Received: 18 October 2017 | Accepted: 16 December 2017
DOI: 10.1002/dev.21616

RESEARCH ARTICLE

WILEY Developmental Psychobiology

Sibling experience modulates perceptual narrowing toward adult faces in the first year of life

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Abstract

During the first year of life face discrimination abilities narrow toward adult human faces of the most frequently encountered ethnic group/s. Earlier studies showed that perceptual learning under laboratory-training protocols can modulate this narrowing process. Here we investigated whether natural experience acquired in everyday settings with an older sibling's face can shape the trajectory of perceptual narrowing towards adult faces. Using an infant-controlled habituation procedure we measured discrimination of adult (Experiment 1) and child faces (Experiment 2) in 3- and 9- month-old infants with and without a child sibling. Discrimination of adult faces was observed for infants at both ages, although accompanied by posthabituation preferences in opposite directions, whereas at both ages the discrimination of child faces critically depended on sibling experience. These results provide the first evidence that natural experience acquired with siblings affects the tuning properties of infant face representation.

KEYWORDS
age bias, face discrimination, infancy, perceptual narrowing, sibling experience

1 | INTRODUCTION

Faces are one of the most important visual stimuli in our social environment as they carry a wealth of information regarding other individuals, such as identity, gender, age, emotional status, etc. The importance of this stimulus category is confirmed not only by the high level of perceptual expertise that human adults manifest in the processing of faces, but also by the spontaneous bias that infants exhibit in their attentional responses to faces right from birth (Johnson, Dziurawiec, Ellis, & Morton, 1991; Valenza, Simion, Macchi, & Umiltà, 1996). Indeed, newborn infants spontaneously prefer to look at a number of visual attributes that are inherent to faces (Macchi, Turati, & Simion, 2004; Macchi, Valenza, Simion, & Leo, 2008) and this preference becomes specific to faces by 3 months of age (e.g., Macchi, Kuefner, Westerlund, & Nelson, 2006). The attentional bias towards face stimuli allows infants to rapidly learn about the perceptual properties of the faces they are more frequently exposed to, so that, for example, by 3 days of life they have developed a reliable preference for their mother's face, as opposed to a female stranger's face (Bushnell, 2001; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). Similarly, by 3 months of age the preference for face-like configurations becomes selective to stimuli that more realistically resemble the face (Chien, 2011; Macchi Cassia et al., 2006). Within the same time window, infants develop a familiarity preference for human over non-human faces (Di Giorgio, Meary, Pascalis, & Simion, 2013) and for faces of people from the most frequently encountered ethnic group (e.g., Kelly et al., 2005, but see Montoya, Westerlund, Troller-Renfree, Righi, & Nelson, 2017 who did not find evidence of an own-race bias in 4-month-old infants), whose gender matches that of the primary caregiver (e.g., Liu et al., 2015; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002).

This evidence suggests that, right from birth, infants start building a perceptual representation that progressively adapts to include diagnostic attributes of those individual faces and/or face categories that are more prevalent in their social environment, through a process known as perceptual narrowing (for reviews, see Cashon & DeNicola, 2011; Scherf & Scott, 2012; Scott, Pascalis, & Nelson, 2007). Perceptual narrowing is a general developmental pattern occurring during the first year of life across several domains of perceptual processing and different sensory modalities, whereby infants' perceptual sensitivity narrows to stimuli that are most relevant in the infants' environment, resulting in decreased sensitivity to infrequent and non-relevant stimuli (see Maurer & Werker, 2014).

As a result of this process, by the end of the first year, infants' ability to distinguish among individual faces becomes selective to human (Pascalis, de Haan, & Nelson, 2002; Simpson, Varga, Frick, & Fragaszy, 2011) adult faces (Kobayashi, Macchi, Kanazawa, Yamaguchi, & Kakigi, 2018; Macchi, Bulf, Quadrelli, & Proietti, 2014) and faces of the race that is more represented in his/her social environment (Anzures, Quinn, Pascalis, Slater, & Lee, 2013; Pascalis & Kelly, 2009; Spangler et al., 2013). Additionally, within the same time window, infants start using more expert visual exploration strategies to process faces of these familiar categories in comparison to other face types (Ferguson, Kulkofsky, Cashon, & Casasola, 2009; Gaither, Pauker, & Johnson, 2012; Liu et al., 2011). Perceptual attunement to these face categories also translates by 9 months of age into an increased specificity and right-lateralization of electrophysiological and/or hemodynamic responses (e.g., Balas, Westerlund, Hung, & Nelson, 2011; de Haan, Pascalis, & Johnson, 2002; Kobayashi et al., 2018; Righi, Westerlund, Congdon, Troller-Renfree, & Nelson, 2014; Scott & Monesson, 2009). For example, although 3-month-old Caucasian infants can differentiate equally well among individual adult and infant Caucasian faces, at 9 months they maintain this ability for adult faces but not anymore for infant faces (Macchi Cassia, Bulf et al., 2014). This same developmental pattern has been recently observed in Asian infants, who, by the age of 9 months, show enhanced right-hemisphere activation in response to own-race adult faces compared to infant faces (Kobayashi et al., 2018).

This tuning process has been interpreted as deriving from the natural asymmetries in the amount of experience infants accumulate with different face types. Recently, a few studies have tried to quantify infants' exposure to different face categories through interviews administered to parents (Rennels & Davis, 2008) or directly measuring infants' visual experience with the use of a camera located on the baby's head (Jayaraman, Fausey, & Smith, 2015; Sugden, Mohamed-Ali, & Moulson, 2014). These studies reported that infants spent the majority of waking time exposed to individuals that share the same demographic characteristic as the caregivers (i.e., individuals of the same ethnicity, age group, and gender as the primary caregiver).

Further evidence confirming that this fine-tuning of the infant perceptual system is experience-dependent derives from studies showing that when the natural statistics of facial experience are artificially altered, for example, by delivering visual training with unfamiliar face categories, the trajectory of perceptual narrowing changes. Experimental exposure to other-race faces (Anzures et al., 2012; Heron-Delaney et al., 2011) or monkey faces (Pascalis et al., 2005; Scott & Monesson, 2009) between 6 and 9 months, or immediately after this period, prevents the decrease in infants' discrimination ability for individuals belonging to these, otherwise unfamiliar, face types. In particular, Scott and Monesson (2009, 2010) showed that what makes perceptual training effective in maintaining infants' ability to discriminate monkey faces (Scott & Monesson, 2009) and trigger neural specialization for those faces (Scott & Monesson, 2010) is the extent to which infants' attention is drawn to individual faces by verbal labeling (i.e., each face labeled with an individual name): Neither category (i.e., all faces labeled "monkey") nor passive (i.e., exposure without labeling) training exerted an effect at the behavioral or neural level.

Notwithstanding the relevance of this research for the understanding of how experience can prompt perceptual learning under laboratory-training protocols, it leaves open the question of how the trajectory of perceptual narrowing changes as effect of variations in the amount of differential facial experience that occur naturally—as opposed to artificially—in infants' everyday environment. Indeed, research exploring this issue is quite limited. Interesting insights into this topic come from a well-known comparative study conducted with monkeys by Sugita (2008). The main finding of the study was that infant monkeys who were deprived of facial input from birth and were subsequently exposed to either human or monkey faces showed selective discrimination abilities for the exposed species, in line with the prediction of the perceptual narrowing account. However, a related finding from the same study was that non-deprived control monkeys tested as adults after being raised in captivity with other monkeys and human caregivers showed successful discrimination of monkey faces, but not human faces. As noted by Scherf and Scott (2012), the perceptual narrowing account would predict that these monkeys would maintain recognition abilities for human faces as a result of experience with individuating the faces of their caregivers, as the human infants did following the individuation training with monkey faces in Scott and Monesson's (2009, 2010) studies. In contrast to this prediction, despite experiencing daily contacts with their human caregivers, these monkeys showed a typical own-species bias. In as much as these findings can inform us about perceptual narrowing in humans, they seem to suggest that the effects of experience acquired through laboratory training cannot be extended to naturally-acquired experience.

However, work investigating the developmental trajectories of the race and gender biases provides other relevant evidence on how natural variations in the amount of differential experience with specific face categories influence infant's face processing abilities. With regard to race, studies have shown that by 3 months of age only infants brought up in ethnically homogeneous environments show visual preference for faces belonging to their same racial group, while infants raised in biracial environments do not show the same preference (Bar-Haim, Ziv, Lamy, & Hodes, 2006). There is also evidence that at this same point in development monoracial and biracial infants employ different visual scanning strategies to explore and memorize own and other-race faces (Gaither et al., 2012). In a similar vein, when it comes to gender, Quinn et al. (2002) (see also Liu et al., 2015 for similar evidence with Asian infants) reported that 3- to 4-month-old infants reared primarily by a female caregiver showed a spontaneous preference for female faces, while male-reared infants showed a preference for male faces. Taken together, these findings show that, by 3-months of age, experience provided to each infant by their social environment is already shaping their face representation. However, because the critical time-frame for perceptual narrowing is 3 to 9 months, they leave open the question of whether experience occurring naturally within the infant's everyday social environment is capable of influencing the trajectory of the narrowing process. To our knowledge, no study has been conducted so far to investigate whether and how natural variations in the amount of differential experience with specific face categories affect face processing abilities across the first year of life, and specifically within the 3–9 months time-frame, when perceptual narrowing is known to occur.

The present study aimed to fill this gap in the literature by investigating whether experience with child faces provided by the presence of an older sibling in the infant's household affects perceptual narrowing towards adult faces, which is known to occur by 9 months of age (Kobayashi et al., 2018; Macchi Cassia, Bulf et al., 2014). We hypothesized that sibling experience would prevent the decrease in discrimination ability for child faces, thus modulating the selective tuning towards adult faces that would occur otherwise, in the absence of that specific experience.

To the best of our knowledge, no study to date has investigated the impact of sibling experience on face processing abilities in infancy. Previous research has provided indirect evidence for such an effect by showing that 3-year-old children, who either were born having an older sibling in their house (Macchi, Luo, Pisacane, Li, & Lee, 2014; Macchi Cassia, Pisacane, & Gava, 2012) or had a younger sibling born when they themselves were 15 months or older (Macchi Cassia, Kuefner, Picozzi, & Vescovo, 2009), differed from children without siblings in their processing and discrimination of, respectively, child and infant faces (see Macchi, Proietti, & Pisacane, 2013 for similar evidence from 6-year-old children with younger siblings). In these studies, 3-year-old children's ability to discriminate adult and child or infant faces was measured in a two-alternative forced choice matching-to-sample task, in which participants had to match a briefly presented target face to two simultaneously presented test faces appearing shortly after the target. Perceptual processing strategies evoked by adult versus non-adult faces were compared by testing the disrupting effect produced on participants' performance by stimulus inversion. This disrupting effect, typically known as face inversion effect (Yin, 1969), is usually taken as a gross indicator of the ability to extract the relevant configural and/or featural cues needed for upright-face recognition (see review by Rossion & Gauthier, 2002), and developmental studies have shown that it is face specific at 3 years (Picozzi, Macchi Cassia, Turati, & Vescovo, 2009). Studies conducted with preschool-aged children showed that, unlike singletons, who showed superior discrimination and a selective inversion effect for adult compared to non-adult faces, 3-year-olds with an older or a younger sibling were equally skilled at differentiating adult and child or infant faces, respectively, and showed a generalized inversion effect for both face ages.

The authors of these studies (Macchi Cassia et al., 2012) interpreted the modulation of the age effect among children with older siblings as the resultant of the experience these children have accumulated with the sibling's face during infancy, whose effects persisted unaltered into childhood. Because for children with a younger sibling exposure to the sibling's face began slightly after the second year of life (mean age at the sibling's birth = 27 months; range = 15–41), the authors (Macchi Cassia, Kuefner et al., 2009) also concluded that experience with newly encountered face types can easily shape face representation even beyond the proposed time window for perceptual narrowing.

Although this evidence indicates that sibling experience acquired during and beyond the first year of life contributes to the later development of a face representation whose tuning properties suit child faces, as well as, adult faces, there is currently no direct evidence showing that exposure to a sibling's face from birth is capable of tuning face processing abilities already in infancy. The present study aimed to provide such evidence by comparing 3- and 9-month-old infants' ability to discriminate among child faces in the absence versus presence of sibling experience. More specifically, to replicate and extend earlier demonstrations of perceptual narrowing towards adult (vs. infant) faces (Kobayashi et al., 2018; Macchi Cassia, Bulf et al., 2014), we tested 3- and 9-month-old infants' discrimination abilities for adult (Experiment 1) and child faces (Experiment 2) in the absence of sibling experience; to test for the effects of sibling experience we compared the ability to discriminate among child faces in 3- and 9-month-old infants with and without older siblings.

Infants in both age groups were tested using an infant-controlled habituation procedure followed by two test trials providing a visual-paired comparison of the familiar face with a novel face, modelled after Macchi Cassia, Bulf et al. (2014). Infants' ability to perceptually discriminate among different facial identities was inferred from the participants' ability to discriminate the novel face from the familiar one during test trials. We expected that, following continuous experience with adult caregivers, both 3- and 9-month-old infants in Experiment 1 would succeed at discriminating the female adult face to which they have been habituated from a novel face of another unfamiliar adult, whereas infants' ability to show successful discrimination between the familiar and the novel child face in Experiment 2 would depend critically on the presence/absence of a child sibling. Specifically, we predicted that, if natural experience acquired in the context of social interactions can modulate perceptual narrowing, only 9-month-old infants with an older sibling, but not those without siblings, would succeed at discriminating among child faces. Finally, the comparison between the habituation and preferential looking performance of the 3-month-olds in the sibling group versus the no sibling group will reveal whether 3 months of exposure to the sibling's face is sufficient to trigger any modulation in the processing of child faces.

2 | EXPERIMENT 1

Experiment 1 tested 3- and 9-month-old infants' discrimination of adult faces, with the aim to replicate and extend earlier demonstration that, likely as a consequence of continued exposure to adult caregivers (Jayaraman et al., 2015; Sugden et al., 2014), the infants' perceptual system progressively tunes to adult human faces, resulting in increasing sensitivity to differences among individual faces from this age category. Specifically, in a study investigating perceptual narrowing toward adult faces (vs. infant faces), Macchi Cassia, Bulf et al. (2014) have shown that, although the ability to discriminate among adult faces was maintained across the 3 and 9 months age groups, infants in these two age groups seemed to rely on different strategies to perform identity discrimination, as the direction of post-habituation preference in the visual-paired comparison (VPC) trials switched from a familiarity preference (i.e., a preference for the familiar face over the novel one) at 3 months to a novelty preference (i.e., a preference for the novel face over the familiar one) at 9 months. Many factors can affect the direction of infants' visual preference in these kinds of tasks: stimulus complexity, the duration of the familiarization phase, the real-time dynamics of infant looking behaviours (Fisher-Thompson, 2014; Roder, Bushnell, & Sasseville, 2000), and age differences in processing speed (Roder et al., 2000) have all been found to play a role. For example, younger infants may need more time to form a strong representation of the familiarized stimulus in comparison to older infants, who have higher processing speed and thus may disengage their attention from the familiarized stimulus sooner, directing their attention to the novel stimuli at test (Rose, Jankowski, & Feldman, 2002; Shinskey & Munakata, 2010). A switch across development from familiarity to novelty preference has been frequently reported in previous studies investigating infants' visual processing across different visual domains, and it may thus reflect a general developmental trend (Pascalis & de Haan, 2003).

Nevertheless, it is important to note that in Macchi Cassia, Bulf et al. (2014), such a switch from familiarity to novelty preference was observed for adult faces only, leading the authors to propose that the familiarity preference exhibited by the 3-month-old infants may reflect infants' motivation to seek attentional proximity to the familiarized adult face. In keeping with the perceptual narrowing account of the development of face processing, the transition to a novelty preference at 9 months was interpreted as reflecting the acquisition of perceptual expertise with adult faces.

Experiment 1 was aimed to test for the robustness of these earlier findings by replicating the shift from a familiarity preference to a novelty preference in adult face discrimination across the 3-to-9-month time-frame.

2.1 | Method

2.1.1 | Participants

Fifteen 3-to-4-month-old infants (seven females, M age = 116 days; range = 101–135 days) and fifteen 9-to-10-month-olds (five females, M age = 306 days; range = 274-328 days) were included in the final sample. All participants were Caucasian, healthy and full-term, and they were all first-born (i.e., without siblings). An additional eleven infants were tested but not included in the analyses because of fussiness ($N = 9$) or because they showed a side bias during the VPC test trials (i.e., they looked more than 85% of the time to one side across the two test trials; $N = 2$). Participants were recruited via a written invitation that was sent to parents based on birth records provided by neighboring cities; parents provided their informed written consent. The protocol was carried out in accordance with the ethical standards of the Declaration of Helsinki (BMJ 1991; 302: 1194) and approved by the Ethics Committee of the University of Milano-Bicocca. At the end of the testing session parents were asked to fill in a questionnaire with general demographic enquiries, and contact questions aimed at assessing the amount of experience that infants had acquired with female and male individuals. The questionnaire confirmed that both the 3- and the 9-month-old infants included in the sample had the majority of their facial experience with female adult faces, as, on average, they spent 80% of their waking time with female adult individuals.

2.1.2 | Stimuli

Stimuli consisted of colored photographs of four female adult faces of Caucasian origin, all displaying a full-front neutral expression with open eyes. Because all infants included in the sample had more exposure to female than male faces, and by 3 months of age infants develop a processing advantage for faces of the same gender as their primary caregiver (Quinn et al., 2002), stimulus gender was kept constant, with all adult faces being female. Faces were paired based on subjective criteria of luminance and overall similarity to generate two invariable pairs. Using the software Adobe Photoshop, face images were cropped maintaining some external features like ears and hair, and pasted on a black background (Figure 1). When viewed from approximately 60 cm, the stimuli subtended 13.37° of visual angle vertically and 13.52° of visual angle horizontally.

Apparatus

All infants were tested in a dedicated cabin, while seated in an infant-seat or on their parent's lap and positioned at a distance of approximately 60 cm from a 24-inches computer screen. The parent was blind to the hypothesis of the study and the predicted direction of infants' looking preference in each specific experimental condition, and was instructed to remain silent and keep the infant aligned with the monitor's midline. The whole experiment was recorded through a video-camera, hidden over the screen, which fed into a TV monitor and a digital video recorder, both located outside the testing cabin. The live image of the infant's face displayed on the TV monitor allowed the online coding of the infant's looking times by the experimenter. The video-recorded image of the infant's face allowed offline coding of looking times during test trials.

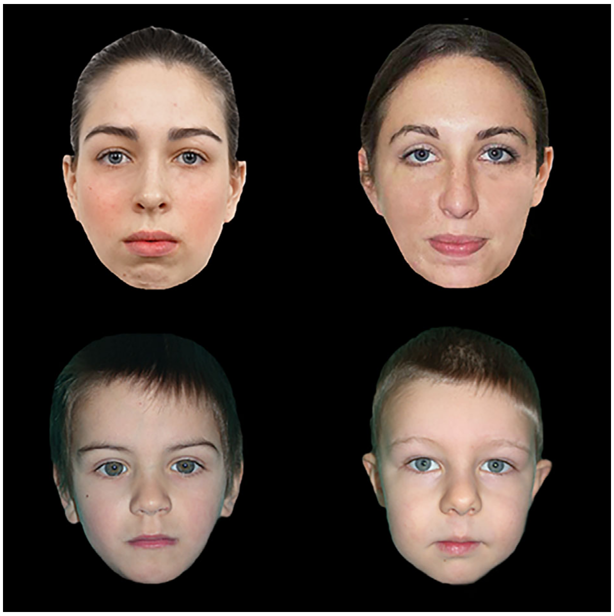

FIGURE 1 Examples of adult and child faces used as stimuli in Experiments 1 and 2

2.1.3 | Procedure

Infants were tested in a visual habituation task with an infant-controlled procedure. The testing session began with a colored cartoon animated image associated to a sound displayed on a black background to direct infants' attention toward the center of the screen. As soon as the infant fixated the image the experimenter turned off the cartoon and started the habituation phase by activating the face stimulus, that was presented centrally on the screen. The experimenter recorded infants' looking time by holding the mouse button whenever the infant fixated on the stimulus. Each habituation trial lasted until the infant looked away from the stimulus for more than 2 s, at which point the stimulus was automatically turned off and the cartoon animation reappeared on the screen to re-attract the infant's attention on the center of the screen before the stimulus presentation was repeated. The infant was judged to have been habituated when, from the fourth fixation on, the sum of any three consecutive fixations was 50% or less than the total of the first three, with a maximum limit of 14 trials. When this habituation criterion was reached, the test session began. Infants were presented with two test trials with the familiar face paired with a novel face; each trial ended following the same criterion used for the habituation trials (2 s-look away). Left-right position of the stimuli on the screen was counterbalanced across infants on the first test trial and reversed on the second test trial for each infant. The direction and duration of looking times were coded online throughout the whole testing session by the experimenter. For 22 of the 30 infants (11 3-month-olds and 11 9-month-olds) a second observer coded frame by frame the digitized video of the infants' eye movements during test trials, yielding to an interobserver agreement (Pearson correlation), as computed on total fixation times on the novel and familiar face across the two test trials, of $r = .98$. Both the experimenter and the second observer were blind to the left/right position of the familiar and novel faces on the screen.

2.2 | Results

2.2.1 | Habituation phase

All infants reached the habituation criterion (average number of trials to habituate = 7.87, range = 6–13). A two-way Analyses of Variance (ANOVAs) with participant's age (3, 9 months) as the between-subjects factor and habituation trials (first three, last three) as the within-subjects factor confirmed the presence of an overall significant decline in mean looking times from the first three to the last three habituation trials, F (1,28) = 29.57, $p < .001$, $\eta^2 = .51$. There was also a main effect of participant's age, F (1,28) = 9.85, $p = .004$, $\eta^2 = .26$, which was qualified by a significant Participant's Age × Habituation Trials interaction, $F(1,28) = 6.43$, $p = .017$, $\eta^2 = .19$. Post-hoc comparisons (Bonferroni corrected) confirmed that, for both age groups, looking times decreased significantly between the first three and the last three trials (both ps < .002, *d*s > 1.0), and that during both the first and the last three test trials 3-month-old infants looked significantly longer than 9-month-olds (both ps < .01, *d*s > 1.05) (Table 1). Total habituation time and number of trials to habituate were compared between 3- and 9-month-old infants by means of two separate independent-sample *t*-tests, which showed that younger infants looked longer during habituation than older infants, $t(28) = 3.363$, $p = .002$, $d = 1.22$, but required a similar number of trials to do so, $t(28) = .728$, $p = .473$, $d = 0.265$ (Table 1).

2.2.2 | Test phase

Average length of the test trials was 31.6 s for the 3-month-old infants and 23.5 s for the 9-month-olds. To facilitate the comparison of looking times during test trials across the two age groups, a novelty preference score was computed for each participant by dividing looking time toward the novel face by total looking duration toward the novel and familiar face across both test trials and multiplying this ratio by 100. A group mean novelty score that is significantly different from the chance level of 50% reflects discrimination, whereas a score that is not different from 50% indicates a lack of discrimination; also, a novelty score above 50% indicates a preference for the novel stimulus, whereas a novelty score below 50% indicates a preference for the familiar stimulus. Novelty preference scores manifested by younger and older infants were compared through an independent *t*-test (two-tailed), which attained statistical significance, $t(28) = 3.76$, $p = .001$, $d = 1.37$, indicating that 9-month-old infants spent a larger percentage of time looking at the novel stimulus compared to 3-month-olds (M = 55.7 % vs 43.9 %) (Figure 2). These findings were further explored through two one-sample *t*-tests (two-tailed), which showed that the percentage of time spent looking at the novel stimulus was significantly above the chance level of 50% for the 9-month-old infants, $t(14) = 2.61$, $p = .021$, $d = 0.67$, and significantly below the chance level for the 3-month-olds, $t(14) = 2.71$, $p = .017$, $d = 0.69$,

TABLE 1 Mean and standard deviation of mean fixation duration in the first three and the last three habituation trials, mean and standard deviation of overall fixation duration, and habituation trials required to reach the habituation criterion for 3- and 9-month-old infants tested in Experiment 1

		Habituation trials							
		First three		Last three		Overall			
(m)	*N*	M (s)	SD (s)	M (s)	SD (s)	M (s)	SD (s)	*N*	SD
3	15	34.89	27.62	9.34	5.61	171.05	99.28	7.53	2.39
9	15	13.65	5.67	4.35	2.11	78.73	38.05	8.20	2.62

indicating that although infants in both age groups reliably discriminated the adult faces, the direction of post-habituation preference was reversed across the two ages (Figure 2).

Examination of the data for individual infants through binomial tests (two-tailed) did not reveal significant differences in the number of infants who looked longer to the novel stimulus compared to the familiar one among the 3-month-old age group (6 vs. 9, $p = .61$) or the 9-month-old group (11 vs. 4, $p = .12$).

2.3 | Discussion

Results from Experiment 1 confirm earlier demonstrations that discrimination of female adult faces is maintained across the 3-to-9-months period, which is when perceptual narrowing is known to occur (e.g., Kelly et al., 2007; Macchi Cassia, Bulf et al., 2014; Sangrigoli & de Schonen, 2004). Specifically, our findings replicate those obtained by Macchi Cassia, Bulf et al. (2014) by showing that, when tested in an infant-controlled habituation task, 3-month-old and 9-month-old infants exhibited reliable discrimination of female adult faces, which was accompanied by post-habituation preferences in opposite directions: 3-month-olds preferred the familiar face over the novel one, whereas 9-month-olds preferred the novel face over the familiar one.

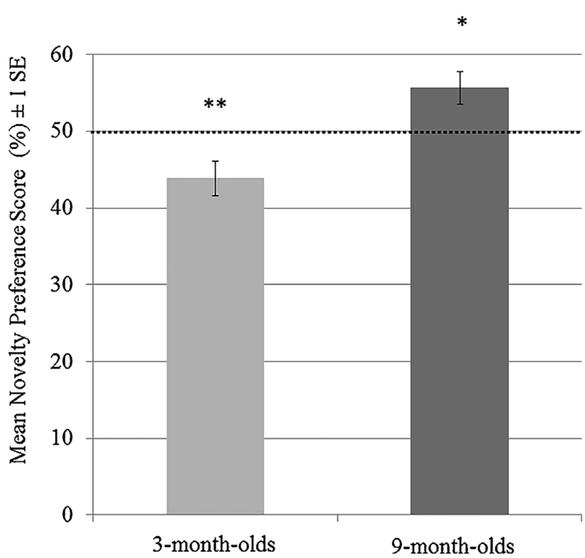

FIGURE 2 Mean novelty preferences and standard errors (in percentage) in test trials for 3- and 9-month-old infants in Experiment 1. $^{*}p < .05$; $^{**}p < .02$ (one-sample t-tests vs 50%)

The presence of post-habituation preferences in opposite directions indicates that adult faces are treated differently by 3- and 9-month-old infants. As discussed in Macchi Cassia, Bulf et al. (2014), the familiarity preference exhibited by the 3-month-old infants may reflect infants' motivation to maintain attentional proximity to the familiarized adult face, brought about by infants' tendency to follow a familiarity rule as the most functional strategy to face the developmental task of building an attachment relationship with the caregivers (see Scherf & Scott, 2012 for a discussion of how developmental tasks may constraints infants' face processing abilities). The transition from a familiarity preference to a novelty preference at 9 months may reflect the acquisition of perceptual expertise with adult faces; this would be in line with the perceptual narrowing account which predicts that extensive and continued experience with caregivers and other adult individuals leads to increased sensitivity and more efficient processing for adult faces.

Of note, the opposite pattern of post-habituation preferences exhibited by 3- and 9-month-old infants also allows us to rule out the possibility that having the parent holding the baby and seeing the stimuli during the testing session could have influenced the infant's preference. Indeed, because the parents were blind to the predicted direction of infants' looking preference in each specific experimental condition, their influence would have had similar effects on the performance of both the 3- and the 9-month-old infants. Instead, only one group of infants displayed a canonical novelty preference, with the other displaying a less common familiarity preference.

Critically, the perceptual narrowing hypothesis predicts that perceptual attunement to adult faces would not only bring about improvement in the perception of this face age category, but would also lead to a decline in sensitivity to perceptual differences among non-adult faces when infants lack the experience needed to maintain their initial sensitivity to these face types (see Maurer & Werker, 2014). Accordingly, it has been shown that the ability to discriminate among infant faces is apparent in infants aged 3 months, and decreases significantly by the age of 9 months (Macchi Cassia et al., 2012), suggesting that between 3 and 9 months of age facial experience narrows the infant's initially broadly tuned sensitivity to differences among individual faces. In Experiment 2 we aimed to provide further evidence for this phenomenon by extending this earlier demonstration of a decline in discrimination abilities for non-adult faces across the 3- to 9-months period to a second type of non-adult faces, namely child faces. A more crucial goal of Experiment 2 was to test whether infants would maintain the ability to discriminate among child faces between 3 and 9 months of age in the presence of continued exposure to the face of their older sibling.

3 | EXPERIMENT 2

In Experiment 2, 3- and 9-month-old infants were tested for their ability to discriminate among child faces in the absence versus presence of sibling experience. To this end, we selected infants in each age group for belonging to one of two possible groups: One group included first-born infants (i.e., without siblings) who had virtually no contact with older children; the other group included infants who had daily exposure to a child face through the presence of an older sibling in their home. Earlier studies have shown that 3-year-old children with an older sibling were just as accurate at discriminating adult and child faces, whereas those without an older sibling were much less accurate at discriminating child faces in comparison to adult faces (Macchi Cassia et al., 2012; Macchi Cassia, Luo et al., 2014). In light of this evidence, and in keeping with earlier demonstrations that laboratory-training protocols can modulate the trajectory of perceptual narrowing toward human (Scott & Monesson, 2009, 2010) and own-race faces (Anzures et al., 2012; Heron-Delaney et al., 2011), we predicted that continued and consistent experience with an older sibling would prevent the diminution of discrimination ability for child faces that would otherwise occur by the end of the first year of life. Specifically, we expected that, although 3-month-old infants would display the ability to discriminate child faces irrespective of their sibling experience, this ability would be apparent at 9 months for infants with older siblings, but not for those who lacked sibling experience.

3.1 | Method

3.1.1 | Participants

Thirty 3- to 4-month-old infants (14 females, *M* age = 111 days; range = 91-132 days) and thirty 9- to 10-month-olds (11 females, *M* age = 307 days; range = 275–333 days) were included in the final sample; they were all Caucasian, healthy, and full-term. Infants in each age group were assigned to one of two groups based on the absence/presence of at least one older sibling, so that, for each age group, the sibling group and the no-sibling group each were composed of 15 infants. Thirty additional infants were tested but excluded from the final sample because of fussiness ($N = 27$) or because they showed a side bias during the VPC test trials (i.e., they looked more than 85% of the time to one side across the two test trials; $N = 3$). Participants were recruited as in Experiment 1, and parents gave their written informed consent. The protocol was carried out in accordance with the ethical standards of the Declaration of Helsinki (BMJ 1991; 302: 1194) and approved by the Ethics Committee of the University of Milano-Bicocca. At the end of the testing session, they filled out a questionnaire with general demographic enquiries, and specific enquiries aimed at assessing if, in the past 9 months, their infants have had contact with children aged between 2 and 6 years. Infants in the no-sibling group were included in the final sample only if they had no more than 10 hr of experience per week with children within this age range ($M = 1$ hr/week, range = 0–10 hr/week). Within the sibling group, 22 infants had one older sibling, five infants had two older siblings, two infants had three older siblings and one infant had four older siblings. The mean age of the youngest among the older siblings at the time of the participants' birth was 3;9 years (range = 2;0–6;0).

3.1.2 | Stimuli, apparatus, and procedure

Stimuli were color photographs of eight Caucasian child faces (four male and four female), all displaying a full-front neutral expression with open eyes. The age of the child faces ranged between 3 and 6 years, so that it matched with the age of the siblings at the time of the participants' birth. Faces were paired based on subjective criteria of luminance and overall similarity to generate four invariable pairs. Using the software Adobe Photoshop, face images were cropped maintaining external features like ears and hair, and pasted on a black background. When viewed from approximately 60 cm, the stimuli measured 13.24° of visual angle in height and 13.61° in width. For each infant in the sibling group the gender of the child face stimuli (male, female) was matched to the gender of the youngest among the older siblings; for infants in the no-sibling group stimulus gender was selected randomly. The apparatus and procedure were the same as in Experiment 1. For 43 of the 60 infants in the final sample (21 3-month-olds and 22 9-month-olds) a second observer coded the digitized video of the infants' eye movements during the two test trials, yielding to an interobserver agreement (Pearson correlation) of $r = .98$.

3.2 | Results

3.2.1 | Habituation phase

Three infants, one 3-month-old and one 9-month-old with siblings and one 3-month-old without siblings, failed to meet the habituation criterion; they showed the same pattern of test trial looking as the majority of the other infants in their condition. All other infants reached the habituation criterion across an average of eight trials (range = 6–14). To examine whether 3- and 9-month-old infants differed in their habituation pattern as a function of sibling experience, we analyzed mean looking times during the first three and the last three habituation trials, total habituation time and number of trials to habituate. Mean looking times were entered into a 2 × 2 × 2 ANOVA with participant's age (3, 9 months) and sibling group (no-sibling, sibling) as between-subjects factors, and habituation trials (first three, last three) as the within-subjects factor. The analysis revealed main effects of participant's age, $F(1,56) = 8.13$, $p = .006$, $\eta^2 = .13$, and habituation trials, $F(1,56) = 82.43$, $p < .001$, $\eta^2 = .60$, as well as, a significant Participant's Age × Habituation Trial interaction, $F(1,28) = 8.23$, $p = .006$, $\eta^2 = .128$. Post-hoc comparisons (Bonferroni corrected) confirmed that for both age groups looking times decreased significantly between the first three and the last three trials (both ps < .001, *d*s > 0.95), and that 3-month-old infants looked significantly

TABLE 2 Mean and standard deviation of mean fixation duration in the first three and the last three habituation trials, mean and standard deviation of overall fixation duration, and habituation trials required to reach the habituation criterion for 3- and 9-month-old infants without older siblings and with older siblings in Experiment 2

			Habituation trails							
			First three		Last three		Overall			
(m)	Sibling group	*N*	M (s)	SD (s)	M (s)	SD (s)	M (s)	SD (s)	*N*	SD
3	No-sibling	15	32.92	24.79	11.52	8.93	187.64	123.63	8.20	3.00
3	Sibling	15	45.59	25.51	13.48	6.33	218.92	108.08	7.27	2.19
9	No-sibling	15	18.38	12.04	5.68	3.47	97.52	59.00	7.87	1.88
9	Sibling	15	24.59	28.44	9.49	12.29	140.72	131.11	8.60	2.50

longer than 9-month-olds only during the first three habituation trials, $t(58) = 2.905$, $p = .005$, $d = 0.75$. No main effect nor interactions involving the factor sibling group attained significance (all Fs < 2.6) (Table 2). Total habituation time and number of trials to habituate were analyzed in two separate ANOVAs with subject's age (3, 9 months) and sibling group (no-sibling, sibling) as between-subjects factors. The analysis on habituation time showed a main effect of age group, $F(1,56) = 8.92$, $p < .005$, $\eta^2 = .137$, as 3-month-olds looked longer during habituation than 9-month-olds, with no significant main effect or interaction involving the factor sibling group (both ps > .19). The ANOVA on number of trials to habituate did not reveal any significant effect (all *ps* > .18) (Table 2).

3.2.2 | Test phase

The average length of test trials was 36.1 s for the 3-month-old infants and 21.8 s for the 9-month-olds. Novelty preference scores were analyzed in a 2 × 2 ANOVA with participant's age (3, 9 months) and sibling group (no-sibling, sibling) as between-subjects factors.[1] The analysis yielded a significant interaction between the two factors, $F(1,56) = 11,57$, $p = .001$, $\eta^2 = .17$. To investigate novelty preferences within each age group, we conducted independent *t*-tests (two-tailed) to compare the percentage of time spent looking at the novel stimulus in the two sibling conditions. The comparison was significant for both the 3-month-old infants, $t(28) = 2.17$, $p = .039$, $d = 0.79$, and the 9-month-olds, $t(28) = 2.83$, $p = .009$, $d = 1.03$, showing that novelty preferences differed between the sibling and no-sibling groups for both the younger and the older infants (Figure 3). Specifically, one-sample *t*-tests (two-tailed) showed that, for the 3-month-olds, the percentage of time spent looking at the novel stimulus did not differ from the chance level of 50% for infants in the sibling group ($M = 48.9\%$), $t(14) = .47$, $p = .64$, $d = 0.12$, but was significantly above chance for infants in the no-sibling group ($M = 57.3\%$), $t(14) = 2.3$, $p = .037$, $d = 0.59$. For the 9-month-olds, the novelty preference scores were above the chance level for infants in the sibling group ($M = 56.1$ %), $t(14) = 4.13$, $p = .001$, $d = 1.06$, but not dissimilar from chance for infants in the no-sibling group ($M = 48,4$ %), $t(14) = .69$, $p = .50$, $d = 0.18$ (Figure 3).

Binomial tests (two-tailed) confirmed the results of the analyses on mean novelty preference scores, revealing that, for the 3-month-olds, the scores were above 50% for only seven out of the 15 infants in the sibling group (7 vs. 8, *n.s.*), and for 12 out of the 15 infants in the no- sibling group (12 vs. 3, $p < .05$). For the 9-month-olds, the preference scores were above 50% for 13 out of the 15 infants in the sibling group (13 vs. 2, $p < .05$), and for seven out of the 15 infants without an older sibling (7 vs. 8, *n.s.*).

3.3 | Discussion

Experiment 2 tested for the modulating effect of sibling experience on perceptual narrowing towards adult faces in 3- and 9-month-old infants. Results confirmed our predictions that (1) in the absence of sibling experience, infants would manifest the ability to discriminate among child faces at 3 months of age, but not at 9 months, and (2) child face discrimination would be apparent at 9 months only for infants with older siblings. These findings replicate earlier demonstrations that, between 3 and 9 months, infants who, from birth, spent the majority of their waking time with a female adult caregiver show reduced capacity to discriminate among infant faces (Macchi Cassia, Bulf et al., 2014), and extend this evidence to another category of non-adult faces, namely child faces. Moreover, by showing that experience with a child sibling critically affected 9-month-olds' ability to discriminate among child faces, these findings provide the first

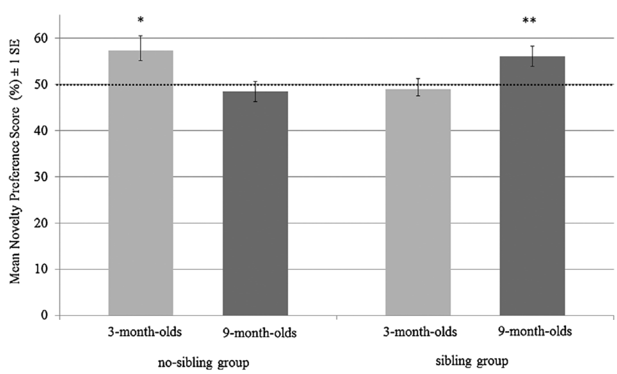

FIGURE 3 Mean novelty preferences and standard errors (in percentage) in test trials shown by 3- and 9-month-old infants without and with an older sibling in Experiment 2. *$p < .05$; **$p < .02$ (one-sample *t*-tests vs. 50%)

demonstration that experience occurring naturally within the infant's social environment can shape face representation by modulating the trajectory of the narrowing process.

Although results confirmed our main predictions, one aspect of our findings proved unexpected, namely infants' failure to show evidence of significant child face discrimination at 3 months in the presence of sibling experience. Indeed, in keeping with the predictions of the perceptual narrowing hypothesis, we expected that 3-month-olds' broad sensitivity to perceptual differences among facial exemplars would have allowed infants to perform successful discrimination, irrespective of their sibling experience. In fact, evidence from various perceptual domains shows that, at 3 months of age, infants' perceptual sensitivity is still broadly tuned and allows them to discriminate exemplars from both familiar and unfamiliar categories (see reviews by Maurer & Werker, 2014 and Scott et al., 2007).

In contrast to such prediction, and quite counterintuitively, successful discrimination in the current study was achieved by 3-month-olds who lacked sibling experience, and not by those who did have access to such experience. It should be noted that successful child face discrimination for the 3-month-olds in the no-sibling group took the form of a standard post-habituation preference for the novel over the familiar face, a pattern opposite to that observed for 3-month-olds' discrimination of adult faces in Experiment 1. These findings replicate those obtained by Macchi Cassia, Bulf et al. (2014) with infant faces, showing that, although in post-habituation VPC trials 3-month-olds tested with adult faces preferred the familiar face, those tested with infant faces preferred the novel face. Together, these data indicate that, although in the absence of sibling experience infants at this very young age show generalized discrimination abilities for faces of different ages, they already treat adult and non-adult faces differently. Moreover, because both the 3-month-olds participating in Macchi Cassia, Bulf et al. (2014) study and those included in the no-sibling group of the current study had no sibling experience but quite a lot of experience with adult faces, it is tempting to conclude that, at this young age, infants' behavior in the context of VPC tasks follows a novelty rule or a familiarity rule depending on the baseline familiarity of the faces infants are presented with: they would pursue novelty when confronted with unfamiliar faces, and familiarity when confronted with familiar faces.

Within this view, the absence of a significant post-habituation preference for the 3-month-olds with siblings in the current study might be the outcome of the competition between infants' preference for the novel stimulus over the familiar one, and their tendency to follow a familiarity rule (i.e., re-explore the familiar face) as much as they did when they preferred the familiar adult face over the novel one in Experiment 1, or when they look longer at mother over stranger in visual preference tasks (e.g., Bushnell, 2001). In fact, we have claimed that infants' difficulty to disengage attention from the familiar adult face during post-habituation trials in Experiment 1 was a side effect of the constraints generated by the age-appropriate developmental task of building an attachment relationship with caregivers. In a similar vein, it is possible that the formation of an attachment relationship with the older sibling/s, which follows a similar developmental trajectory as attachment relationship with caregivers (Dunn, 1983), generated an analogous, although more subtle, tendency to re-explore the familiar child face in 3-month-old infants with siblings. By competing with infants' proclivity to explore novelty, this tendency to re-explore the familiar face might have obscured infants' ability to differentiate among the two child faces, generating a random (i.e., a preference score not dissimilar from 50%) post-habituation behavior.

Whatever the mechanism/s driving 3-month-olds' failure to show a significant preference during post-habituation trials in the presence of sibling experience, the results suggest that discrimination of child faces is achieved through different processes by both 3-month-olds without older siblings and 9-month-olds with siblings, who both manifested a standard novelty preference at test. This pattern of results indicate that 3 months of sibling experience is sufficient to affect infants' face processing abilities, although it is only after 9 months of exposure to the sibling's face that infants' processing of child faces comes to resemble their processing of adult faces.

4 | GENERAL DISCUSSION

It is known that contact and natural experience provided to each individual by their social environment influences face processing abilities across the lifespan, as face representation and its neural underpinnings maintain enough flexibility to adapt to newly encountered face races (Rhodes, Ewing, Hayward, Maurer, Mondloch, & Tanaka, 2009; Sangrigoli, Pallier, Argenti, Ventureyra, & de Schonen, 2005) or ages (e.g., Macchi, Picozzi, Kuefner, & Casati, 2009; Wiese, Wolff, Steffens, & Schweinberger, 2013) in adulthood and even into old age (e.g., Wiese, Komes, & Schweinberger, 2012). However, infant research has shown that the face processing biases (i.e., processing advantage mediating superior recognition for familiar over unfamiliar face categories) that adults typically manifest have their developmental origins in the first year of life, when perceptual attunement to the most familiar face traits leads to superior discrimination of human adult faces from the most frequently encountered ethnic group/s (see review by Scherf & Scott, 2012).

Recent studies investigating the long-term effects of sibling experience have provided indirect evidence for the role of early natural experience in building face processing biases (Macchi Cassia, Kuefner et al., 2009). These studies have shown that exposure to a younger sibling's face occurring within the first 3 years of life not only has immediate effects on 3-year-olds' processing of infant faces (Macchi Cassia, Kuefner et al., 2009, Experiment 1), but also continues to affect processing skills for infants faces at 6 years (Macchi Cassia et al., 2013), and leaves permanent traces into adulthood, when it facilitates the acquisition of perceptual expertise for infant faces (Macchi Cassia, Kuefner et al., 2009, Experiments 2 and 3). However, none of these studies has provided direct evidence for the immediate effects of natural experience acquired with a specific type of faces in infants. The only available evidence comes from laboratory training studies, showing that training at verbal labeling individual faces maintains infants' discrimination abilities for other-race faces (Anzures et al., 2012; Heron-Delaney et al., 2011) and monkey faces (Scott & Monesson, 2009), and improves neural processing for the latter (Scott & Monesson, 2010).

The current study provides the first evidence that exposure to an older sibling's face occurring naturally within the infant's social environment has immediate effects on child face processing and discrimination skills. Results show that, even if between 3 and 9 months of age infants maintain their discrimination skills for adult faces (Experiment 1), in the absence of sibling experience they show a decrease in their ability to discriminate among child faces (Experiment 2). More specifically, our data show that perceptual experience provided by everyday contact with an older sibling right from birth affects infants' processing of child faces already at 3 months of age, inducing competition between seeking novelty and pursuing familiarity, that results in random post-habituation behavior. By 9 months of age perceptual learning engendered by sibling experience allows infants to generalize their successful discrimination of novelty to include child faces.

These findings provide an important contribution to the understanding of the development of face processing biases, by showing how the natural statistics of early facial experience affects infants' face processing abilities. Moreover, the evidence they offer proves critical to the interpretation of earlier demonstrations of long-term effects of sibling experience (Macchi Cassia, Kuefner et al., 2009; Macchi Cassia et al., 2013) and its role in preserving the plasticity of the perceptual processes involved in face recognition. By showing that exposure to the sibling face has immediate effects on infants' face processing skills, current results provide further empirical support to the claim that the modulating effects of sibling experience on face processing skills observed in adulthood are the long-term outcomes of perceptual learning engendered by early-acquired experience.

ACKNOWLEDGMENT

The authors thank the parents and infants who donated their time to participate in the study. The authors also thank Carlo Toneatto for programming the experiments. This research was supported by a scholarship from the University of Milano-Bicocca to the first author and a grant from the same University to the last author.

ENDNOTE

[1] Note that an additional ANOVA on the no-sibling groups with participant's age and stimulus gender as between-subjects factor showed that infants' performance was not affected by the gender of the face stimuli presented (all ps including stimulus gender >.14).

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How to cite this article: Proietti V, Rigoldi M, Croci E, Macchi Cassia V. Sibling experience modulates perceptual narrowing toward adult faces in the first year of life. *Developmental Psychobiology*. 2018;60:395–406. https://doi.org/10.1002/dev.21616