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Visual Selective Attention Biases Contribute to the Other-Race Effect

Among 9-month-old Infants

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**Abstract**

During the first year of life, infants maintain their ability to discriminate faces from their own race but become less able to differentiate other-race faces. Though this is likely due to daily experience with own-race faces, the mechanisms linking repeated exposure to optimal face processing remain unclear. One possibility is that that frequent experience with own-race faces generates a selective attention bias to them. Selective attention elicits enhancement of attended information and suppression of distraction to improve visual processing of attended objects. Thus attention biases to own-race faces may boost processing and discrimination of these faces relative to other-race faces. We used a spatial cueing task to bias attention to own- or other-race faces among Caucasian 9-month-old infants. Infants discriminated faces in the focus of the attention bias, *regardless of race*, indicating that infants remained sensitive to differences among other-race faces. Instead, efficacy of face discrimination reflected the extent of attention engagement.

*Keywords: perceptual narrowing, infancy, selective attention, other-race effect, face perception*

Visual Selective Attention Biases Contribute to the Other-Race

Effect Among 9-month-old Infants

Across the first year of life infants demonstrate increasingly optimal processing of frequently experienced faces and reduced sensitivity to face information that they do not routinely experience (Maurer & Werker, 2014; Pascalis, de Haan, & Nelson, 2002; Scott, Pascalis, & Nelson, 2007; Slater et al., 2010). Three month-old infants discriminate both own- and other-race faces, but by 9 months infants show increasing difficulty discriminating other-race faces while continuing to successfully discriminate own-race faces, a perceptual narrowing phenomenon termed the Other-Race Effect (ORE) (Kelly et al., 2009; Kelly, Quinn, et al., 2007).

The specific mechanisms underlying the ORE in infancy is a topic of active investigation, as it informs issues ranging from brain plasticity to developing social prejudice. The ORE has been described as a phenomenon in which frequent experience with own-race faces leads to optimal perceptual processing of own-race faces and reduced perceptual sensitivity to other-race faces (Pascalis et al., 2014; Scott et al., 2007). Infants develop a preference for own-race faces between birth and 3 months of age (Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005; Kelly, Liub, et al., 2007; Liu et al., 2015), suggesting that frequent exposure to own-race faces during this period supports the emergence of an attentional bias favoring own-race faces over other-race faces. At 4 months of age infants process both own- and other-race faces holistically but by 8 months of age infants process only own-race faces holistically (Ferguson, Kulkofsky, Cashon, & Casasola, 2009). Coupled with a decline in the ability to recognize other-race faces (Kelly et al., 2009; Kelly, Quinn, et al., 2007), these data suggest that frequent experience with own-race faces supports the development of visual representations of faces, and possible refinement of associated neural systems (Pascalis et al., 2014; Scott et al., 2007), that is optimal

for differentiating own-race faces but results in less effective discrimination of other-race faces (Anzures et al., 2013).

Others have placed less emphasis on a decline in discrimination of infrequently experienced faces, instead suggesting that perceptual narrowing in the face domain is best characterized as a process of enhancement in which repeated experience promotes the development of perceptual sensitivity to experienced faces while sensitivity to other-race faces is never fully eliminated. (Fair, Flom, Jones, & Martin, 2012; Maurer & Werker, 2014). Fair et al., (2012) found that increased familiarization time counteracted the typical perceptual narrowing effect among 12-month-old infants, suggesting that infants do not lose the ability to discriminate less frequently experienced faces. Similar evidence that the ORE can be attenuated with increased exposure to other-race faces (Anzures et al., 2012; Heron-Delaney et al., 2011; Spangler et al., 2013) suggests that the frequency and timing of experience with faces is critical in determining the strength of the ORE in infancy. Recent research showing that older infants rely on an increased number of features for successful face discrimination also suggests that infants may learn to attend to the most salient features of experienced faces (Simpson, Jakobsen, Fragaszy, Okada, & Frick, 2014). Repeated experience with own-race faces supports the development of scanning strategies that are optimized for these faces, both in terms of the distribution of fixations across specific facial features and the frequency with which infants shift fixations from one feature to another within a face (Liu et al., 2015; Wheeler et al., 2011; Xiao, Xiao, Quinn, Anzures, & Lee, 2013). In particular, the emergence of the ORE tends to be associated with increased attention to the eyes of own-race faces (Wheeler et al., 2011; Xiao et al., 2013). Older infants also shift attention between paired own- and other-race faces more

frequently, suggesting that increased exposure to own-race faces supports more efficient processing of these faces (Liu et al., 2015).

Cutting across all of these accounts is the idea that repeated experience with own-race faces during the first year of life faces leads to optimal perceptual processing of that face category. But what is it specifically about repeated experience that supports enhanced face processing? We suggest that one mechanism involves selective attention allocation — and the associated enhancement in visual processing — to own-race faces. The research described above demonstrates that infants' orienting strategies – *what* is preferentially attended – are intricately linked to their experience with faces and the development of the ORE. However, selective attention comprises both orienting strategies as well as allocation of attention resources – *how deeply* information is processed. We investigate here the role of the latter form of attention biases in modulating visual processing and recognition of own- and other-race faces in infancy. Numerous studies with adults have established that selective attention acts to enhance processing of information at the attended location and to suppress distraction (Gandhi, Heeger, & Boynton, 1999; Kastner, Pinsk, De Weerd, Desimone, & Ungerleider, 1999; Markant, Worden, & Amso, 2015; Slotnick, Schwarzbach, & Yantis, 2003). This excitation/suppression mechanism improves the quality of early vision, enhancing contrast sensitivity, acuity, and visual processing of attended information (Carrasco, 2011, 2013; Zhang et al., 2011). This modulation of visual processing in turn supports improved encoding and recognition of attended information over unattended information among adults (Rutman, Clapp, Chadick, & Gazzaley, 2009; Uncapher & Rugg, 2009; Zanto & Gazzaley, 2009). If emerging selective attention biases support more effective processing of own-race faces during the first year of life, experimentally biasing

selective attention to a face while suppressing distraction should improve online visual processing and subsequent discrimination/recognition of that face, *regardless of race*.

This hypothesis is consistent with, but extends, previous attention-based explanations of the ORE in infancy. Three-month-old infants showed differential attention orienting to own- and other-race face singletons surrounded by distracting faces (Hayden, Bhatt, Kangas, Zieber, & Joseph, 2012; Hayden, Bhatt, Zieber, & Kangas, 2009). Three- to 10-month-old infants additionally showed different fixation and scan patterns when looking at own- versus other-race faces (Liu et al., 2015; Wheeler et al., 2011; Xiao et al., 2013) and by 9 months of age infants preferentially oriented to other-race faces that are paired with an own-race face (Liu et al., 2015). We suggest that frequent experience with own-race faces may generate selective attention biases to these faces, which serve to bring visual details into focus, improving visual processing (Carrasco, 2011; Zhang et al., 2011) and in turn supporting enhanced memory encoding (Gazzaley & Nobre, 2012; Markant & Amso, 2013, 2014). We also suggest that observed differences in orienting/scanning strategies observed in previous studies may also derive from differences in the quality of visual processing of own- versus other-race faces resulting from these selective attention biases. Eyes and mouth hold contrast value and may be experienced more prominently when attention is differentially engaged by own-race faces (Herrmann, Montaser-Kouhsari, Carrasco, & Heeger, 2010), theoretically driving eye movements to these features. We thus hypothesize that infants' superior learning of own-race faces is a function of selective attention biases to own-race faces that elicit greater attentional engagement and enhanced perceptual processing of these faces relative to other-race faces.

In previous work, Markant and Amso (2013) found that 9 month-old infants' learning could be manipulated by biasing their attention to locations containing abstract objects for

encoding. Specifically, infants successfully learned category exemplars that appeared in the location of the attention bias, but failed to learn category exemplars that appeared outside the location of the attention bias. Here, we capitalized on the same design to experimentally bias 9-month-old infants' attention to locations containing own- versus other-race faces and examined their subsequent discrimination of those faces. Our primary question was whether experimentally inducing a selective attention bias – and the associated enhancement in visual cortex signal/perceptual processing – to other-race faces would boost recognition memory to the same level as frequently experienced own-race faces. The critical test of this question was whether infants showed similar recognition capabilities regardless of whether own- versus other-race faces appeared in the location of the attention bias.

We used a classic spatial cueing task (Posner, 1980) to manipulate infants' attention. In this task a peripheral cue captures attention, followed by a delay and subsequent target presentation in the cued or noncued location. When the delay is sufficiently long, the cued location becomes suppressed and attention is biased to the *noncued* location, an effect called *inhibition of return* (IOR) (Posner, Rafal, & Choate, 1985). In a recent adult fMRI study we observed the expected selective attention dynamics in the context of an IOR spatial cueing task, with enhanced visual cortex signal associated with the location of the attention bias (i.e., the noncued location) and reduced/suppressed visual cortex signal associated with the previously cued location (Markant et al., 2015). Moreover, the extent of this attention modulation of visual cortex activity predicted adults' subsequent memory for objects appearing in the location of the attention bias. Specifically, greater enhancement of signal at the attended target location *and* greater suppression at the previously cued location both predicted better recognition memory performance. These results suggest that inducing spatial selective attention (i.e., enhanced

target/suppressed distractor cortical dynamics) in the context of an IOR spatial cueing task among 9-month-old infants should similarly result in enhanced perceptual processing and improved recognition memory for targets appearing in the location of the attention bias.

IOR is routinely observed by 9 months of age (Johnson & Tucker, 1996; Markant & Amso, 2013; Richards, 2000). However, previous work has also shown that using highly salient faces as stimuli in the spatial cueing task elicits arousal (Pérez-Dueñas, Acosta, & Lupiáñez, 2014; Weaver, Aronsen, & Lauwereyns, 2012) that could lead to individual variability in spatial cueing scores and add noise to the measurement of the IOR effect at the group level. Nonetheless, the IOR spatial cueing task is uniquely appropriate to our experimental question in that it mimics the covert orienting/cueing tasks that have been shown to support enhanced visual processing among adults (Carrasco, 2011; Markant et al., 2015). Moreover, although differences in orienting latencies provide an indication that attention has been biased to the noncued location, the *attention bias* itself is not a function of that difference in latency but rather of the cueing manipulation.

We specifically asked whether 9 month-old Caucasian infants' discrimination of own- and other-race faces would be a function of those faces appearing in the selective attention-biased (noncued) versus unbiased (cued) locations. All infants saw the same number of own- and other-race faces; the only difference was which race category appeared in the attention bias location. If the ORE at 9 months reflects stable perceptual narrowing or learned differences in scanning strategies, infants will learn own-race faces better than other-race faces regardless of this manipulation. Alternatively, if biasing attention induces differences in online perceptual processing of faces, infants will successfully learn any face presented in the location of the attention bias, regardless of race.

**Method**

**Participants**

The final sample included forty 9-month-old infants (19 M, 21 F; $M_{Age}$ = 9 months, 14

days, $SD$ = 12.32 days). Six additional infants were excluded due to fussiness (5) or technical

error (1). All participants were reported by their parents to be Caucasian.

**Eye tracking apparatus**

We recorded eye movements using a remote eye tracker (SensoMotoric Instruments 60

Hz RED system). Infants sat on their parent's lap 70 cm from a 22" monitor. All parents were

blind to the hypotheses of the study. A digital video camera (Canon ZR960) recorded infants'

head movements and allowed for online coding during the test phase. The video output was also

recorded as a digital file.

Stimuli were presented using the SMI Experiment Center software. We used a 2-point

calibration and 4-point calibration accuracy check as described in Markant and Amso (2013).

Average deviation was 2.6° ($SD$ = 2.4°). The digital eye recording was used for offline coding of

left/right eye movements if an accurate calibration or stable position of gaze (POG) was not

obtained. To confirm the accuracy of these data, reliability between coded and POG data was

calculated for a subset of videos for infants who had successful eye movement recordings, $r >$ .

90, $p <$ .05.

**Procedure and Design**

The task included a spatial cueing/encoding phase (Figure 1) and a subsequent memory

test. The first 56 trials comprised the spatial cueing phase of the session. Each trial began with a

purple X with a cartoon face that loomed in and out (2.5 - 5.67 cm$^2$) to engage infants' fixation in

the center of the display. The fixation was presented alone for 1100 ms and then a cue (a yellow

ring, 2.5 cm diameter; see Figure 1) was presented 16° (19.4 cm) to the left/right of the central

fixation, for 100 ms. This was followed by a 600 ms delay period in which only the fixation

stimulus was visible. Then the target face was presented in either the cued or noncued location. A

600 ms delay between cue offset and target onset is sufficient to selectively bias attention to

targets in the *noncued* location IOR (Hood, 1993; Johnson & Tucker, 1996; Markant & Amso,

2013; Richards, 2000) .

[INSERT FIGURE 1]

After this delay the fixation disappeared and a target face appeared in the cued or

noncued location for 1500 ms. An equal number of cued and noncued faces were presented in

random order. Infants were randomly assigned to one of two conditions ($N = 20$ per condition):

in the 'Black-noncued' condition, Black faces were presented in the noncued (biased) location

and White faces were presented in the cued (unbiased) location, and in the 'White-noncued'

condition, White faces were presented in the noncued (biased) location and Black faces were

presented in the cued (unbiased) location. Three Black and three White female faces (each 6.1 x

4.7 cm on the screen) were selected from the MacBrain Face Stimulus Set[1] (Tottenham, 1998).

For each infant, two Black and two White faces were selected as encoding stimuli. Thus, every

infant received 14 trials with each White face and 14 trials with each Black face across the 56

spatial cueing trials.

After the spatial cueing phase, infants saw 5 test trials, one with each of five different

faces: (1) a familiar face from the cued category, (2) a novel face from the cued category, (3) a

familiar face from the noncued category, (4) a novel face from the noncued category, and 5) a

completely novel Asian face (items 2 and 4 were the third exemplar from each category).

Stimulus order was pseudo-randomized so that each of the five test items was presented first with equal frequency. Each test stimulus was presented individually in the center of the screen for up to 20 s. An experimenter (unaware of the stimulus) viewed the live video feed and advanced to the next trial if the infant looked away for more than 2 s. Look durations were validated offline, $r > .90$, $p < .01$.

**Preliminary data processing**

*Eye tracking measures.* Our primary variables for the spatial cueing phase were saccade latencies and duration of looking to the targets. Initial processing of the eye movement data utilized the SMI BeGaze analysis software. Three areas of interest (AOIs) were identified based on the central, left, and right stimulus locations. These AOIs were equivalent 14.2-cm$^2$ regions over each of these locations. Usable looks were defined as segments of the data in which the POG remained within 7.1 cm$^2$ (5.8°) for at least 100 ms. Saccade latencies were based on the time when a look first entered the AOI. Duration of looking was computed by summing the duration of all looks that occurred within the AOI following target onset.

On average, infants contributed 34 trials ($SD = 8.9$ trials) to their spatial cueing scores (out of 56 total trials), including an average of 16.9 cued trials ($SD = 5.2$ trials) and 16.9 noncued trials ($SD = 5.2$ trials). During these trials infants' first looks were always directed to the target face (i.e., to the cued location during cued trials and to the noncued location during noncued trials). Individual trials were discarded for only the analyses of orienting latency during encoding if the infant looked at the cue prior to target onset *(M = 4.3 trials, 7.6%; SD = 3.9 trials, 7.0%)*, looked away from the screen before looking at a target ($M = 10.0$ trials, 17.8%; $SD = 5.7$ trials, 10.1%), or if eye tracking data was unavailable ($M = 8.0$ trials, 14.2%; $SD = 6.6$ trials, 11.7%). There were no differences in the number of trials that were excluded across the cued and

noncued trial types (all $p$s > .09) or across the Black-noncued and White-noncued conditions (all $p$s > .10). High rates of looking at the cued location or looking off-screen could reflect individual variability in infants' attentional states at the time of testing. As such, these variables were included as covariates for analyses of spatial cueing effects and memory test performance.

*Test.* All looking time trials were used for analyses of test performance. No data were excluded. Individual infants' overall mean looking times (averaging across the five test trials) ranged from 2.19 s − 15.54 s. To correct for these individual differences in level of looking, we calculated z-scores based on each individual infant's looking time during each test trial. Z scores were computed as $z$ = (trial look duration - overall mean look duration)/overall *SD*).

## Results

### Spatial Cueing Effects

*Orienting Latency.* Our first set of analyses examined the effectiveness of our procedure in eliciting spatial cuing effects. We first evaluated infants' orienting latencies to cued and noncued locations. To account for individual variability associated with using face stimuli we included the number of trials with Looks to the Cue as a covariate to index arousal/alerting and examined spatial cueing effects during the first half (Trials 1-28) and second half (Trials 29-56) of the task separately. We examined mean orienting latencies using an ANCOVA with Trial type (cued, noncued) as a within-subjects variable and the Looks to the Cue treated as a covariate. Results showed that there was no effect of Trial type during the first half of the task ($M_{Cued}$ = 520.85, *SD* = 126.31; $M_{Noncued}$ = 511.06, *SD* = 129.08; $F(1,38)$ = 0.14, $p$ = .709). However, there was a reliable main effect of Looks to the Cue ($F(1,38)$ = 6.49, $p$ = .015, $\eta_p^2$ = .15), reflecting a negative relationship between infants' overall mean reaction time and their rate of looking to the cue ($r(40)$ = 0.38, $p$ = .015). Thus, there was an alerting effect of the cue where infants who

broke fixation and looked at the cue more frequently showed faster latencies overall, regardless

of trial type.  In contrast, in the second half of the task there was a trend-level significant main

effect of trial type indicating IOR ($F(1,35) = 3.23$, $p = .081$, $\eta_p^2 = .08$), with slower orienting

latencies to the cued location ($M = 528.31$, $SD = 148.18$) relative to the noncued location ($M =$

512.32, $SD = 139.26$).  The main effect of Looks to the Cue remained marginally significant

($F(1,35) = 4.01$, $p = .053$, $\eta_p^2 = .10$), reflecting the same negative relationship between infants'

rates of looking to the cue and their overall mean latencies during the second half of the task

($r(39) = -.30$, $p = .062$). Importantly, Looks to the Cue did not interact with Trial type during the

either portion of the task ($F_{1stHalf}(1,38) = .09$, $p = .770$; $F_{2ndHalf}(1,38) = 2.34$, $p = .135$) indicating

that the alerting effect of the faces influenced orienting latencies equally during cued and

noncued trial types. In other words, the increased alerting would make measurement of IOR

difficult due to a floor effect in orienting latencies but did not alter the balance between

enhancement at the noncued target location and suppression at the previously cued location.

Overall these results suggest a progression over the course of the task in which the face stimuli

led to initially higher levels of arousal/alerting (reflected in individual variability in sensitivity to

the presence of the cue) and overall faster latencies that dampened the behavioral IOR effect.

However, as this initial alerting effect attenuated the behavioral IOR effect began to emerge at

the group level by the second half of the task.

**Duration of Looking.** We assume that enhanced processing at the noncued location

associated with selective attention reflects deeper attentional engagement, not simply longer

looking at the targets. Thus, it is important to show that infants are equally interested in targets

presented in the cued and noncued locations. To confirm this we conducted an ANCOVA with

duration of looking to the cued and noncued target locations as within-subjects variable (Trial

type), Condition (White-noncued, Black-noncued) as a between-subjects variable, and Looks to

the Cue as a covariate. There were two infants with mean look durations that were $> 2\,SD$ above

the group mean; these infants were excluded for this analysis only. Results indicated that there

was no main effect of Trial type, indicating similar durations of looking to targets in the cued ($M$

= 663.06 ms, $SD$ = 197.82 ms) and noncued locations ($M$ = 645.75 ms, $SD$ = 181.65 ms; $F(1,35)$

= 1.08, $p$ = .305). There was also no main effect of Condition ($F(1,35)$ = 0.01, $p$ = .926),

indicating similar looking times to the White ($M$ = 657.08 ms, $SD$ = 216.87 ms) and Black faces

overall ($M$ = 651.43 ms, $SD$ = 145.71 ms;). Importantly, the Trial type x Condition and Trial type

x Looks to the Cue interactions were also not significant ($F(1,35)$ = 0.24, $p$ = .629; $F(1,35)$ =

0.16, $p$ = .692, respectively). These data confirm that infants in the Black-noncued condition and

the White-noncued condition received similar durations of exposure to targets appearing in the

cued and noncued locations during encoding. Any differences in learning of the faces appearing

in the cued and noncued target locations or across the two conditions can thus be attributed to

differential attentional engagement and associated improvement in perceptual processing

resulting from the spatial cueing-induced attention bias rather than any difference in duration of

exposure during encoding.

**Test**

Our primary analyses were those that evaluated infants' discrimination of the familiar and

novel faces. If they did not sufficiently encode the familiar face, they will look equally at the two

faces. We entered infants' standardized looking times at test into a mixed ANCOVA with Trial

type (cued, noncued) and Face Novelty (familiar, novel) as within-subjects factors, Condition

(Black-noncued, White-noncued) as a between-subjects factor, and proportion of Looks to the

Cue and Looks Away from the screen as covariates. Results indicated a Trial type x Face Novelty interaction, $F(1, 36) = 7.35$, $p = .01$, $\eta^2 = .17$ and a Trial type x Face Novelty x Looks to Cue interaction, $F(1, 36) = 5.96$, $p = .02$, $\eta^2 = .14$. Figure 2 shows that infants looked significantly longer at the novel than at the familiar face for items presented in the *noncued* (attention bias) location ($M_{Familiar} = 7.25$ s, $SD = 5.34$ s; $M_{Novel} = 8.8$ s, $SD = 4.94$ s; $F(1,37) = 10.23$, $p = .003$, $\eta^2 = .22$). However, their looking to the novel and familiar faces did not differ for items presented in the *cued* location, ($M_{Familiar} = 7.18$ s, $SD = 5.29$ s; $M_{Novel} = 8.02$ s, $SD = 5.53$ s; $F(1,37) = 0.75$, $p = .392$). Thus, Caucasian infants successfully discriminated faces that were the focus of selective attention, *regardless of race.* These data indicate that, although spatial cueing measurements were variable, the cueing manipulation was successful at biasing attention to the noncued location and that this selective attention bias enhanced learning and subsequent memory for faces presented in the noncued relative to the cued locations during the spatial cueing/encoding phase of the task.

[INSERT FIGURE 2]

Importantly, the Trial type x Face Novelty x Condition interaction was not significant, $F(1,36) = 0.17$, $p = .686$. There were no differences in this general effect—a novelty preference for faces presented in the noncued location but not for faces presented in the cued location—as a function of own- versus other-race. Although statistically unnecessary, we wanted to further confirm this with planned comparisons, especially for the critical Black-noncued condition. We conducted separate Trial type (cued, noncued) x Face Novelty (familiar, novel) ACOVAs with proportion of Looks to the Cue and Looks Away treated as covariates for the Black-noncued and White-noncued conditions. Caucasian infants who experienced the Black-noncued condition

(i.e., were biased towards other-race faces) during the spatial cueing task looked significantly longer at the novel than the familiar other-race face at test ($F(1,17) = 5.69$, $p = .029$, $\eta^2 = .25$). That is, they discriminated between the other-race faces at test. These same Caucasian infants showed no significant difference in looking times to the own-race White faces presented in the cued location ($F(1,17) = 0.49$, $p = .493$). These data constitute a reversal of the ORE. Caucasian infants in the White-noncued condition (i.e., who were biased towards own-race faces) during spatial cueing showed reliable preferential looking to the novel White face from the noncued location ($F(1,17) = 4.26$, $p = .055$, $\eta^2 = .20$) but showed no significant difference in looking times to the Black other-race faces presented in the cued location ($F(1,17) = 0.25$, $p = .627$). Thus, these infants showed the expected ORE and this condition is perhaps most like the experience of a Caucasian infant, where selective attention is biased toward own-race faces. Thus, Caucasian infants discriminated *either* own- or other-race faces, provided that those faces were the focus of the attention bias. Conversely, they had difficulty discriminating *both* own- and other- race faces when they were presented outside the attention bias.

Recall that all infants saw the same number of Black and White faces during the spatial cueing phase of the experiment. Their response to the completely novel Asian face, therefore, provides additional insight into their processing of these faces. We next examined infants' treatment of the completely novel Asian face as a function of condition. A Trial type (familiar noncued, novel Asian) x Condition (Black-noncued, White-noncued) ANCOVA with Looks to cue and Looks away as covariates revealed a main effect of Trial type, $F(1,36) = 8.73$, $p = .005$, $\eta^2 = .20$, reflecting longer looking to the novel Asian face relative to the familiar noncued faces ($M_{Noncued} = 7.1$ s, $SD = 5.24$ s, $M_{Novel} = 10.11$ s, $SD = 5.95$ s). However, this main effect was moderated by the race of the faces appearing in the location of the attention bias, indicated by a

significant Trial type x Condition interaction, $F(1,36) = 4.63$, $p = .038$, $\eta^2 = .11$. This was driven

by significantly longer looking times to the Asian face in the Black-noncued ($M = 11.96$ s, $SD =$

5.60 s) relative to the White-noncued condition ($M_{Novel} = 7.62$ s, $SD = 4.74$ s; $t(38) = 2.30$, $p = .$

012). There was no difference in looking times to the familiar face from the noncued location

across the two conditions ($M_{White} = 8.02$, $SD = 5.81$, $M_{Black} = 6.49$, $SD = 4.85$; $t(38) = 1.59$, $p = .$

373). These data suggest that although Caucasian infants saw an equal number of White and

Black faces in both conditions, the race of the face that is focus of selective attention bias

influenced the extent to which Asian faces were treated as novel.

## Discussion

Although previous work has shown that 9 month-old infants have difficulty individuating

other-race faces, we found that infants at this age discriminated both own- and other-race faces

when they were the focus of an induced selective attention bias. This is particularly striking

given that all infants saw the same number of own- and other-race faces; the only difference

across conditions was whether these faces appeared in the attention bias location during the

spatial cueing/encoding phase. To our knowledge, this is the first demonstration that infants show

superior discrimination of *other*-race faces compared to own-race faces, and the first

demonstration of infants' differential sensitivity to own- versus other-race faces based on which

category benefitted from selective attention engagement. We also found differences in infants'

treatment of Asian faces based on which race category appeared in the attention bias location.

Caucasian infants biased to attend to Black faces treated the Asian faces as particularly novel

relative to Caucasian infants biased to attend to White faces.

The present data suggest that inducing a selective attention bias, defined as enhancement

at the attended location and suppression of the previously cued location, during online face

processing benefits individuation of faces within race categories and shapes the boundaries of cross-race face categories.  The selective attention bias resulted in successful face recognition regardless of race, suggesting that enhanced visual processing of other-race faces can boost recognition memory of these faces to the same level as frequently experienced own-race faces. The ORE may thus in part reflect the online cortical mechanisms of selectivity for frequently-experienced own-race faces. Moreover, the same infants showed no discrimination of *either* own- or other-race faces when those faces appeared outside the selective attention bias. Adult fMRI studies have shown that allocating attention to a stimulus results in both enhanced visual cortex processing for that stimulus as well as reduced processing for those that appear outside the selected region (Gandhi et al., 1999; Kastner et al., 1999; Slotnick et al., 2003). Adults showed similar attention dynamics in the context of the IOR spatial cueing task design used in this study, with enhanced visual cortex signal in the location of the attention bias (i.e., the noncued location) and suppressed signal in the unattended (i.e., cued) location (Markant et al., 2015). Our data are consistent with these dynamics, as infants failed to discriminate the faces that had appeared in the cued location regardless of whether they were own- or other-race faces.

Importantly, infants' performance at test cannot be explained by differences in overt orienting or duration of looking to the targets during encoding. There were no differences in infants' frequency of orienting or duration of looking to the targets appearing in the cued versus noncued locations. Additionally, there were no differences in the rates of looking to the cue and looking away across the cued and noncued trial types. These points are critical for an attentional interpretation of the results, as they indicate that infants learned the faces in the noncued target location more effectively than those in the cued location despite receiving equal exposure to them during encoding. This differential learning can thus be attributed to differences in the extent

of attention engagement rather than simple differences in overt looking patterns. Finally, given the attention dynamics inherent to IOR it is important to consider whether infants' memory performance was driven by enhancement at the noncued location or suppression at the cued location. In previous work (Markant & Amso, 2013) 9-month-old infants encoded target objects in the context of IOR, facilitation, or no-cue baseline conditions in a between-subjects design. Results showed that infants successfully learned the target objects only in the context of IOR and performance was equivalent across the facilitation and baseline conditions. Similarly, adults showed superior memory performance for targets appearing in the noncued location of an IOR task but similar recognition memory for targets in the cued location and those appearing in a no-cue baseline condition (Markant et al., 2015). These data suggest that learning of targets in the noncued location during an IOR spatial cueing task reflects an enhancement above baseline rather than a suppression of learning at the cued location. The current findings are consistent with these previous studies. Nine-month-old infants typically do not discriminate other-race faces but were able to do so when those faces were encoded in the noncued location, reflecting an enhancement above the typical "baseline" for this age group. However, the lack of discrimination of own-race faces from the cued location suggests that in this study the suppression at the cued location may have also played a role in reducing learning at that location.

The IOR effect in the present study was weaker than would be typically expected by 9 months of age (Johnson & Tucker, 1996; Markant & Amso, 2013; Richards, 2000). We attribute this to the presence of face stimuli since previous adult studies have shown that the use of salient face stimuli in the spatial cueing task can elicit arousal that leads to generally fast orienting latencies and attenuates the typical IOR effect (Pérez-Dueñas et al., 2014; Weaver et al., 2012). Our data are consistent with this work and suggest that the face stimuli in the current task elicited

a similar alerting effect that obscured our ability to measure a robust behavioral IOR effect at the group level. Specifically, infants who broke fixation and looked at the cue more frequently showed faster orienting latencies overall during encoding, suggesting that these infants may have experienced greater alerting in response to the face stimuli. Although this alerting should not interfere with the IOR effect elicited by the previous cue, these overall faster orienting latencies lead to floor effects that make it more difficult to detect subtle differences in response times across cued and noncued trial types. Additionally, while there was no evidence of an IOR effect during the first half of the spatial cueing data, the IOR effect began to emerge at the group level by the second half of the task, when infants would be expected to begin to habituate to the initial alerting effect elicited by the faces. Given the complexities of using face stimuli in the spatial cueing task it will be important for future work to further examine the role of selective attention in the development of the ORE using a variety of attention manipulations.

These data suggest that emerging selective attention biases towards own-race faces during the first year of life (Hayden et al., 2012, 2009; Liu et al., 2015) may promote enhanced visual processing and recognition of these faces over other-race faces. Like all other lab-based studies, we cannot know for sure whether these results can directly extrapolate to infants' daily experiences. Nonetheless, one possibility for further examination is that infants' frequent experience with own-race face generates a selective attention bias towards these faces, which in turn supports enhanced online perceptual processing and improved discrimination relative to other-race faces. That is, the ORE may in part reflect the value assigned to specific face categories, which in turn drives differential selective attention to the valued categories. Critically, our data do not address how repeated experience with own-race faces generates a selective attention bias to these faces. Related work sheds light on the issue. Previous ERP research

highlights the role of attention networks at 5 and 9 months of age (Vogel, Monesson, & Scott, 2012). After viewing own- and other-race faces paired with laughing or crying sounds, 9-month-old infants showed the ORE and a race-specific ERP signal for the face/sound congruency manipulation. Five-month-old infants showed similar ERP signals for both own- and other-race faces, consistent with an absence of the ORE at this age. Furthermore, at this early age the activated ERP components were consistent with anterior attention networks whereas the ERP components activated at 9 months of age were consistent with posterior perceptual processing networks (Vogel et al., 2012). That is, emotional valence is associated with attentional strategies during face processing by 9 months.

One possibility is that an initial bias to selectively attend to own-race faces may promote visual processing of these faces, leading to greater reliance on perceptual systems as infants become more expert in encoding/discriminating these own-race faces. However, the system remains plastic and re-engagement of selective attention towards other-race faces can boost perceptual processing and recognition of these faces to the same level. One question for future research is whether there are time periods when re-engaging selective attention can more or less successfully boost perceptual processing and recognition of own- and other-race faces to the same level. This selective attention account is particularly compelling as it celebrates the plasticity inherent in the system. Although there is surely a benefit to increasing attention to own-race faces, it would be detrimental to lifelong flexible function if this benefit is obtained at the cost of a loss of ability to discriminate other-race faces. An attentional bias to own-race faces exploits the benefits of attentional enhancement of vision, allowing for a powerful yet efficient way to increase the gain to daily relevant faces while retaining flexibility if other-race faces become relevant.

## Notes

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**Figure Legend**

*Figure 1.* (1) Examples[1] of spatial cueing trials presented to infants in the White-Noncued and Black-Noncued conditions. (B) Examples of images presented during the subsequent test phase.


*Figure 2.* Infants showed a significant novelty preference for faces presented in the noncued location but no significant difference in looking to faces presented in the cued location, regardless of race. (A) Raw looking time data, (B) Z-scored looking time data corrected for each infant's mean look duration at test.

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1 The faces depicted in Figure 1 were drawn from Center from Vital Longevity Face Database (Minear & Park, 2004) and are for illustration purposes only. The specific faces we used in our task could not be depicted due to copyright rules. The MacBrain stimulus set codes for these faces were 2F-HA-O, 6-HA-O, 7-HA-O, 11F-HA-O, 12F-HA-O, 14F-HA-O, 15F-HA-O.
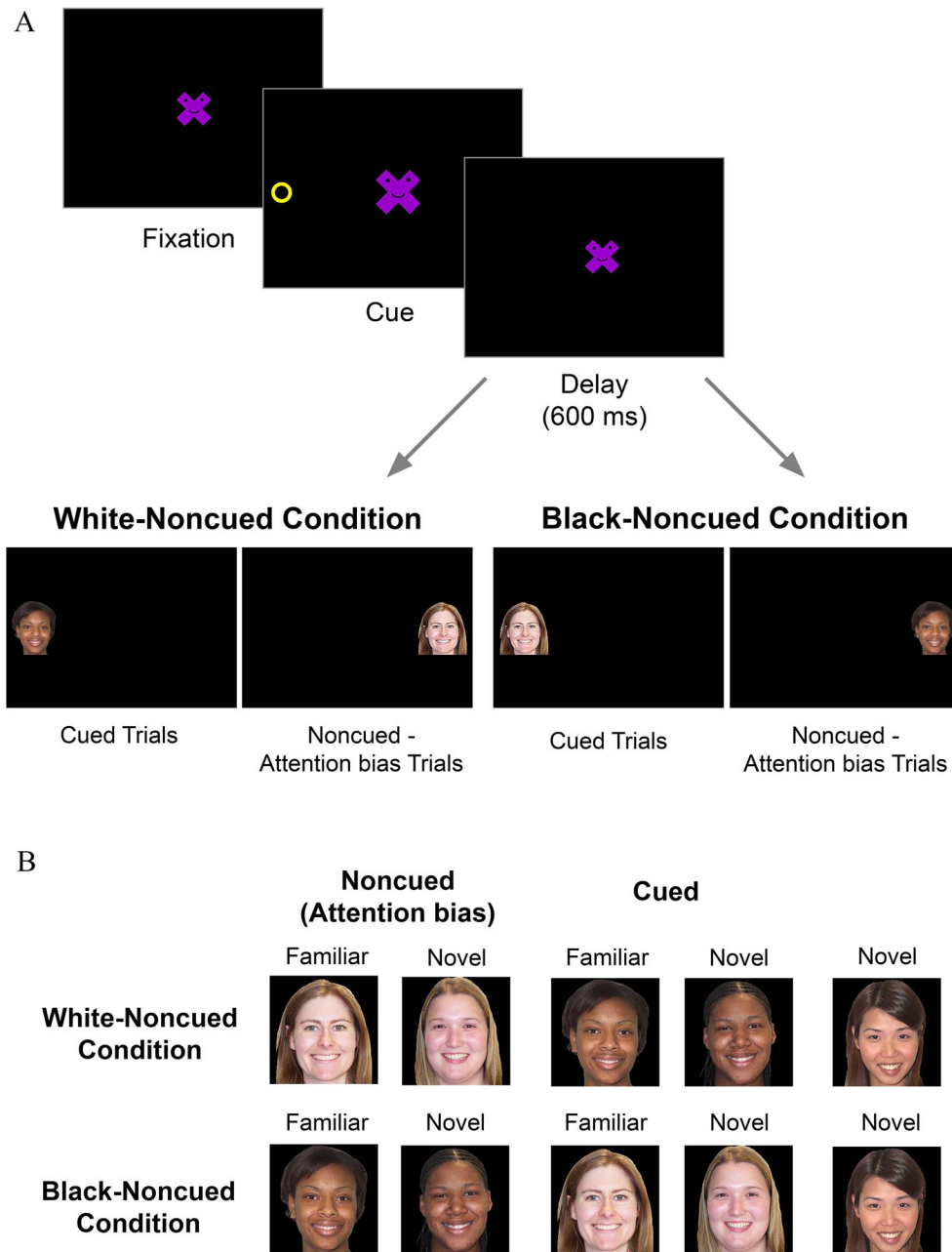
Figure 1

Figure 2