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PAPER

Narrowing in categorical responding to other-race face classes by infants

Paul C. Quinn,[1] Kang Lee,[2] Olivier Pascalis[3] and James W. Tanaka[4]

1. Department of Psychological and Brain Sciences, University of Delaware, USA
2. Department of Applied Psychology and Human Development, University of Toronto, Canada
3. LPNC, Université Grenoble Alpes, France
4. Department of Psychology, University of Victoria, Canada

Abstract

Infants can form object categories based on perceptual cues, but their ability to form categories based on differential experience is less clear. Here we examined whether infants filter through perceptual differences among faces from different other-race classes and represent them as a single other-race class different only from own-race faces. We used a familiarization/novelty-preference procedure to investigate category formation for two other-race face classes (Black vs. Asian) by White 6- and 9-month-olds. The data indicated that while White 6-month-olds categorically represented the distinction between Black and Asian faces, White 9-month-olds formed a broad other-race category inclusive of Black and Asian faces, but exclusive of own-race White faces. The findings provide evidence that narrowing can occur for mental processes other than discrimination: category formation is also affected. The results suggest that frequency of experience with own-race versus other-race classes of faces may propel infants to contrast own-race faces with other-race faces, but not different classes of other-race faces with each other.

Research highlights

- White 6-month-olds responded to the perceptual differences between Black and Asian faces, and represented them as distinct classes of other-race faces.
- White 9-month-olds formed a broad category of other-race faces that excluded own-race White faces, but included faces from two perceptually distinct other-race face classes (Black and Asian).
- From 6 to 9 months, just as there is a tuning out (or narrowing) to individual faces within other-race classes, there is also a tuning out (or narrowing) to different classes of other-race faces.
- Nine-month-old representation of face race may be a precursor of an initial race-based ingroup–outgroup differentiation of faces.

Introduction

It is well established that humans are highly skilled at categorizing objects (Murphy, 2002). They can form categories based not only on perceptual cues, but also conceptual ones (Hampton, Estes & Simmons, 2007). Human prowess in forming categories additionally extends to the social domain (Banaji & Gelman, 2013). For example, racial categories can be based not only on facial physiognomy (e.g. White vs. Black vs. Asian), but also on a dichotomous ingroup-outgroup membership (e.g. own race vs. other race), rooted in differential experience (contact), kinship, or affiliation (Jones, Dovidio & Vietze, 2014). The ability to form social categories enables individuals to function efficiently within their social environment, although it also leads to stereotyping and prejudice.

Ample evidence indicates that human ability to form categories emerges in early infancy. Infants can use percep-

Address for correspondence: Paul C. Quinn, Department of Psychological and Brain Sciences, University of Delaware, Newark, DE 19716, USA; e-mail: pquinn@udel.edu

tual similarities to form categories for a variety of object classes including geometric forms, animals, and furniture (for a review, see Quinn, 2011).[1] However, evidence on infant learning of social categories such as race is sparse. Although a recent study suggests that White 6- to 9-month-olds can form one category for own-race White faces and another for other-race Asian faces (Anzures, Quinn, Pascalis, Slater & Lee, 2010), the basis for such categorization is unclear. Because White and Asian faces differ in facial morphology (Farkas, Katic & Forrest, 2005), infants in the Anzures *et al.* study could simply rely on physiognomic differences between White and Asian faces to form separate categories (Xiao, Quinn, Pascalis & Lee, 2014). However, they may also form categories based on differential experience with own- versus other-race faces (Rennels & Davis, 2008; Sugden, Mohamed-Ali & Moulson, 2014; Waxman, 2013).[2]

Infants have been shown to be highly sensitive to differential experience with own- versus other-race faces (Quinn, Anzures, Lee, Pascalis, Slater *et al.*, 2013). For example, robust evidence shows a narrowing phenomenon in terms of individual face discrimination. That is, infants are initially able to discriminate among own-race faces as well as among other-race faces; with increased age accompanied by increased exposure to own-race faces and a lack of exposure to other-race faces, infants maintain an ability to discriminate own-race faces, but increasingly have difficulty discriminating other-race faces from multiple race categories (Kelly, Quinn, Slater, Lee, Ge *et al.*, 2007; Kelly, Liu, Lee, Quinn, Pascalis *et al.*, 2009). Narrowing can be interpreted as reflecting an adaptive tuning by experience to process frequently encountered own-race faces optimally while tuning out information that differentiates individual other-race faces (e.g. Macchi Cassia, Bulf, Quadrelli & Proietti, 2014; Maurer & Werker, 2014; Pascalis, Loevenbruck, Quinn, Kandel, Tanaka *et al.*, 2014).

Given the experience-based narrowing that has been observed for discrimination of individual faces from different races, we reasoned that experience-based narrowing might also occur in category formation for classes of faces from different races. Specifically, with regard to other-race faces, younger infants may sort various other-race faces into different categories according to their distinctive racial physiognomy. However, with increased age, older infants might combine different racial classes into a single other-race category, different only from an own-race class of faces. In other words, differential experience with own- versus other-race faces may induce older infants to form two race-based categories of faces, one own-race category and another other-race category that encompasses a broad range of perceptually marked different races. The suggestion is that whereas younger infants might distinguish categories of other-race faces based on the perceptual features of faces from different races, older infants may engage more in a differentiation between the categories that is driven by differential experience (i.e. own race vs. all other races). We examined whether evidence might be obtained for this possible developmental trajectory by investigating categorical responding to other-race (Black and Asian) and own-race White faces in White 6- and 9-month-olds. These age groups were chosen because they represent the traditional comparison of pre- and post-narrowing age groups in studies of perceptual narrowing (e.g. Balas, 2012).

General method

Participants

The infants in each experiment were predominantly from middle-class backgrounds. All of the parents reported

[1] A typical procedure used to assess category formation by infants begins with familiarization with exemplars from a common category. Subsequently, during a novel category preference test, two new exemplars are presented – one is a novel instance from the familiarized category, and the other is a novel instance from a novel category. Generalization of looking time responsiveness to the new instance from the familiarized category and a preference for the new instance from the novel category are taken as evidence that the infants have in some manner grouped together the instances from the familiarized category, and that the representation of this category excludes the non-instance.

[2] An issue regarding the category formation processes of infants is whether they reflect on-line learning processes occurring during the course of an experiment, or whether an experiment is simply tapping into category representations that were constructed prior to arrival at the laboratory. One variable to consider in this context is experience. In the case of stimuli presented in the laboratory that do not map onto prior experience, infants are presumed to construct a category representation as exemplars from the familiar category are presented (see Mareschal & French, 2000, for an explicit computational model of the on-line category formation process). In the case of stimuli presented in the laboratory that correspond with abundant prior real-world experience, the expectation is that infants would be more likely to tap this experiential knowledge when performing in laboratory experiments. Evidence consistent with this expectation has previously been reported for how infants respond to gender and race information in faces (Quinn, Yahr, Kuhn, Slater & Pascalis, 2002; Anzures *et al.*, 2010). Based on this reasoning and evidence, we would suggest that category formation processes for other-race faces may reflect more on-line learning, whereas category formation processes for own-race faces may reflect more tapping of experiential knowledge. However, even with prior experience as a guideline, we concede that it is difficult to determine the precise mix of perceptual process and knowledge access responsible for the category representations mediating performance in a particular experiment. Moreover, as the current investigation implies, how infants respond to categories on-line (i.e., other-race faces) may be influenced by background knowledge infants have for contrast categories (i.e., own-race faces).

that their infant had little to no experience with Black or Asian faces. The local racial demographics include 87% White, 6% Black, and 4% Asian. In Experiments 1 and 2, we planned to collect data from 16 participants per condition (as is typical of previous research in our and other laboratories), and we tested the planned 16 infants per condition. However, in Experiment 3 and the study mentioned in footnote 3, given prior evidence consistent with the effects we were observing (e.g. Anzures *et al.*, 2010; Kelly *et al.*, 2007), we only included 12 participants per condition.

Stimuli

The stimuli consisted of photographs of Black, Asian, and White female faces that were taken from the NimStim face set (Tottenham, Tanaka, Leon, McCarry, Nurse *et al.*, 2009). There were four faces from each category, all depicting a neutral expression. Each photograph was cropped lightly (so as to eliminate hairstyle differences as a category cue), centered, and pasted onto a white 17.7 × 17.7 cm posterboard for presentation. The Black, Asian, and White faces had mean heights of 10.00 cm (SD = 0.32 cm), 9.68 cm (SD = 0.51 cm), and 10.00 cm (SD = 0.40 cm), and mean widths of 6.78 cm (SD = 0.19 cm), 6.80 cm (SD = 0.22 cm), and 6.53 cm (SD = 0.24 cm), respectively. Neither the height measure (F[2, 9] = .81, p = .475), nor the width measure (F[2, 9] = 1.99, p = .192), differed between the three categories (Black vs. Asian vs. White). The particular stimulus faces used from the Nimstim set were: 11, 12, 13, and 14 (Black), 15, 16, 17, and 18 (Asian), and 7, 8, 9, and 10 (White). Six White adults (mean age = 26.5 years, SD = 1.87; 3 females) who were born and raised in the local community were asked to categorize the stimulus faces as Black, Asian, or White; each participant categorized the faces with 100% accuracy.

We undertook further analyses of luminance and contrast, comparing the images across the categories, even breaking down the luminance and contrast properties by red, green, and blue color channels. These analyses are reported in the Supporting Information file. Critically, in no case was there a pattern of differences between the own-race class and both classes of other-race faces that was greater than the difference between the two classes of other-race faces. Moreover, as has been done in previous papers (e.g. Hu, Wang, Fu, Quinn & Lee, 2014), the Saliency Toolbox (Walther & Koch, 2006) was used to calculate the salience of each area in each face image. This salience analysis is also included in the Supporting Information file. It showed that there was no differential salience of the various regions of the face images across the Black, Asian, and White categories.

Apparatus

Infants were tested in a visual preference apparatus, modeled after Fagan (1970). The apparatus has a gray display panel that includes two compartments to hold the stimuli. The stimuli were illuminated by a fluorescent lamp that was shielded from the infant's view. Center-to-center distance between compartments was 30.5 cm and on all trials the display panel was situated approximately 30.5 cm in front of the infant. There was a 0.62 cm peephole located midway between the compartments that permitted an observer to record infant visual fixations. A second peephole, 0.90 cm in diameter, located directly below the first peephole, permitted a Pro Video CVC-120PH pinhole camera and Magnavox DVD recorder to record infant gaze duration.

Procedure

All infants underwent the following general procedure. The infant was brought to the laboratory by a parent and seated in a reclining position on the parent's lap. There were two experimenters, both of whom were naive to the hypotheses under investigation. The first experimenter positioned the apparatus so that the midline of the infant's head was aligned with the midline of the display panel. On any given trial, the first experimenter loaded the stimuli into the compartments of the display panel, and closed the panel, thereby exposing the stimuli to the infant. The parent was unable to see the stimuli.

During each trial, the first experimenter observed the infant through the small peephole and recorded visual fixations to the left and right stimuli by means of two 605 XE Accusplit electronic stopwatches (San Jose, CA, USA), one of which was held in each hand. The second experimenter timed the duration of the trials and signaled the end of each trial. Between trials, the first experimenter opened the panel, changed stimuli, recorded infant looking times, and reclosed the panel. The first and second experimenters changed places for the test trials. The experimenter who presented the stimuli and measured infant fixations during familiarization now measured trial duration and signaled the end of each test trial, whereas the second experimenter presented the test stimuli and measured infant fixations. The second experimenter was always naive with respect to the information presented to the infant during familiarization. The two experimenters changed roles across infants.

Trained observers, naive to the hypotheses, recorded looking times to the stimuli. Inter-observer agreement, as determined by comparing looking times measured by the experimenter using the center peephole, and an additional naive observer measuring looking times offline from DVD records, was calculated for the test trials of 22 randomly selected infants participating across the three experiments (eight infants from Experiment 1, eight from Experiment 2, and six from Experiment 3, or 25% of the infants tested in the three experiments). Average level of agreement for the novel category preference scores was 97.93% (SD = 2.11). In addition, the average of the difference scores for the original and reliability-check novel category preference scores was −0.14, SD = 1.32, which was not significantly different from 0, $t(21) = -0.49$, p = .890, two-tailed, indicating that the differences between observers were randomly distributed, rather than having one observer with consistently higher or lower scores relative to the other observer.

Experiment 1

In Experiment 1, White 6-month-olds were familiarized with color photographs of Black or Asian faces, and then tested with a novel Black face versus a novel Asian face.

Method

Participants

Participants were 32 White 6-month-olds (14 females), mean age = 190.97 days, SD = 15.62 days. Two additional infants were tested, but did not complete the procedure due to fussiness.

Stimuli

Stimuli were the Black and Asian faces described in the General Method section.

Procedure

Half of the infants were familiarized with three Black faces and the other half with three Asian faces. During familiarization, the three faces were presented twice over the course of six 15 s familiarization trials. Infants were presented with one face (i.e. two identical copies of that face in the left and right stimulus compartments) on the first trial, another face on the second trial, and the third face on the third trial, with the sequence repeated on trials 4 through 6. Two 10 s test trials immediately followed the familiarization trials and paired a novel Black face with a novel Asian face. There were 16 such pairs, randomly selected, and each pair, which was seen on both test trials, was assigned to one infant who had seen Black faces and one infant who had seen Asian faces during familiarization. The test trial stimuli were thus identical for both groups of infants. Left–right positioning of the novel face from the novel category was counterbalanced across infants on the first test trial and reversed on the second test trial. The three stimuli presented during familiarization to each infant were the remaining instances from the familiarization category (i.e. those not selected for presentation on the test trials). Their order of presentation on the first three familiarization trials was randomly determined. By way of example, then, if the first randomly selected pair was Black Face 1 and Asian Face 1, then that pair would be shown to one infant who was familiarized with Black faces and one infant who was familiarized with Asian faces, and the stimuli presented during familiarization would be Black Face 2, Black Face 3, and Black Face 4 to the infant familiarized with Black faces, and Asian Face 2, Asian Face 3, and Asian Face 4 to the infant familiarized with Asian faces.

Results and discussion

Familiarization trials

Individual looking times were summed over left and right copies of the stimulus presented on each trial and then averaged across the first three and last three trials. Mean looking times are shown in Table 1. An analysis of variance (ANOVA), Face Category (Black vs. Asian) × Trials (1–3 vs. 4–6), performed on the individual scores revealed only a significant Trials effect, $F(1, 30) = 9.14$, p = .005, partial eta^2 = .23. Neither the effect of Face Category, $F(1, 30) = .002$, p = .965, nor the interaction of Face Category × Trials, $F(1, 30) = 2.21$, p = .144, was significant. Using the standard operational definition of habituation as a decline in responsiveness with repeated stimulation (Cohen & Gelber, 1975), the decrement in looking time from the first to the second half of familiarization for infants presented with either Black or Asian faces indicates that both groups habituated to the stimuli.

Preference test trials

Each infant's looking time to the novel stimulus from the novel category was divided by the looking time to both test stimuli and converted to a percentage score. Mean novel category preference scores are shown in Table 1 and Figure 1. Table 1 also shows corresponding SDs, relation to chance performance, p values, and Cohen's d values. As can be seen, t tests comparing the preference scores to 50% revealed that both groups of infants (those familiarized with Black faces and those familiarized with Asian faces) significantly preferred to look at the novel category stimuli. These results indicate that White 6-month-olds formed a category representation for Black faces that included novel Black faces, but excluded novel Asian faces, and a category representation for Asian

Table 1 *Mean fixation times (seconds) during the familiarization trials and mean novel category preference scores (percentages) during the preference test trials of Experiment 1*

	Fixation time								
	Trials 1–3		Trials 4–6		Novel category preference				
Familiarization Category	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	t^a	*p*	*d*
Black	8.90	(3.10)	8.07	(4.25)	60.32	(16.23)	2.54	.023	0.64
Asian	9.76	(3.37)	7.31	(2.58)	56.50	(10.51)	2.47	.026	0.62
Combined	9.33	(3.21)	7.69	(3.48)	58.41	(13.59)	3.50	.001	0.62

[a] *t* vs. chance.

faces that included novel Asian faces, but excluded novel Black faces. The findings suggest that 6-month-old infants respond categorically to the perceptual differences between different classes of other-race faces.[3]

[3] To determine whether the categories were formed through categorization (i.e. equivalent responding to a group of discriminably different entities; Murphy, 2002) or categorical perception (i.e. equivalent responding to similar exemplars that are difficult to discriminate, Harnad, 1987), we measured whether instances from within each of the categories were discriminable. This issue arises in part because 6 months has been reported in some papers to be a time of transition in the emergence of narrowing with findings of greater or lesser discriminability of individual instances from less frequently experienced categories (e.g. Kelly *et al*., 2007). Each of 24 6-month-olds (14 females, mean age = 194.17 days, *SD* = 14.83 days) was familiarized with one exemplar from an other-race category for two 10 s familiarization trials, and then tested with the familiar exemplar paired with a novel exemplar from the same category for two 10 s test trials. For half of the infants, the faces were Black; for the other half, the faces were Asian. Familiarization and test faces were randomly selected for each infant. Two familiarization trials were used because that matched the number of familiarization trials on which an exemplar was presented in the category formation task. Left–right positioning of the stimuli was counterbalanced across infants on the first test trial and reversed on the second test trial. Mean looking time per trial during familiarization was 8.36 s (*SD* = 2.19) for the Black faces and 9.14 s (*SD* = 2.77) for the Asian faces. Mean novelty preference was above chance for the Black faces (*M* = 61.87%, *SD* = 16.92, $t[11] = 2.94$, $p = .013$, two-tailed, $d = 0.70$), but not different from chance for the Asian faces (*M* = 53.15%, *SD* = 20.98, $t[11] = 0.52$, $p = .613$, two-tailed). In the context of interpreting the results of Experiment 1, the above-chance discrimination of the Black faces suggests that they were represented through categorization, whereas the at-chance discrimination of the Asian faces suggests that they were represented through categorical perception. We would emphasize here that even though the discriminability of the instances within the two categories differed by our measure, it is also the case that parametric variation in procedure could give rise to different outcomes suggesting differing degrees of discriminability (see, for example, Fair, Flom, Jones & Martin, 2012; Zieber, Kangas, Hock, Hayden, Collins *et al*., 2013). We would also note that categorization and categorical perception are analogous in terms of producing sets of entities that are treated as equivalent (i.e. equivalence classes).

Experiment 2

Experiment 2 examined whether responsiveness to the category distinctions between different classes of other-race faces that was observed in 6-month-olds would be maintained or lost in 9-month-olds. Experiment 2 was thus a replication of Experiment 1, but conducted with 9-month-olds.

Method

Participants

Participants were 32 White 9-month-olds (16 females), mean age = 280.72 days, *SD* = 12.33 days. Two additional infants were tested, but one did not complete the procedure due to fussiness, and the other was excluded from the data analysis because of failure to compare the test stimuli.

Stimuli

Stimuli were the same as those used in Experiment 1.

Procedure

The procedure was the same as in Experiment 1.

Results and discussion

Familiarization trials

Mean looking times are shown in Table 2. An ANOVA, Face Category (Black vs. Asian) × Trials (1–3 vs. 4–6), performed on the individual scores revealed only a significant Trials effect, $F(1, 30) = 4.18$, $p = .047$, partial eta^2 = .12. Neither the effect of Face Category, $F(1, 30) = .253$, $p = .619$, nor the interaction of Face Category × Trials, $F(1, 30) = .000$, $p = 1.00$, was significant. The decrement in looking time from the first to the second

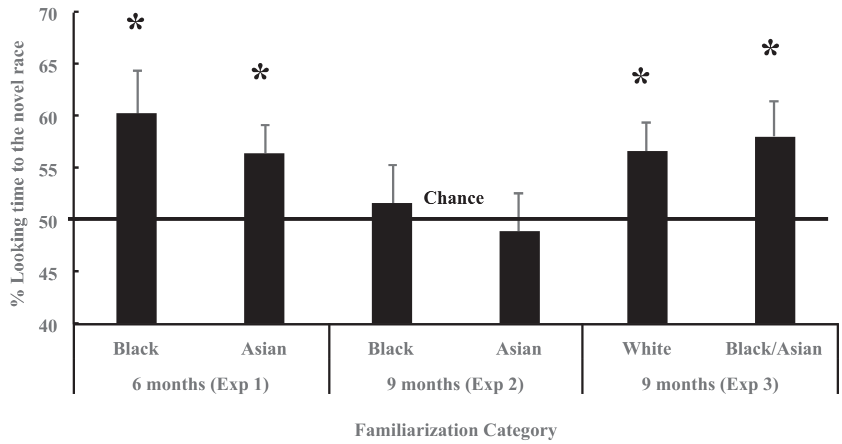

Figure 1 *Mean novel category preference scores (in percentages) as a function of the race of the familiarization category and the age of the participants. Error bars show standard errors of the mean. Scores that differed from chance (50%) are marked with an asterisk.*

half of familiarization suggests that the 9-month-olds in Experiment 2, like the 6-month-olds in Experiment 1, habituated to the Black and Asian faces.

Preference test trials

Mean novel category preference scores are shown in Table 2 and Figure 1. Table 2 also shows corresponding *SD*s, relation to chance, *p* values, and Cohen's *d* values. *t* tests comparing the preference scores to 50% revealed that neither group of infants (i.e. neither those familiarized with Black faces nor those familiarized with Asian faces) preferred to look at the novel category stimuli. In addition, when the combined mean novel category preference score for other-race faces from Experiment 1 conducted with 6-month-olds (M = 58.41, SD = 13.59) was compared with the combined mean novel category preference score for other-race faces from Experiment 2 with 9-month-olds (M = 50.23, SD = 14.94), the difference was reliable, $t(62) = 2.29$, p = .025, d = 0.57.

The results from Experiments 1 and 2 indicate that the period from 6 to 9 months of age reflects a time of developmental change in how infants represent different classes of other-race faces. Whereas White 6-month-olds in Experiment 1 responded to the perceptual differences between Black and Asian faces and represented them as distinct classes of other-race faces, White 9-month-olds did not respond differentially to Asian faces after familiarization with Black faces or to Black faces after familiarization with Asian faces. However, because the results of Experiment 2 were null, there is ambiguity in how to interpret them. It is possible that the infants in Experiment 2 formed a broad category of other-race faces that included both Black and Asian faces. It is also possible that the infants in Experiment 2 simply did not form category representations. Experiment 3 was undertaken to distinguish between these possibilities.

Experiment 3

In Experiment 3, White 9-month-olds were assigned to one of two conditions. In the own-race condition, familiarization with own-race (White) faces was followed by testing with a novel own-race (White) face paired with a novel other-race face (either Black or Asian). In the other-race condition, familiarization with other-race faces (Black or Asian) was followed by testing with a novel face from the familiarized other-race category paired with a novel own-race (White) face. If the 9-month-olds in each condition of Experiment 3 formed categories of own-race versus other-race faces (i.e. generalized to novel instances from the familiarized category and preferred novel instances from the novel category), then this would suggest that the 9-month-olds in Experiment 2 had formed a broad category of other-race faces that was inclusive of exemplars from novel other-race classes, but exclusive of own-race faces.

Method

Participants

Participants were 24 White 9-month-olds (10 females), mean age = 279.00 days, SD = 13.77 days. Two additional infants were tested, but one did not complete the procedure due to fussiness, and the other was excluded

Table 2 *Mean fixation times (seconds) during the familiarization trials and mean novel category preference scores (percentages) during the preference test trials of Experiment 2*

	Fixation time								
	Trials 1–3		Trials 4–6		Novel category preference				
Familiar category	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	t^a	*p*	*d*
Black	7.86	(2.34)	7.00	(2.88)	51.61	(15.35)	0.42	.680	0.10
Asian	8.24	(2.25)	7.39	(2.25)	48.86	(14.88)	−0.31	.761	−0.08
Combined	8.05	(2.27)	7.20	(2.55)	50.23	(14.94)	0.09	.929	0.02

[a] *t* vs. chance.

from the data analysis because of interference with the procedure by an older sibling.

Stimuli

The Black and Asian stimuli were those used in Experiments 1 and 2. The White stimuli described in the General Method section were also used.

Procedure

The procedure was the same as in Experiment 1, except that half of the infants were familiarized with own-race White faces and the other half with other-race (either Black or Asian) faces. Both groups were tested with a novel own-race face and a novel other-race face. When the infants were familiarized with own-race White faces, the novel other-race category shown at test was Black for half of the infants, and Asian for the other half. When the infants were familiarized with other-race faces, half were familiarized with Black faces, the other half with Asian faces, and the other-race category shown at test corresponded with that shown during familiarization.

Preliminary analyses indicated that the type of other-race face (Black vs. Asian) did not impact looking time during familiarization trials nor did it influence novel category preference during test trials. These analyses are reported in the Supporting Information file.

Results and discussion

Familiarization trials

Mean looking times are shown in Table 3. An ANOVA, Face Category (Own-Race vs. Other-Race) × Trials (1–3 vs. 4–6), performed on the individual scores revealed only a significant Trials effect, $F(1, 22) = 11.63$, $p < .005$, partial eta^2 = .35. Neither the effect of Face Category, $F(1, 22) = .882$, $p = .358$, nor the interaction of Face Category × Trials, $F(1, 22) = 2.06$, $p = .161$, was significant. The decrement in looking time from the first to the second half of familiarization for infants presented with either own-race (White) or other-race (Black or Asian) faces was once more consistent with habituation to the different categories of faces.

Preference test trials

Mean novel category preference scores are shown in Table 3 and Figure 1. Table 3 also shows corresponding *SD*s, relation to chance, *p* values, and Cohen's *d* values. *t* tests comparing the preference scores to 50% revealed that both groups of infants (those familiarized with own-race [White] faces and those familiarized with other-race [Black or Asian] faces) significantly preferred to look at the novel category stimuli. These results indicate that the White 9-month-olds formed a category of own-race White faces that included novel White faces, but excluded other-race (Black or Asian) faces. In addition, the data indicate that the infants formed category representations for either class of other-race faces (Black or Asian) that included novel exemplars from the familiarized other-race category, but excluded novel exemplars from the novel own-race (White) category. Moreover, the latter result suggests that infants in Experiment 2 had formed a broad category representation for other-race faces that included exemplars from novel other-race categories, but excluded exemplars from the own-race category.[4]

[4] Given prior evidence from several studies indicating that White 9-month-olds discriminate between own-race White faces and have greater difficulty discriminating among other-race faces, whether Black or Asian (Anzures, Pascalis, Quinn, Slater & Lee, 2011; Anzures *et al.*, 2010; Kelly *et al.*, 2007), we would assume in the current study that the White faces were discriminable for White 9-month-olds, and that the Black and Asian faces were less so (but see Fair *et al.*, 2012; Zieber *et al.*, 2013). It follows that category formation for own-race faces was achieved through categorization, whereas a category formation process closer to categorical perception was more likely to be occurring for other-race faces. Again, however, via either process, the end product is an equivalence class.

Table 3 *Mean fixation times (seconds) during the familiarization trials and mean novel category preference scores (percentages) during the preference test trials of Experiment 3*

	Fixation time								
	Trials 1–3		Trials 4–6		Novel category preference				
Familiarization	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)	t^a	*p*	*d*
Own race (Wh)	7.78	(2.21)	7.08	(2.52)	56.58	(10.09)	2.26	.045	0.65
Other race (Bl/As)	7.51	(2.06)	5.80	(1.96)	58.09	(11.86)	2.36	.038	0.68
Combined	7.65	(2.09)	6.44	(2.30)	57.33	(10.80)	3.32	.003	0.68

[a] *t* vs. chance.

General discussion

The current investigation examined how infants represent other-race category information in the developmental period between 6 and 9 months. In Experiment 1, White 6-month-olds formed distinct category representations for Black versus Asian faces, each of which excluded instances of the other. In Experiment 2, White 9-month-olds familiarized with either Black or Asian faces did not display a preference for novel exemplars from the novel category. This latter outcome was consistent with White infants either not forming category representations based on race information or with White infants forming a broad category representation of other-race faces that included both Black and Asian faces. The findings from Experiment 3 ruled out the first possibility: White 9-month-olds formed a category representation for own-race White faces that excluded both Black and Asian other-race faces and a category representation for either Black or Asian other-race faces, each of which excluded own-race White faces. That White 9-month-olds responded to the categorical distinction between own-race White and other-race Asian faces is consistent with the findings of Anzures *et al.* (2010). The combined results from Experiments 2 and 3 suggest that by 9 months, White infants form a broad category representation for other-race faces that includes instances from multiple classes of other-race faces (i.e. Black and Asian) but excludes own-race White faces.

The findings indicate that individual face discrimination is not the only mental process for which narrowing may be observed. It can additionally be observed for the mental process of category formation (see also Ferry, Hespos & Waxman, 2013, for a report of species narrowing in the vocalizations that promote learning of object categories by human infants). Thus, whereas prior work had demonstrated a reorganization in the ability to distinguish between different faces from within particular other-race classes, the current work shows that there is also a reorganization in the process of representing different classes of other-race faces as being distinct from one another. That White 6-month-olds responded to the perceptual differences between Black and Asian face classes, whereas White 9-month-olds formed a broad other-race grouping of faces, supports this observation.

One can ask whether maturation or experience accounts for the difference in performance on Experiments 1 and 2. On the one hand, a downturn in classification performance on other-race faces could reflect the age difference in participants. On the other hand, it seems reasonable to argue that most 9-month-olds will have seen more same-race faces than most 6-month-olds and that such experience is at the root of the performance difference in classification. Given that the downturn in recognition performance for individual faces within a given other-race class has been shown to be under experiential control (i.e. Anzures, Wheeler, Quinn, Pascalis, Slater *et al.*, 2012; Heron-Delaney, Anzures, Herbert, Quinn, Slater *et al.*, 2011), our inclination is to consider the present results to be driven by differential experience. However, to choose between the maturational and experiential alternatives in the present case in a more convincing way, one could compare other-race face classification performance of the White 9-month-olds in Experiment 2 with White 9-month-olds living in a neighborhood with many Asian and Black individuals. Thus, while the effects we have reported apply to our particular sample of infants who had limited exposure to other-race faces, we do not know how they would apply to infants exposed to a greater diversity of faces.

What seems to matter more to White 9-month-olds growing up in an environment with primary exposure to White faces is whether a face is White or not White, a finding that may foreshadow the other-race advantage in social categorization observed in adults (Hugenberg, Young, Bernstein & Sacco, 2010). Presumably this is so because of almost exclusive exposure to own-race White faces with limited, if any, exposure to Black and Asian other-race faces. We would propose here that the 9-month-old representation of face race may provide a foundation or be a precursor of an initial race-based ingroup–outgroup differentiation of faces. On this view, the ingroup category is defined by the race of faces that the infant is predominantly experiencing (i.e. White faces for White infants), and the outgroup category includes any face that does not match the ingroup (i.e. Black and Asian faces for White infants). This view is consistent with the observation that smaller (minority) groups are more distinctive than larger (majority) groups, thus making smaller groups more likely as outgroup targets (Bigler & Liben, 2007). Moreover, the initial differentiation may transition to a more adult-like ingroup–outgroup formulation when infants are able to match the representation of the race of their own face with that of the class of predominant experience (i.e. 'like me'; Meltzoff, 2007). It may be from that latter development that racial bias subsequently develops (Kinzler & Spelke, 2011).

Of theoretical significance is that the data reported here may represent an instance in which a lower-level process drives development of a higher-level representation. That is, frequency of experience with own-race versus other-race classes of faces may propel infants to contrast own-race faces with other-race faces, but not different classes of other-race faces with each other. Labeling may also play a role (e.g. Scott & Monesson, 2009): some frequently experienced own-race exemplars would likely be labeled with individual names for infants (e.g. family members), whereas most infrequently experienced other-race faces may not be labeled. Regardless of which of these or other accounts of face race classification comes to be accepted, the present results suggest that 9-month-olds represent an own-race (i.e. the predominantly experienced own-race class of faces) versus other-race (i.e. the lesser experienced classes of other-race faces) partitioning of faces.

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