for 3- to 6-year-old children. In this investigation, children fixated a randomly located fixation star prior to the presentation of the face, allowing for analysis of the first fixation without the influence of a biased start position (Arizpe et al., 2012). Given that the initial two fixations are thought to be most important for recognition (Hsiao & Cottrell, 2008), it is unsurprising that the first fixation would be directed toward the center of the face in order to efficiently gather information. For inverted faces, children may have naturally looked more toward the larger interest areas, as the AOIs for each eye were smaller than the nose or mouth (4% of the face area compared to 8%). However, if this were the case, one would expect greater looking to the larger interest areas for both upright and inverted faces.

The pattern of first fixations reported here are consistent with evidence from adults but differ from infants' fixation patterns when viewing upright and inverted faces. That is, adults direct their visual attention toward the top half of the stimuli and not to a specific facial feature (Barton et al., 2006; Man & Hills, 2016), whereas infants have been shown to focus on the eye region regardless of stimulus orientation (Oakes & Ellis, 2013). However, recent findings show a general looking preference toward the upper visual field compared to the lower visual field in infants (Tsurumi et al., 2023), which may explain the differences in first fixation location between upright and inverted faces. Moreover, previous work with adults shows that the location of the first fixation is predictive of recognition accuracy, with best recognition performance when the first fixation is directed to the eyes (Hills et al., 2013a).

The first fixation duration was also greater for upright faces relative to inverted faces, suggesting that selecting and sustaining visual attention is impacted by face inversion in 3- to 6-year-old children. The current inversion effects may reflect disrupted processing of inverted faces, as is typically reported in adults (Valentine, 1988), but suggest this disruption may be driven by the first visual fixation. The longer duration first fixations to upright faces relative to inverted faces may indicate enhanced selective attention and encoding for highly experienced stimuli. Our findings suggest that the first fixation may be an important contributor to the face inversion effect in children. Future work should examine whether the first fixation is also important for face identity discrimination and recognition in children.

In line with previous work, results suggest that the first fixation may be important for visual selective attention, which enhances learning for attended information and suppresses irrelevant information (Kastner et al., 1999; Markant et al., 2015, 2016). To further examine the impact of face orientation on visual fixations, a spatial cueing task could be used to measure inhibition of return or the suppression of a cued stimulus in favor of the noncued stimulus after a delay. In 9-month-old infants, spatial cueing to own- and other-race faces led to face discrimination regardless of face race (Markant et al., 2016), suggesting that selective attention drives face encoding above and beyond long-term experience with faces. One avenue of future research would be to examine inhibition of return in older children to determine whether these effects are stable across development.

Further, there were shorter duration and a greater number of fixations for inverted relative to upright face trials, suggesting more frequent shifts in attention for inverted faces and more efficient processing for upright faces (Kato & Konishi, 2013). The presence of the face inversion effect indicates 3- to 6-year-old children are differentially processing upright versus inverted faces, suggesting adult-like first-order configural/holistic processing of faces (Maurer et al., 2002). Although behavior was not measured in the present investigation, the current results appear to support the classic adult inversion effect with greater efficiency for processing upright faces, rather than the inverted inversion effect reported in children (Brace et al., 2001). Further, the differences in fixation duration and fixation number between upright and inverted face trials were driven by the unfamiliar-race faces. While this finding is unexpected, it is possible that these results are task and measure dependent. Future studies should aim to include both visual fixations and behavioral measures to more intricately piece together the mechanisms underlying these differences.

While face race impacted the face inversion effects, there were no main effects of race or interactions between race and sex. The absence of a main effect for face race is inconsistent with previous work showing a shorter duration and greater number of fixations for familiar-race compared to unfamiliar-race faces in both children and adults (e.g., Goldinger et al., 2009; Hu et al., 2014; Wu et al., 2012). Although inconsistent, the stimuli used here were highly controlled by converting all faces to grayscale, removing hair and other external features, and equating (within a range) the luminance and contrast of faces across races. It is possible that previously reported race-dependent differences in adults and children may be explained by the presence of these low-level stimulus differences.

The importance of disproportionate levels of experience with individuals of the same race as one's primary caregiver (Scherf & Scott, 2012) is highlighted by the greater number of fixations to familiar-race compared to unfamiliar-race faces for the upright condition but not the inverted condition. Unlike when faces are upright, when faces are inverted children do not readily differentiate between the familiar and the unfamiliar race. This interpretation is supported by previous work in which 3- 5-year-old children recognized upright own-race faces better than upright other-race faces but showed no differences for inverted faces (Sangrigoli & de Schonen, 2004).

Finally, there were shorter duration and a greater number of fixations for female compared to male face trials. Although past work shows mixed results for the direction of face sex/gender effects (e.g., Quinn et al., 2002; Ramsey et al., 2005), the current results support infant findings showing longer fixation durations toward male faces (Ramsey et al., 2005). However, prior work has mainly examined face sex/gender effects for infants, with little to no work examining visual fixations toward male and female faces in children. Our results demonstrate that children differentiate male and female faces, suggesting more active scanning for female faces (Kato & Konishi, 2013). Longer fixation durations toward male faces could relate to novelty or unfamiliarity, and the need for more time to process male faces (Ramsey et al., 2005). However, it is unclear whether differences in visual attention contribute to downstream sex/gender behavioral biases. Although measures of face recognition are not available here, the scanning strategies implemented in free exploration tasks could provide useful information about how children learn from different faces. Adult work suggests that more dynamic exploration patterns are implemented when viewing familiar faces, with more frequent and shorter fixations characterizing active exploration of own-race faces (i.e., familiar) versus other-race faces (Wu et al., 2012) and adult (i.e., familiar) versus nonadult faces (Proietti et al., 2015). Similarly, the present results speak in favor of an active fixation strategy for female faces in children, characterized by more fixations of shorter duration during trials with female faces. In sum, the differences reported here likely suggest that female faces continue to be more salient and/or experienced by preschool-age children than male faces.

Overall, the current findings show that familiarity with face features including race and sex/gender impacts fixation strategies, including the inversion effect. The results presented here provide evidence for an experience-dependent view of face processing biases and suggest that visual fixations in early childhood differ for faces that share characteristics of a child's primary caregiver compared to faces that do not share similar characteristics (Scherf & Scott, 2012). Children exhibit shorter duration and a greater number of fixations when presented with more familiar face types, such as female compared to male faces or upright familiar-race compared to unfamiliar-race faces. Children show different visual fixation patterns relative to the race and sex of the face, likely due to greater experience with certain face groups relative to others (Rennels & Davis, 2008; Sugden et al., 2014). However, the current results suggest that the first fixation is not impacted by face race or sex and may be less sensitive to previous experience with face groups. The first fixation did differ based on face orientation, suggesting that the face inversion effect in children may be partially carried by the first fixation, supporting previous literature with adults (Arizpe et al., 2012; Hills et al., 2013a).

Given the limited sample and stimuli in the present investigation, the generalization of these findings is limited to the groups and ages examined. Future work examining visual fixations for race and sex/gender in other groups or cultures would provide necessary data to determine whether the current results are sensitive to cultural differences. Given an extensive body of work suggesting experience is critical for face processing (for reviews, see Anzures et al., 2013; Lee et al., 2013; Scherf & Scott, 2012; Scott & Arcaro, in press), children with different visual experiences should show experience-dependent fixation effects, in line with the present investigation. Since the present study only used White and Asian faces and participants, future work would benefit from inclusion of additional races as well as participants with a variety of developmental experiences. Further, the present study only included one face of each type (White male, White female, Asian male, and Asian female), and thus differences reported here could be related to the individual faces used. Including a greater number of faces would increase the generalizability of the results. Finally, including face stimuli that have not been converted to grayscale or equated in luminance and contrast and comparing results to the current stimulus set may allow for a better understanding of how stimulus features or task demands impact visual fixations to faces.

5 | CONCLUSION

In summary, face race and sex/gender impact visual fixation strategies and a key index of face processing, the inversion effect, in 3- to 6-year-old children. Children's visual fixations differ when faces are presented in novel positions (i.e., inverted), if they are from a familiar or unfamiliar race group, or if they appear male or female. The face inversion effect is carried, at least in part, by the initial fixation to face features, while face race and sex do not impact the initial fixation, instead emerging over longer periods of looking. These findings suggest that visual attentional biases seen in infancy continue into early childhood and are experience dependent.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the relevant discussions and work of Dr. Ethan Kutlu, Gabriella Silva, Zoe Pestana, Dr. Natalie Ebner, Dr. Timothy Vollmer, and the members of the University of Florida's (UF) Brain, Cognition and Development Laboratory.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

Data that support the findings of this study are openly available in Databrary at https://nyu.databrary.org/volume/1446.

ORCID

Julia Farrell https://orcid.org/0000-0002-9512-3315

REFERENCES

Aljuhanay, A., Milne, E., Burt, D. M., & Pascalis, O. (2010). Asymmetry in face processing during childhood measured with chimeric faces. *Laterality*, *15*(4), 439–450. https://doi.org/10.1080/13576500902972823

Anzures, G., Quinn, P. C., Pascalis, O., Slater, A. M., Tanaka, J. W., & Lee, K. (2013). Developmental origins of the other-race effect. *Current Directions in Psychological Science*, *22*(3), 173–178. https://doi.org/10.1177/0963721412474459

Arizpe, J., Kravitz, D. J., Yovel, G., & Baker, C. I. (2012). Start position strongly influences fixation patterns during face processing: Difficulties with eye movements as a measure of information use. *PLoS ONE*, *7*(2), e31106. https://doi.org/10.1371/journal.pone.0031106

Balas, B., & Moulson, M. C. (2011). Developing a side bias for conspecific faces during childhood. *Developmental Psychology*, *47*(5), 1472–1478. https://doi.org/10.1037/a0024494

Barton, J. J. S., Radcliffe, N., Cherkasova, M. V., Edelman, J., & Intriligator, J. M. (2006). Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception*, *35*(8), 1089–1105. https://doi.org/10.1068/p5547

Bindemann, M., Scheepers, C., & Burton, A. M. (2009). Viewpoint and center of gravity affect eye movements to human faces. *Journal of Vision*, *9*(2), 7–7. https://doi.org/10.1167/9.2.7

Bothwell, R. K., Brigham, J. C., & Malpass, R. S. (1989). Cross-racial identification. *Personality and Social Psychology Bulletin*, *15*(1), 19–25. https://doi.org/10.1177/0146167289151002

Brace, N. A., Hole, G. J., Kemp, R. I., Pike, G. E., Van Duuren, M., & Norgate, L. (2001). Developmental changes in the effect of inversion: Using a picture book to investigate face recognition. *Perception*, *30*(1), 85–94. https://doi.org/10.1068/p3059

Butler, S., Gilchrist, I. D., Burt, D. M., Perrett, D. I., Jones, E., & Harvey, M. (2005). Are the perceptual biases found in chimeric face processing reflected in eye-movement patterns? *Neuropsychologia*, *43*(1), 52–59. https://doi.org/10.1016/j.neuropsychologia.2004.06.005

Cashon, C. H., & Holt, N. A. (2015). Developmental origins of the face inversion effect. In J. B. Benson (Ed.), *Advances in child development and behavior* (Vol. 48, pp. 117–150). https://doi.org/10.1016/bs.acdb.2014.11.008

Damon, F., Quinn, P. C., Méary, D., & Pascalis, O. (2022). Asymmetrical responding to male versus female other-race categories in 9- to 12-month-old infants. British Journal of Psychology. https://doi.org/10.1111/bjop.12582

de Haan, M., Johnson, M. H., & Halit, H. (2003). Development of face-sensitive event-related potentials during infancy: A review. *International Journal of Psychophysiology*, *51*(1), 45–58. https://doi.org/10.1016/S0167-8760(03)00152-1

de Heering, A., Liedekerke, C. D., Deboni, M., & Rossion, B. (2010). The role of experience during childhood in shaping the other-race effect. *Developmental Science*, *13*(1), 181–187. https://doi.org/10.1111/j.1467-7687.2009.00876.x

Elhamiasl, M., Silva, G., Cataldo, A. M., Hadley, H., Arnold, E., Tanaka, J. W., Curran, T., & Scott, L. S. (2022). Dissociations between performance and visual fixations after subordinate- and basic-level training with novel objects. *Vision Research*, *191*, 107971. https://doi.org/10.1016/j.visres.2021.107971

Farah, M. J., Tanaka, J. W., & Drain, H. M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance*, *21*(3), 628–634. https://doi.org/10.1037/0096-1523.21.3.628

Freire, A., Lee, K., & Symons, L. A. (2000). The face-inversion effect as a deficit in the encoding of configural information: Direct evidence. *Perception*, *29*(2), 159–170. https://doi.org/10.1068/p3012

Gaither, S. E., Pauker, K., & Johnson, S. P. (2012). Biracial and monoracial infant own-race face perception: An eye tracking study. *Developmental Science*, *15*(6), 775–782. https://doi.org/10.1111/j.1467-7687.2012.01170.x

Ge, L., Zhang, H., Wang, Z., Quinn, P. C., Pascalis, O., Kelly, D., Slater, A., Tian, J., & Lee, K. (2009). Two faces of the other-race effect: Recognition and categorisation of Caucasian and Chinese faces. *Perception*, *38*(8), 1199–1210. https://doi.org/10.1068/p6136

Golarai, G., Ghahremani, D. G., Greenwood, A. C., Gabrieli, J. D. E., & Eberhardt, J. L. (2021). The development of race effects in face processing from childhood through adulthood: Neural and behavioral evidence. *Developmental Science*, *24*(3), e13058. https://doi.org/10.1111/desc.13058

Goldinger, S. D., He, Y., & Papesh, M. H. (2009). Deficits in cross-race face learning: Insights from eye movements and pupillometry. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(5), 1105–1122. https://doi.org/10.1037/a0016548

Guo, K., Smith, C., Powell, K., & Nicholls, K. (2012). Consistent left gaze bias in processing different facial cues. *Psychological Research*, *76*(3), 263–269. https://doi.org/10.1007/s00426-011-0340-9

Herlitz, A., & Lovén, J. (2013). Sex differences and the own-gender bias in face recognition: A meta-analytic review. *Visual Cognition*, *21*(9/10), 1306–1336. https://doi.org/10.1080/13506285.2013.823140

Heron-Delaney, M., Damon, F., Quinn, P. C., Méary, D., Xiao, N. G., Lee, K., & Pascalis, O. (2017). An adult face bias in infants that is modulated by face race. *International Journal of Behavioral Development*, *41*(5), 581–587. https://doi.org/10.1177/0165025416651735

Hills, P. J., Cooper, R. E., & Pake, J. M. (2013a). First fixations in face processing: The more diagnostic they are the smaller the face-inversion effect. *Acta Psychologica*, *142*(2), 211–219. https://doi.org/10.1016/j.actpsy.2012.11.013

Hills, P. J., Cooper, R. E., & Pake, J. M. (2013b). Removing the own-race bias in face recognition by attentional shift using fixation crosses to diagnostic features: An eye-tracking study. *Visual Cognition*, *21*(7), 876–898. https://doi.org/10.1080/13506285.2013.834016

Hsiao, J. H., & Cottrell, G. (2008). Two fixations suffice in face recognition. *Psychological Science*, *19*(10), 998–1006. https://doi.org/10.1111/j.1467-9280.2008.02191.x

Hu, C., Wang, Q., Fu, G., Quinn, P. C., & Lee, K. (2014). Both children and adults scan faces of own and other races differently. *Vision Research*, *102*, 1–10. https://doi.org/10.1016/j.visres.2014.05.010

Kastner, S., Pinsk, M. A., De Weerd, P., Desimone, R., & Ungerleider, L. G. (1999). Increased activity in human visual cortex during directed attention in the absence of visual stimulation. *Neuron*, *22*(4), 751–761. https://doi.org/10.1016/S0896-6273(00)80734-5

Kato, M., & Konishi, Y. (2013). Where and how infants look: The development of scan paths and fixations in face perception. *Infant Behavior and Development*, *36*(1), 32–41. https://doi.org/10.1016/j.infbeh.2012.10.005

Kawakami, K., Friesen, J., & Vingilis-Jaremko, L. (2018). Visual attention to members of own and other groups: Preferences, determinants, and consequences. *Social and Personality Psychology Compass*, *12*(4), e12380. https://doi.org/10.1111/spc3.12380

Kelly, D. J., Liu, S., Rodger, H., Miellet, S., Ge, L., & Caldara, R. (2011). Developing cultural differences in face processing. *Developmental Science*, *14*(5), 1176–1184. https://doi.org/10.1111/j.1467-7687.2011.01067.x

LaFreniere, P., Strayer, F. F., & Gauthier, R. (1984). The emergence of same-sex affiliative preferences among preschool peers: A developmental/ethological perspective. *Child Development*, *55*(5), 1958–1965. https://doi.org/10.2307/1129942

Lee, K., Quinn, P. C., & Pascalis, O. (2017). Face race processing and racial bias in early development: A perceptual-social linkage. *Current Directions in Psychological Science*, *26*(3), 256–262. https://doi.org/10.1177/0963721417690276

Lee, K., Quinn, P. C., Pascalis, O., & Slater, A. (2013). Development of face-processing ability in childhood. In P. D. Zelazo (Ed.), *The Oxford handbook of developmental psychology* (Vol. 1, pp. 337–337). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199958450.013.0012

Lindsay, D. S., Jack, P. C., & Christian, M. A. (1991). Other-race face perception. *Journal of Applied Psychology*, *76*(4), 587–589. https://doi.org/10.1037/0021-9010.76.4.587

Liu, S., Quinn, P. C., Wheeler, A., Xiao, N., Ge, L., & Lee, K. (2011). Similarity and difference in the processing of same- and other-race faces as revealed by eye tracking in 4- to 9-month-olds. *Journal of Experimental Child Psychology*, *108*(1), 180–189. https://doi.org/10.1016/j.jecp.2010.06.008

Malsert, J., Palama, A., & Gentaz, E. (2020). Emotional facial perception development in 7, 9 and 11 year-old children: The emergence of a silent eye-tracked emotional other-race effect. *PLoS ONE*, *15*(5), e0233008. https://doi.org/10.1371/journal.pone.0233008

Man, T. W., & Hills, P. J. (2016). Eye-tracking the own-gender bias in face recognition: Other-gender faces are viewed differently to own-gender faces. *Visual Cognition*, *24*(9–10), 447–458. https://doi.org/10.1080/13506285.2017.1301614

Mardo, E., Avidan, G., & Hadad, B.-S. (2018). Adults' markers of face processing are present at age 6 and are interconnected along development. *Perception*, *47*(10–11), 1002–1028. https://doi.org/10.1177/0301006618794943

Markant, J., Oakes, L. M., & Amso, D. (2016). Visual selective attention biases contribute to the other-race effect among 9-month-old infants. *Developmental Psychobiology*, *58*(3), 355–365. https://doi.org/10.1002/dev.21375

Markant, J., & Scott, L. S. (2018). Attention and perceptual learning interact in the development of the other-race effect. *Current Directions in Psychological Science*, *27*(3), 163–169. https://doi.org/10.1177/0963721418769884

Markant, J., Worden, M. S., & Amso, D. (2015). Not all attention orienting is created equal: Recognition memory is enhanced when attention orienting involves distractor suppression. *Neurobiology of Learning and Memory*, *120*, 28–40. https://doi.org/10.1016/j.nlm.2015.02.006

Maurer, D., Grand, R. L., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, *6*(6), 255–260. https://doi.org/10.1016/s1364-6613(02)01903-4

Meissner, C. A., & Brigham, J. C. (2001). Thirty years of investigating the own-race bias in memory for faces: A meta-analytic review. *Psychology, Public Policy, and Law*, *7*(1), 3–35. https://doi.org/10.1037/1076-8971.7.1.3

Motta-Mena, N., Picci, G., & Scherf, K. S. (2016). Dominance elicits the own-gender bias in males. *Journal of Vision*, *16*(12), 497–497. https://doi.org/10.1167/16.12.497

Oakes, L. M., & Ellis, A. E. (2013). An eye-tracking investigation of developmental changes in infants' exploration of upright and inverted human faces. *Infancy*, *18*(1), 134–148. https://doi.org/10.1111/j.1532-7078.2011.00107.x

Or, C. C.-F., Peterson, M. F., & Eckstein, M. P. (2015). Initial eye movements during face identification are optimal and similar across cultures. *Journal of Vision*, *15*(13), 12–12. https://doi.org/10.1167/15.13.12

Pascalis, O., Demont, E., de Haan, M., & Campbell, R. (2001). Recognition of faces of different species: A developmental study between 5 and 8 years of age. *Infant and Child Development*, *10*(1–2), 39–45. https://doi.org/10.1002/icd.245

Pezdek, K. (2003). Children's face recognition memory: More evidence for the cross-race effect. *Journal of Applied Psychology*, *88*(4), 760–763. https://doi.org/10.1037/0021-9010.88.4.760

Picci, G., & Scherf, K. S. (2016). From caregivers to peers: Puberty shapes human face perception. *Psychological Science*, *27*(11), 1461–1473. https://doi.org/10.1177/0956797616663142

Pickron, C. B., Fava, E., & Scott, L. S. (2017). Follow my gaze: Face race and sex influence gaze-cued attention in infancy. *Infancy*, *22*(5), 626–644. https://doi.org/10.1111/infa.12180

Picozzi, M., Cassia, V. M., Turati, C., & Vescovo, E. (2009). The effect of inversion on 3- to 5-year-olds' recognition of face and nonface visual objects. *Journal of Experimental Child Psychology*, *102*(4), 487–502. https://doi.org/10.1016/j.jecp.2008.11.001

Proietti, V., Dell'Amore, F., Bricolo, E., & Macchi Cassia, V. (2015). Face age affects the way we visually process and recognize faces: A study with adult and infant faces. *Journal of Vision*, *15*(12), 708. https://doi.org/10.1167/15.12.708

Quinn, P. C., Lee, K., & Pascalis, O. (2019). Face processing in infancy and beyond: The case of social categories. *Annual Review of Psychology*, *70*(1), 165–189. https://doi.org/10.1146/annurev-psych-010418-102753

Quinn, P. C., Yahr, J., Kuhn, A., Slater, A. M., & Pascalils, O. (2002). Representation of the gender of human faces by infants: A preference for female. *Perception*, *31*(9), 1109–1121. https://doi.org/10.1068/p3331

Ramsey, J. L., Langlois, J. H., & Marti, N. C. (2005). Infant categorization of faces: Ladies first. *Developmental Review*, *25*(2), 212–246. https://doi.org/10.1016/j.dr.2005.01.001

Ramsey-Rennels, J. L., & Langlois, J. H. (2006). Infants' differential processing of female and male faces. *Current Directions in Psychological Science*, *15*(2), 59–62. https://doi.org/10.1111/j.0963-7214.2006.00407.x

Rennels, J. L., & Davis, R. E. (2008). Facial experience during the first year. *Infant Behavior & Development*, *31*(4), 665–678. https://doi.org/10.1016/j.infbeh.2008.04.009

Righi, G., Westerlund, A., Congdon, E. L., Troller-Renfree, S., & Nelson, C. A. (2014). Infants' experience-dependent processing of male and female faces: Insights from eye tracking and event-related potentials. *Developmental Cognitive Neuroscience*, *8*, 144–152. https://doi.org/10.1016/j.dcn.2013.09.005

Sangrigoli, S., & de Schonen, S. (2004). Effect of visual experience on face processing: A developmental study of inversion and non-native effects. *Developmental Science*, *7*(1), 74–87. https://doi.org/10.1111/j.1467-7687.2004.00324.x

Sangrigoli, S., Pallier, C., Argenti, A.-M., Ventureyra, V. A. G., & de Schonen, S. (2005). Reversibility of the other-race effect in face recognition during childhood. *Psychological Science*, *16*(6), 440–444. https://doi.org/10.1111/j.0956-7976.2005.01554.x

Scherf, K. S., & Scott, L. S. (2012). Connecting developmental trajectories: Biases in face processing from infancy to adulthood. *Developmental Psychobiology*, *54*(6), 643–663. https://doi.org/10.1002/dev.21013

Schlesinger, M., Amso, D., & Johnson, S. P. (2007). The neural basis for visual selective attention in young infants: A computational account. *Adaptive Behavior*, *15*(2), 135–148. https://doi.org/10.1177/1059712307078661

Schwarzer, G. (2000). Development of face processing: The effect of face inversion. *Child Development*, *71*(2), 391–401. https://doi.org/10.1111/1467-8624.00152

Scott, L. S., & Arcaro, M. J. (in press). A domain-relevant framework for the development of face processing. Nature Reviews Psychology.

Scott, L. S., Pascalis, O., & Nelson, C. A. (2007). A domain-general theory of the development of perceptual discrimination. *Current Directions in Psychological Science*, *16*(4), 197–201. https://doi.org/10.1111/j.1467-8721.2007.00503.x

Sugden, N. A., Mohamed-Ali, M. I., & Moulson, M. C. (2014). I spy with my little eye: Typical, daily exposure to faces documented from a first-person infant perspective: Infants' daily exposure to faces. *Developmental Psychobiology*, *56*(2), 249–261. https://doi.org/10.1002/dev.21183

Tham, D. S. Y., Bremner, J. G., & Hay, D. (2015). In infancy the timing of emergence of the other-race effect is dependent on face gender. *Infant Behavior and Development*, *40*, 131–138. https://doi.org/10.1016/j.infbeh.2015.05.006

Tham, D. S. Y., Bremner, J. G., & Hay, D. (2017). The other-race effect in children from a multiracial population: A cross-cultural comparison. *Journal of Experimental Child Psychology*, *155*, 128–137. https://doi.org/10.1016/j.jecp.2016.11.006

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., Marcus, D. J., Westerlund, A., Casey, B., & Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. https://doi.org/10.1016/j.psychres.2008.05.006

Tsurumi, S., Kanazawa, S., Yamaguchi, M. K., & Kawahara, J. (2023). Development of upper visual field bias for faces in infants. *Developmental Science*, *26*(1), e13262. https://doi.org/10.1111/desc.13262

Turati, C., Sangrigoli, S., Ruely, J., & Schonen, S. d. (2004). Evidence of the face inversion effect in 4-month-old infants. *Infancy*, *6*(2), 275–297. https://doi.org/10.1207/s15327078in0602_8

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology*, *79*(4), 471–491. https://doi.org/10.1111/j.2044-8295.1988.tb02747.x

Vogel, M., Monesson, A., & Scott, L. S. (2012). Building biases in infancy: The influence of race on face and voice emotion matching. *Developmental Science*, *15*(3), 359–372. https://doi.org/10.1111/j.1467-7687.2012.01138.x

Wang, X., & Tang, X. (2009). Face photo-sketch synthesis and recognition. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, *31*(11), 1955–1967. https://doi.org/10.1109/TPAMI.2008.222

Wheeler, A., Anzures, G., Quinn, P. C., Pascalis, O., Omrin, D. S., & Lee, K. (2011). Caucasian infants scan own- and other-race faces differently. *PLoS ONE*, *6*(4), e18621. https://doi.org/10.1371/journal.pone.0018621

Wiese, H. (2012). The role of age and ethnic group in face recognition memory: ERP evidence from a combined own-age and own-race bias study. *Biological Psychology*, *89*(1), 137–147. https://doi.org/10.1016/j.biopsycho.2011.10.002

Willenbockel, V., Sadr, J., Fiset, D., Horne, G. O., Gosselin, F., & Tanaka, J. W. (2010). Controlling low-level image properties: The SHINE toolbox. *Behavior Research Methods*, *42*(3), 671–684. https://doi.org/10.3758/BRM.42.3.671

Wright, D. B., & Sladden, B. (2003). An own gender bias and the importance of hair in face recognition. *Acta Psychologica*, *114*(1), 101–114. https://doi.org/10.1016/S0001-6918(03)00052-0

Wu, E. X. W., Laeng, B., & Magnussen, S. (2012). Through the eyes of the own-race bias: Eye-tracking and pupillometry during face recognition. *Social Neuroscience*, *7*(2), 202–216. https://doi.org/10.1080/17470919.2011.596946

Xiao, W. S., Xiao, N. G., Quinn, P. C., Anzures, G., & Lee, K. (2013). Development of face scanning for own- and other-race faces in infancy. *International Journal of Behavioral Development*, *37*(2), 100–105. https://doi.org/10.1177/0165025412467584

Xu, B., & Tanaka, J. W. (2013). Does face inversion qualitatively change face processing: An eye movement study using a face change detection task. *Journal of Vision*, *13*(2), 22–22. https://doi.org/10.1167/13.2.22

Yin, R. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, *81*(1), 141–145. https://doi.org/10.1037/h0027474

How to cite this article: Farrell, J., Conte, S., Barry-Anwar, R., & Scott, L. S. (2023). Face race and sex impact visual fixation strategies for upright and inverted faces in 3- to 6-year-old children. *Developmental Psychobiology*, *65*, e22362. https://doi.org/10.1002/dev.22362

APPENDIX

ANOVA Results

ANOVA results summary							
Independent Variable(s)	**df**	**F**	**p**	**Independent Variable(s)**	**df**	**F**	**p**
1. First fixation duration				3. Average fixation duration			
Orientation	1, 40	11.349	.002	Orientation	1, 43	18.333	<.001
Race	1, 40	0.407	.527	Race	1, 43	0.235	.63
Sex	1, 40	3.061	.088	Sex	1, 43	6.752	.013
Orientation × race	1, 40	1.63	.209	Orientation × race	1, 43	4.131	.048
Orientation × sex	1, 40	1.43	.239	Orientation × sex	1, 43	2.771	.103
Race × sex	1, 40	0.002	.966	Race × sex	1, 43	0.04	.842
Orientation × race × sex	1, 40	1.106	.299	Orientation × race × sex	1, 43	0.003	.954
2. First fixation location				4. Fixation number			
AOI	3, 44	30.767	<.001	Orientation	1, 41	5.107	.029
Orientation × AOI	3, 44	39.883	<.001	Race	1, 41	0.989	.326
Race × AOI	3, 44	1.351	.27	Sex	1, 41	4.881	.033
Orientation × Race × AOI	3, 44	1.967	.133	Orientation × race	1, 41	10.242	.003
Sex × AOI	3, 44	2.1	.114	Orientation × sex	1, 41	1.484	.23
Orientation × sex × AOI	3, 44	0.963	.419	Race × sex	1, 41	3.971	.053
Race × sex × AOI	3, 44	1.643	.193	Orientation × race × sex	1, 41	0.034	.855
Orientation × race × sex × AOI	3, 44	0.895	.451				