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Brief daily exposures to Asian females reverses perceptual narrowing for Asian faces in Caucasian infants

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Abstract

Perceptual narrowing in the visual, auditory, and multisensory domains has its developmental origins in infancy. The present study shows that experimentally induced experience can reverse the effects of perceptual narrowing on infants' visual recognition memory of other-race faces. Caucasian 8- to 10-month-olds who could not discriminate between novel and familiarized Asian faces at the beginning of testing were given brief daily experience with Asian female faces in the experimental condition and Caucasian female faces in the control condition. At the end of three weeks, only infants who received daily experience with Asian females showed above-chance recognition of novel Asian female and male faces. Further, infants in the experimental condition showed greater efficiency in learning novel Asian females compared to infants in the control condition. Thus, visual experience with a novel stimulus category can reverse the effects of perceptual narrowing in infancy via improved stimulus recognition and encoding.

Keywords

perceptual narrowing; other-race face recognition; infancy

Perceptual narrowing refers to the process during which an initially broadly tuned perceptual system becomes specialized to process familiar and biologically relevant stimuli. An original ability during early infancy to discriminate and recognize stimuli from different categories is altered with experience so that more sophisticated discriminatory and

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recognition abilities develop and are maintained only for familiar categories (e.g., human faces, native speech sounds and music; Hannon & Trehub, 2005a; Pascalis, de Haan, & Nelson, 2002; Scott & Monesson, 2009; Weikum et al., 2007; Werker, Gilbert, Humphrey, & Tees, 1981; Werker & Lalonde, 1988). This more specialized perceptual system that becomes fine-tuned in discriminating and recognizing stimuli only from certain familiar categories has been noted, in a few instances, to be preceded and accompanied by infants' preferences for the familiar classes of stimuli (e.g., own-race faces; Bar-Haim, Ziv, Lamy, & Hodes, 2006; Kelly et al., 2005; native speech sounds; Moon, Cooper, & Fifer, 1993) – preferences that are likely adaptive in guiding the perceptual narrowing process for tuning into biologically and socially relevant information (e.g., the facial appearance and speech of familiar caregivers that are shared by others within the same race and culture). Such biological and social relevance may be an additionally crucial factor on the perceptual narrowing process in that familiar stimulus categories with relatively less biological and social relevance may not naturally benefit from more sophisticated object recognition (e.g., 4-year-olds' better recognition of faces compared to cars; Macchi Cassia, Turati, & Schwarzer, 2011).

A more specialized perceptual system is typically observed during the latter half of an infant's first year. In the visual domain, perceptual narrowing is evident in infants' better recognition memory of own-species and own-race faces over other-species and other-race faces (Kelly et al., 2007, 2009; Pascalis et al., 2002). In the auditory domain, perceptual narrowing is evident in infants' better discriminatory abilities for native speech sounds over non-native speech sounds (Polka & Werker, 1994; Werker & Lalonde, 1988; Werker & Tees, 2002), different female voices speaking a native language over different female voices speaking a non-native language (Johnson, Westrek, Nazzi, & Cutler, 2011), and familiar culture-specific musical rhythms (Hannon & Trehub, 2005b). Perceptual narrowing is also manifest at an intersensory level. Thus, the ability to integrate visual and auditory information is maintained only for socially relevant stimuli (e.g., human faces and vocalizations vs. monkey faces and vocalizations; Bahrick, Netto, & Hernandez-Reif, 1998; Kuhl & Meltzoff, 1982; Lewkowicz & Ghazanfar, 2006; Patterson & Werker, 2003; Poulin-Dubois, Serbin, Kenyon, & Derbyshire, 1994).

This fine-tuning of the perceptual system is experience-dependent (Burns, Yoshida, Hill, & Werker, 2007; Heron-Delaney et al., 2011; Pascalis et al., 2005; Scott & Monesson, 2009). That is, if exposed to multiple face categories and multiple languages during early infancy, then infants maintain a more broadly tuned perceptual system. For example, if infants who have not yet undergone perceptual narrowing are given experience in individuating between different monkey and other-race faces, they maintain the ability to recognize novel monkey (Pascalis et al., 2005; Scott & Monesson, 2009) and other-race faces, respectively (Heron-Delaney et al., 2011). In addition, infants exposed to multiple languages maintain phonetic representations relevant to each language (Burns et al., 2007).

What happens then when an infant's perceptual system has already become more fine-tuned? Is this fine-tuning reversible? Exposure to foreign music and language during the latter half of an infant's first year has been shown to be effective in reversing the perceptual narrowing effects in the auditory domain (Hannon & Trehub, 2005b; Kuhl, Tsao, & Liu, 2003). In the visual domain, Sangrigoli and de Schonen (2004) showed that a brief two-minute exposure to other-race faces was sufficient to ameliorate 3-month-olds' difficulties in recognizing other-race faces. However, 3-month-olds' face recognition abilities tend to be more broadly tuned compared to older infants (Kelly et al., 2007, 2009). In fact, perceptual narrowing in general appears to be more robust during the latter half of the first year (reviewed in Lewkowicz & Ghazanfar, 2009; Scott, Pascalis, & Nelson, 2007; and Slater et al., 2010). It is thus unknown whether perceptual narrowing in the visual domain is

reversible in later infancy when the visual system is more specialized or more fine-tuned towards visually familiar stimulus categories relative to early infancy.

In contrast to previous studies that have shown an influence of visual experience with a novel stimulus category *before* perceptual narrowing has occurred (Heron-Delaney et al., 2011; Pascalis et al., 2005; Scott & Monesson, 2009), we sought to determine whether other-race visual experience influences infants' other-race face recognition *after* perceptual narrowing has already occurred. We recruited 8- to 10-month-old Caucasian infants and assigned them to 1 of 2 conditions. In the experimental condition, infants were given daily video experience with other-race Asian females. In the control condition, infants were given daily video experience with own-race Caucasian females. Infants' face recognition of novel Asian female and male faces was tested at baseline, at the end of their first lab visit, and at 1 week, 2 weeks, and 3 weeks after their first lab visit. A test of infants' recognition of Asian male faces was included to examine whether any advantages gained from experience with other-race females would transfer to other-race recognition of male faces. If advantages in recognition abilities from exposure to Asian females transfer onto Asian male face recognition, then this would suggest that exposure to Asian females leads to the abstraction of race-specific information rather than gender-specific information from the novel race category.

If a brief exposure to other-race individuals is sufficient to reverse perceptual narrowing in other-race face processing, infants in the experimental condition should show improved recognition of other-race Asian female faces at the end of their first visit and this improvement might be generalized to Asian male faces. Alternatively, if extended exposures to other-race individuals are needed, then above-chance recognition for other-race Asian faces might be achieved only after several weeks of daily exposure to Asians. We hypothesized that above-chance recognition memory for other-race Asian faces would only be evident among the infants in the experimental condition.

Method

Participants

The participants who were included in the analyses were 16 Caucasian infants (8 in the experimental group and 8 in the control group) with little to no experience with Asian individuals (i.e., parents reported that they did not have close family or friends of Asian ethnicity with whom their child may have had previous contact). Infants were between 8 and 10 months of age (M = 285.06 days, SD = 13.50; 8 males) at the beginning of the study. Ten additional infants were excluded due to fussiness/crying, weekly experience with Asians, or attrition.

Stimuli

The DVDs that were shown to infants in the lab and at home were comprised of videos of 8 female adults. The female adults were recruited from within the university and they either conducted research with infants and/or young children or had experience teaching young children in a school setting. During the videotaping session, the female adults were instructed to look directly into the camera and pretend that they were interacting with an infant. Thus, each female talked and sang (in English) in infant-directed speech for a total of 1 minute (8 females × 1 minute = 8 minutes total). The videos included both infant-directed speech and singing to help ensure that the infants would find them interesting and thereby attend to the females in the videos. Indeed, previous studies have shown that infants prefer to listen to infant-directed speech rather than adult-directed speech (Cooper & Aslin, 1990), and they also prefer to listen to infant-directed singing rather than infant-directed speech

(Nakata & Trehub, 2004). The females in the DVDs were videotaped in pairs (i.e., sitting side by side), thereby allowing infants to actively compare the 2 different females. The females took turns speaking/singing and they also introduced themselves by name so as to maximize individuation between the faces – a strategy that has been shown to be crucial in reducing the own-race bias in adults' face recognition (Goldstein & Chance, 1985; Hills & Lewis, 2006; Lebrecht, Pierce, Tarr, & Tanaka, 2009; McGugin, Tanaka, Lebrecht, Tarr, & Gauthier, 2011; Rhodes, Locke, Ewing, & Evangelista, 2009; Tanaka & Pierce, 2009), as well as in enhancing infants' recognition of other-species faces, other-race faces, and unfamiliar non-face classes of stimuli (Heron-Delaney et al., 2011; Scott, 2011; Scott & Monesson, 2009). DVDs for the experimental condition were comprised of videos of Asian females (*M* age in years = 28.54, *SD* = 5.95), and DVDs for the control condition were comprised of videos of Caucasian females (*M* age in years = 24.12, *SD* = 2.41; see Figure 1 for examples). We chose to use videos rather than photographs to familiarize infants in the experimental group with other-race Asian female faces (and infants in the control group with own-race female faces) so as to more closely mimic naturalistic interactions that infants are likely to experience with their social partners. In addition, the dynamic nature of the videos helped to ensure that infants would attend to the female faces in the videos.

Similar to other studies that have examined other-race face recognition in infants, we used photographs of Asian faces for the recognition memory tests conducted across the 4 lab visits. We used color photographs of 10 Asian female adult faces and 10 Asian male adult faces with frontal poses and neutral expressions (see Figure 2).

Procedure

Infants visited the lab 4 times. Each visit was about 1 week apart. During each visit, infants were seated in a high-chair approximately 60 cm from a 42-inch plasma television screen on which the stimuli were presented. Infants were videotaped so that their looking could be measured via frame-by-frame offline coding.

Lab visit #1—Infants' first lab visit consisted of 3 parts: a) an other-race baseline face recognition memory test, b) a 4 minute video exposure to 4 different other-race females for infants in the experimental group or 4 different own-race females for infants in the control group, and c) another other-race face recognition memory test. For each infant, the photographs of the Asian faces in the face recognition memory tests were only used once and they were always different from those shown in the other-race Asian videos.

Other-race face recognition baseline: Baseline measures of infants' other-race face recognition were obtained by giving infants a recognition task with Asian female adult faces, followed by a recognition task with Asian male adult faces. An infant-controlled habituation procedure was used, whereby a single face was presented on the screen until infants looked away from the face for a minimum of two consecutive seconds. The same face was repeatedly presented until infants' looking at the face during a single habituation trial decreased to 50% or less than 50% of the average of the previous two consecutive trials. Once this habituation criterion was reached, infants were presented with two 5-s test trials which showed the familiar face paired with a novel face. Left-right positioning of the familiar and novel test stimuli was counterbalanced across infants on the first test trial and reversed on the second test trial. If infants recognized the familiar face that was presented during the habituation portion of the task, then they should show a novelty preference as indicated by greater looking at the novel face at test. This exact procedure has previously been used to show own-race face recognition among Caucasian infants at the ages tested in the current study (Anzures, Quinn, Pascalis, Slater, & Lee, 2010; Kelly et al., 2007).

Video exposure: Infants were then shown a 4 minute video of 4 different female adults talking and singing in infant-directed speech (each female was seen singing/talking for 1 minute). The females in the videos were shown sitting side by side and they were different from those seen in the recognition memory tasks. Infants in the experimental condition were shown a video of other-race Asian females (i.e., different from those seen in the recognition memory task), and infants in the control condition were shown a video of own-race Caucasian females.

Post-video other-race face recognition test: The videos were followed by another set of recognition memory tasks with novel Asian female adult faces and novel Asian male adult faces. The recognition memory task with Asian female adult faces was always presented first followed by the recognition memory task with Asian male adult faces. It should be noted that in both the experimental and control conditions, the recognition memory tasks were always testing infants' recognition of familiarized Asian faces that were different from those in the videos and in previous recognition memory tasks.

At the end of the first lab visit, parents were sent home with a copy of the DVD featuring 8 female adults (4 of whom the infants saw during the video exposure period). Infants in the experimental condition were given a DVD with Asian females, and infants in the control condition were given a DVD with Caucasian females. Parents were instructed to play the DVD to their infant once everyday, except for the days scheduled for their subsequent lab visits. Parents were also instructed to play the entire DVD for as long as infants were attentive to the videos, and thus, if needed, to play the DVD in several viewing sessions.

Lab visits #2–4—Following the first lab visit, infants' subsequent lab visit consisted of 2 parts: a) a 4 minute video exposure to 4 different other-race females for infants in the experimental group or to 4 different own-race females for infants in the control group, and b) an other-race face recognition memory test. The recognition memory task with Asian female adult faces was always presented first, and followed by the recognition memory task with Asian male adult faces. For each infant, the face stimuli used in the recognition task was only used once across the 4 lab visits. In addition, the face stimuli used in the face recognition tasks across the 4 lab visits were presented in a different order across the infant participants. During infants' subsequent lab visits, parents were asked if their child had watched the videos everyday since their last visit to the lab. All of the infants used in the final analyses were reported to have watched the videos everyday at home except for the days of their lab visits, as instructed.

Results

Looking towards the Caucasian and Asian females during the video exposure period in the first lab visit was examined to ascertain that there were no baseline differences in looking across the two conditions. An independent samples t-test confirmed that infants in the experimental and control conditions showed comparable looking (i.e., percentage of looking as opposed to looking away) at the Asian (M = 71.50%, SD = 9.91%) and Caucasian (M = SD = 13.16%) females, respectively during the video exposure period of their first lab visit (p > 71.32%,.05).

Infants' novelty preference scores in the recognition tasks were computed by obtaining an average percentage of looking at the novel face across the two test trials. Separate novelty preference scores were computed for female and male faces at baseline (i.e., prior to viewing the videos), at the end of the first lab visit (i.e., immediately after viewing the videos), at the end of the second and third lab visit (i.e., after 7–14 days of exposure to the videos), and at the end of the final lab visit (i.e., after 21 days of exposure to the videos). One-sample t-tests

confirmed that, at baseline, the Caucasian infants in the experimental and control conditions showed only chance-level recognition of Asian female and male faces (p values > .05; see Figure 3). These results confirm that the infants were showing poor recognition memory for other-race faces, and suggest that perceptual narrowing had already taken place.

Experimental Condition

At the end of their first lab visit, Caucasian infants in the experimental condition who were shown a short video of Asian females demonstrated only chance-level recognition of novel Asian female and male faces (p values > .05). Thus, by 8 to 10 months of age, brief exposure to other-race faces is insufficient to reverse the effects of perceptual narrowing on other-race face recognition memory. After subsequent daily exposure to Asian female faces for 7–14 days, infants still showed chance-level recognition of novel Asian females (p > .05), but a significant novelty preference for novel Asian males, $t(7) = 4.24$, $p = .004$, Cohen's $d = 1.50$. After 21 days of daily exposure to Asian female faces, infants showed above-chance recognition memory of novel Asian female and male faces, $t(7) = 3.00$, $p = .02$, Cohen's $d = 1.06$, and $t(7) = 3.25$, $p = .01$, Cohen's $d = 1.15$, respectively (see Figure 3).

Control Condition

Caucasian infants in the control condition demonstrated only chance-level recognition of novel Asian female and male faces after a brief exposure to Caucasian females, and after 7 to 14 days of daily exposure to Caucasian females (p values > .05). As predicted, even after 21 days of daily exposure to Caucasian female faces, infants still showed only chance-level recognition of Asian females and males (p values > .05, Cohen's $d = .10$ and .04, respectively; see Figure 3).

Habituation to Asian Faces

Independent samples t-tests with infants' duration of looking in seconds were conducted to examine potential group differences in infants' efficiency in learning novel Asian faces during the habituation phase of the recognition task. Results showed that infants in both conditions were comparable in the amount of time needed to habituate to novel Asian female faces at all time points (p values > .05) except for their final lab visit. After 21 days of daily exposure to Asian females, infants in the experimental group required significantly less time than infants in the control group to habituate to or learn novel Asian female faces, $t(14) = 2.31$, $p = .04$, Cohen's $d = 1.15$ (see Table 1). Infants in both conditions were comparable in the amount of time needed to habituate to novel Asian male faces at all time points (p values > .05).

Discussion

Previous studies have shown that when infants are yet to show perceptual narrowing for experienced classes of visual stimuli, experience with the unfamiliar category can prevent perceptual narrowing from occurring (Heron-Delaney et al., 2011; Pascalis et al. 2005; Scott & Monesson, 2009). By contrast, the present study sought to examine the role of visual experience *after* perceptual narrowing had already occurred. Although perceptual narrowing among 3-month-olds can be reversed after only a brief exposure to other-race faces (Sangrigoli & de Schonen, 2004), our results suggest that a single short exposure to other-race faces is insufficient to reverse the effects of perceptual narrowing among an older group of 8- to 10-month-old infants. Only infants who were given daily experience with Asian female faces during a three-week period showed above-chance recognition memory of novel Asian female faces. Thus, it appears that during infancy, as the perceptual system becomes more specialized, more and more experience with instances from less familiar categories is needed to reverse the effects of perceptual narrowing. However, sufficient experience with

less familiar category exemplars does allow for changes in the developing perceptual system, so that specialization remains malleable enough to incorporate later experience.

The present study also shows that despite infants' lack of daily experience with Asian male faces, Asian male face recognition also improved to above-chance levels. Thus, infants' experiences with Asian females appear to have benefited their recognition memory for the other-race male gender. This suggests that experience with other-race females led to the abstraction of visual cues that are pertinent to other-race female identities – visual cues that may partially overlap with those pertinent to other-race male identities. In contrast, the control group of infants who were given experience with own-race Caucasian females showed no improvement in their recognition memory for Asian female and male faces.

Surprisingly, infants in the experimental group who were given experience with Asian females showed above-chance recognition of Asian males prior to showing above-chance recognition of Asian females. Considering that the male face recognition task was always given after the female face recognition task, the earlier recognition of Asian males may reflect a transitional point at which the cumulative effect of exposure to Asian females led to above-chance recognition of Asian faces. That is, if the male face recognition task had instead been given before the female face recognition task, then above-chance recognition of Asian females may have been observed first. Alternatively, it is possible that infants' typically greater experience with female over male caregivers and individuals (Rennels & Davis, 2008) may have led to such gender related differences in recognition memory. That is, given infants' abundance of experience with own-race females, greater experience with other-race females may be needed to improve recognition memory for other-race females. In contrast, infants' lesser experience with own-race males may lead to a more malleable representation of male faces, so that even experience with other-race females can more easily improve their recognition memory of other-race males. The present pattern of results suggests that experience with a given other-race gender can bootstrap recognition memory for the alternate other-race gender. Although, it remains to be seen whether experience with other-race males can similarly bootstrap recognition memory for other-race females. In contrast, results from the control group of infants suggest that experience with a given gender from one's own race does not bootstrap recognition memory for the same gender of another race.

It should also be noted that the reversal of the effects of perceptual narrowing in other-race face perception in the present study was manifest in two ways. One such manifestation is the improvement in other-race face recognition from chance levels to above-chance levels. In addition, further evidence of a reversal in perceptual narrowing was observed in infants' greater efficiency in learning novel other-race female faces compared to infants in the control group. It appears that with age and with further lack of experience with other-race individuals, infants become less efficient in processing other-race faces. However, experience with other-race faces leads to no such decrement in learning other-race faces. Thus, the role of experience in reversing the effects of perceptual narrowing in other-race face perception is evident in infants' subsequent encoding of other-race faces, as well as in their recognition memory of other-race faces.

The importance of experience in reversing the effects of perceptual narrowing for a given novel face category should also be contrasted with the impact of decreased experience with a previously familiar class of faces. In studies involving Asian individuals who have been adopted into a Caucasian family and live in a predominantly Caucasian environment, decreased exposure to previously familiar own-race faces does not lead to an immediate advantage in recognizing the now more predominantly familiar other-race faces. Six- to 14-year-old Asian children who were adopted into Caucasian families in Western Europe

between the ages of 2 and 26 months showed comparable recognition of Caucasian and Asian faces (de Heering, de Liedekerke, Deboni, & Rossion, 2010). Thus, an abundance of early experience with own-race faces appears to establish a robust representation of own-race faces that is maintained into the middle childhood and early adolescent years even when experience with own-race faces is diminished and a novel other-race face becomes the more predominant face category in one's environment. However, it appears that with even greater prolonged experience with an other-race face category accompanied by a commensurate lack of experience with own-race faces, individuals will demonstrate better recognition of other-race faces compared to their recognition of own-race faces (Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005). That is, in contrast to children and adolescents who were adopted into Caucasian families between 2 to 26 months of age, Asian adults who were adopted into Caucasian families in Europe between 3 to 9 years of age showed better recognition of Caucasian faces compared to their recognition of Asian faces (Sangrigoli et al., 2005). Thus, an abundance of early experience with own-race faces establishes a representation of this face category that is rigid and requires a considerably lengthy period of time to alter even with greatly diminished own-race face experience.

While the current study has revealed important findings regarding the amount of visual experience needed to reverse the effects of perceptual narrowing on infants' other-race face recognition memory, future studies should investigate the potential impact of several factors on such experience. For example, in the present study, simultaneous presentations of two other-race individuals, both of whom introduced themselves by name during the video exposure periods, likely maximized infants' abilities to differentiate between other-race faces. It has yet to be determined whether older infants who already exhibit an other-race effect can benefit from face-name associations when other-race faces are presented one at a time rather than in pairs. Previous studies with younger infants have shown that serially presented face-name associations are critical in *preventing* the other-species and the other-race effect in face recognition (Heron-Delaney et al., 2011; Scott & Monesson, 2009). However, given the presence of an other-race effect in older infants' face recognition, such face-name associations within the context of serial face presentations (i.e., rather than paired) may require more visual experience with such other-race faces (i.e., longer than three weeks) before any advantageous effects on other-race face recognition is observed. That is, because older infants compared to younger infants have more difficulty in recognizing other-race faces, they may find it more difficult to differentiate between different other-race faces presented in a serial (i.e., rather than paired) manner. Alternatively, presenting two faces at a time without assigning names to the other-race individuals may be sufficient to ameliorate infants' other-race effect in face recognition memory because this provides infants with the opportunity to compare how two other-race face exemplars differ from one another.

Another important factor to examine is the number of other-race face exemplars necessary to ameliorate infants' other-race effect in face recognition memory. The present study used eight other-race exemplars, but the question remains as to how many faces would be enough to elicit the same benefits in other-race face recognition. One possibility is that fewer faces might be sufficient, but a longer exposure period might be required to improve other-race face recognition. Moreover, future studies should investigate how experience with a single other-race face category might alter infants' encoding of novel other-race faces. Infants who lack experience with other-race individuals show differences in their visual scanning of own- and other-race faces (Liu et al., 2011; Wheeler et al., 2011). Perhaps experience with other-race individuals alters infants' visual scanning of other-race faces, which in turn leads to more efficient abstraction of race-specific visual cues that are relevant to identity.

Mode and nature of the other-race exposure is another important factor to consider. The present study used videos of females who spoke and sang to the infants due to infants' preferences for infant-directed speech and singing (Cooper & Aslin, 1990; Nakata & Trehub, 2004). However, future studies should examine whether infant-directed speech alone, rather than in conjunction with infant-directed singing, during the video exposure period can reverse the effects of perceptual narrowing on other-race face recognition. In addition, the dynamic nature of and the verbal communication in the videos may have been more engaging than presenting photographs of other-race faces. Thus, video exposure to other-race faces may lead to faster amelioration of the other-race effect relative to presentations of other-race face photographs. Live social interactions with other-race individuals may, in turn, elicit the fastest amelioration of the other-race effect considering the additional advantages of being able to engage infants in contingent social interactions. Indeed, a previous study in the language domain has shown that exposing American 9-month-olds with English speaking parents to live social interactions with Mandarin speakers over a period of 4 weeks reverses the decline in differentiating between Mandarin speech sounds typically seen in infants without such exposure (Kuhl et al., 2003). However, in contrast to the present study, audio-visual exposure to Mandarin speakers via video exposure was insufficient to reverse the effects of perceptual narrowing on Mandarin speech sounds (Kuhl et al., 2003). Thus, it should be noted that although experience with a novel stimulus category after perceptual narrowing has occurred has the potential to reverse the effects of perceptual narrowing, the type of experience is critical and may differ across perceptual domains. In the present study, 8- to 10-month-olds during the first lab visit showed comparable looking at the Asian females speaking/singing in English as the infants who were shown Caucasian female speakers during the video exposure period. However, 9-month-olds exposed to videos of individuals speaking in Mandarin were less attentive towards the speakers compared to 9-month-olds exposed to live social interactions with Mandarin speakers (Kuhl et al., 2003). Thus, audio-visual exposure to Asian females speaking the infant's native language is sufficient to reverse the effects of perceptual narrowing in Caucasian infants' recognition of Asian faces. However, live social interactions seem to be necessary to sufficiently engage infants when learning a new language.

Finally, the transience or permanence of the effects of other-race face exposure on infants' face recognition abilities should be examined further. When exposure to other-race faces stops, infants' other-race face recognition abilities may eventually regress to chance levels. However, re-exposure to other-race faces at a later date might elicit relatively more timely advantages in other-race face recognition (i.e., less than three weeks of exposure required) due to infants' previous experiences with other-race faces. It should be noted that in the language domain, American 9-month-olds with English speaking parents who were exposed to live interactions with Mandarin speakers were proficient in their discrimination between Mandarin speech sounds up to 12 days after their final exposure to Mandarin speech (Kuhl et al., 2003). However, the long-lasting effects of experience with a novel visual (e.g., faces) or auditory (e.g., language) category introduced after perceptual narrowing has occurred during infancy remains unknown.

Overall, our demonstration of a reversal in infants' perceptual narrowing in the visual domain parallels findings in the auditory domain. Experience with other-race faces can reverse the effects of perceptual narrowing in infants' visual processing of other-race faces, and experience with foreign music and speech can likewise reverse the effects of perceptual narrowing in infants' auditory processing of music and language (Hannon & Trehub, 2005b; Kuhl et al., 2003). Combined, these findings allude to the malleability of the developing perceptual system among infants. Early experiences shape the development of an

increasingly specialized perceptual system, however subsequent sustained experiences with novel stimulus categories lead to a broadening of expertise within this system.

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Highlights

- Examine reversibility of infants' perceptual narrowing in other-race recognition.
- Caucasian 8- to 10-month-olds could not initially recognize Asian faces.
- Only infants given daily exposure to Asian females learned to recognize Asian faces.
- These infants learned to recognize both female and male Asian faces.
- Infants with no exposure to Asians continued to show poor other-race recognition.

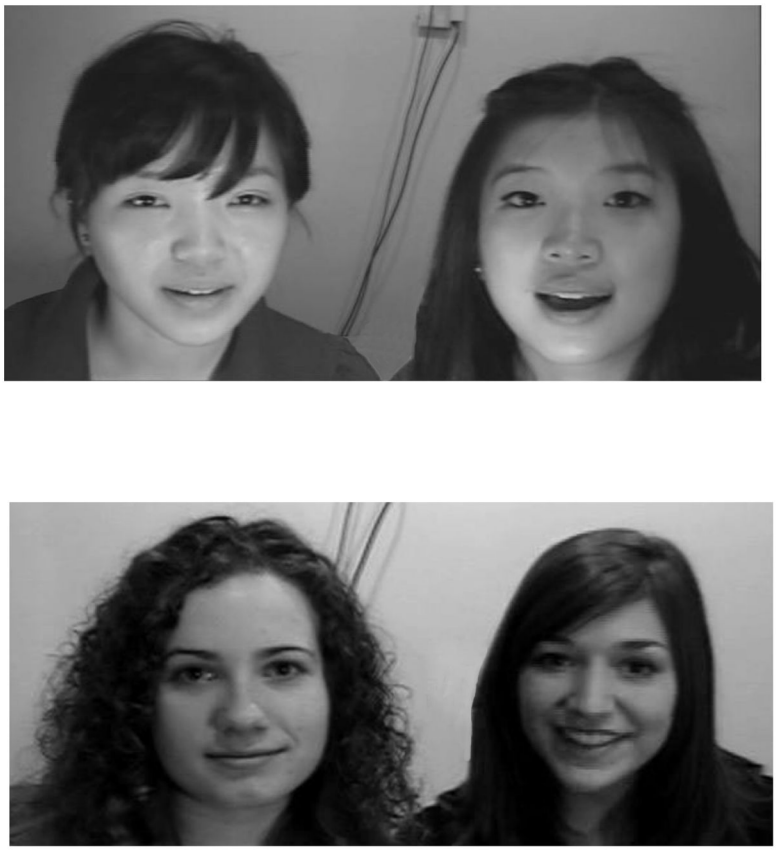

Figure 1.
Example of images from videos of Asian female adults shown to the experimental group (top) and Caucasian female adults shown to the control group (bottom).

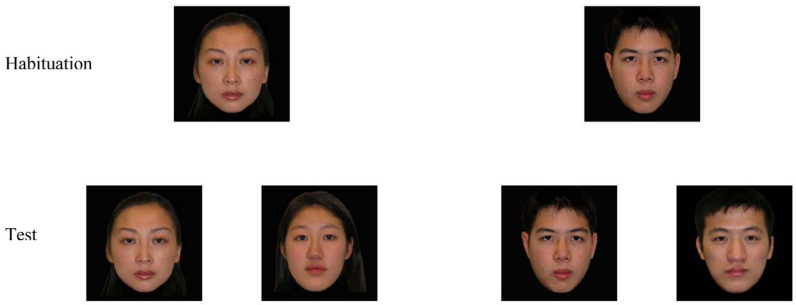

Figure 2.
Examples of stimuli in the recognition memory task with Asian female adult faces (left) and Asian male adult faces (right).

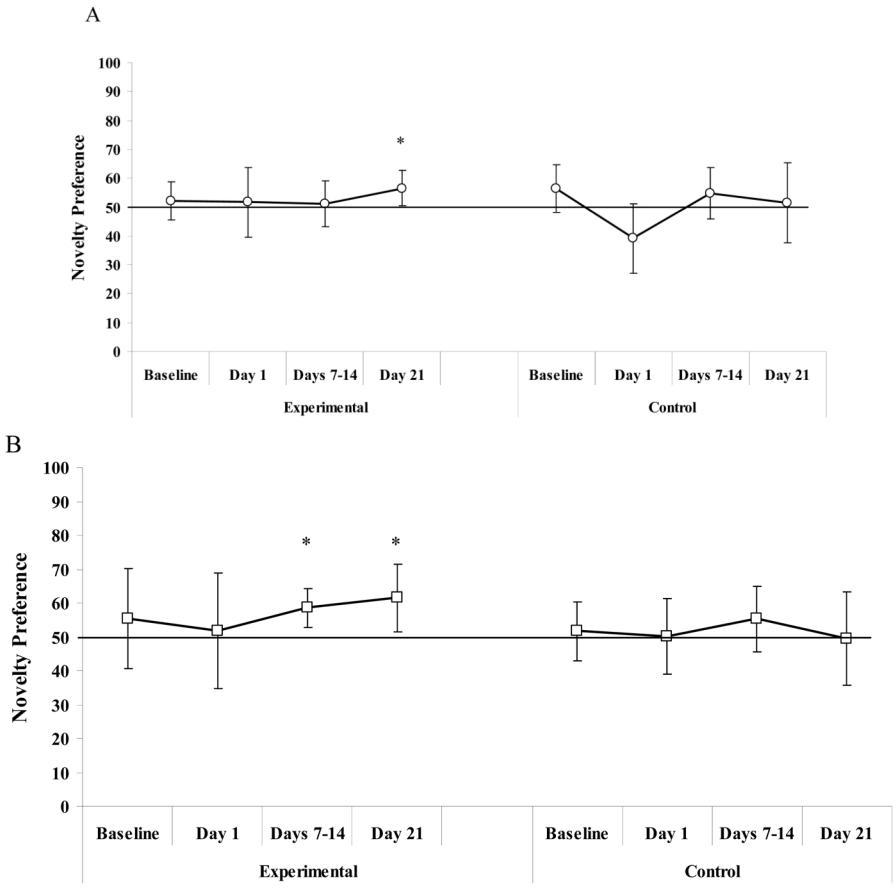

Figure 3.

Infants' Mean Novelty Preference Scores for Asian female faces (A) and Asian male faces (B) prior to video exposure (Baseline), after a brief video exposure (Day 1), after 7 to 14 days of video exposure, and after 21 days of video exposure (* indicates a significant novelty preference at $p < .05$)*

Table 1

Infants' Mean Habituation Time (in seconds) to Asian Faces prior to video exposure (Baseline), after brief video exposure (Day 1), after 7 to 14 days of video exposure, and after 21 days of video exposure (SD in brackets and * indicates a difference between the experimental and control groups at $p < .05$)

	Asian Female Faces				Asian Male Faces			
Condition	**Baseline**	**Day 1**	**Days 7–14**	**Day* 21**	**Baseline**	**Day 1**	**Days 7–14**	**Day 21**
Experimental	16.99 (5.99)	11.36 (6.41)	29.88 (28.19)	15.52 (6.02)	10.98 (4.09)	12.76 (7.09)	15.31 (9.16)	9.27 (4.43)
Control	15.89 (7.08)	10.08 (5.89)	19.79 (11.81)	26.91 (12.59)	13.82 (4.70)	11.34 (5.94)	11.47 (6.34)	19.48 (23.83)