Face Processing in Infancy and Beyond: The Case of Social Categories

Paul C. Quinn, Kang Lee, Olivier Pascalis

Face Processing in Infancy and Beyond:

The Case of Social Categories

Paul C. Quinn

University of Delaware

Kang Lee

University of Toronto

Olivier Pascalis

Universite Grenoble Alpes

Correspondence should be sent to Paul C. Quinn, Department of Psychological and Brain Sciences, University of Delaware, Newark, DE 19716. E-mail: pquinn@udel.edu.

Keywords: infancy, face perception, narrowing, race, gender, implicit bias

Abstract

While prior reviews of infant face processing have emphasized how infants respond to faces in general, the current review highlights how infants come to respond differentially to social categories of faces based on differential experience, with a focus on race and gender. Six different behaviors are examined: preference, recognition, scanning, category formation, association with emotion, and selective learning. Although some aspects of infant responding to face race and gender may be accounted for with traditional models of perceptual development, other aspects suggest the need for a broader model that links perceptual development with social and emotional development. We also consider how responding to face race and gender in infancy may presage responding to these categories beyond infancy, inclusive of discussion of how social biases favoring own-race and female are formed.

Face Processing in Infancy and Beyond:

The Case of Social Categories

Faces are among the most frequently encountered visual stimuli in our social environment. The ability to process faces effectively is crucial for individuals to succeed in their everyday social interactions. By contrast, the inability to process faces is associated with serious impairments in social functioning as seen in individuals with prosopagnosia or autism spectrum disorder. Due to its importance, face processing has received sustained investigation by developmental scientists for over half a century. Among them, many have focused on the origin of face processing in infancy.

Long-standing issues studied by investigators of infant face perception have included the structure of the newborn's representation of faces, and whether that representation is as simple as two laterally separated dots for the eyes above another dot for the mouth (Morton & Johnson, 1991) or something more elaborate, approximating a real face (Quinn & Slater, 2003). In addition, there has been discussion of whether faces are a special class of stimuli or just a category of frequently experienced objects with particular geometric features such as top-heaviness and congruency (Cassia, Turati, & Simion, 2004; Gauthier & Nelson, 2001). There has also been consideration of whether infants process faces as integrated wholes or as a collection of independent features (Cohen & Cashon, 2001; Leo & Simion, 2009). These debates have continued into the present decade (Johnson, Senju, & Tomalski, 2015; Nakabayashi & Liu, 2014; Quinn, Tanaka, Lee, Pascalis, & Slater, 2013; Simion & Di Giorgio, 2015), and in some instances are renewed by fresh data obtained from newly emerging technologies applied to infants (Deen et al., 2017; Reid et al., 2017).

A unifying theme of traditional work on infant face perception was the study of faces as a single, monolithic category, consisting of exemplars with common attributes, i.e., the internal features of the eyes, nose, and mouth in a canonical configuration. By contrast, the work highlighted in the current review will focus on how infants respond to the different social categories that can be extracted from faces (e.g., female vs. male, own-race vs. other-race). This work has been informed by multiple approaches in contemporary psychological science, inclusive of the views of those who study statistical learning (Kirkham, Slemmer, & Johnson, 2002), perceptual expertise (Gauthier & Nelson, 2001), affect or emotion (Cacioppo, Gardner, & Berntson, 1999; Lewis, 2016), intergroup relations (Banaji & Greenwald, 2013; Hugenberg, Young, Sacco, & Bernstein, 2011), and vision science (Jack, Garrod, & Schyns, 2014). On the one hand, our review will embrace the perspective that faces include attributes not present in non-face objects, e.g., gender, race, emotion, trustworthiness (Rule, 2017). On the other hand, it makes use of differences in the frequency of experience with different stimulus classes as a key driver of developmental change (Quinn, 2010). In this way, the review embraces the idea that faces are *both* special and objects of expertise.

Although research exists on how infants respond to at least four different social category attributes of faces (age, gender, race, and species), the current review will focus on the categories of gender and race. This is because we know the most about infant responding to these attributes, inclusive of data on six different behaviors (preference, recognition, scanning, category formation, association with emotion, and selective learning) as well as evidence on how much infants experience female versus male faces and own-race versus other-race faces. There are also findings regarding face gender and race that extend past infancy into childhood and adulthood, thereby allowing us to consider how events occurring in infancy may portend developments occurring beyond infancy.

The Statistics of Face Experience

Rennels and Davis (2008) collected parental report data and found that infants reared by female primary caregivers in Las Vegas, NV see female faces 71% of the time and own-race faces 92% of the time. One might ask how generalizable these findings are beyond the parental report method and particular locale. In response to this question, Sugden, Mohamed-Ali, and Moulson (2014) mounted a camera onto the head of infants growing up in metropolitan Toronto and reported that infants during the first three months were exposed to 70% female faces and 96% own-race faces. Moreover, such differences in frequency of experience do not appear to be limited to North America, given that parental report data indicate that infants from 3 to 9 months reared in Hangzhou, China experience 64% female faces in a locale with a population of over 99% own-race individuals (Liu et al., 2015a). As infants in the age range between 6 and 12 months are sensitive to numerical ratios as slight as 3:2 (Cordes & Brannon, 2009), and can even use such ratios to infer dominance relations (Pun, Birch, & Baron, 2016), it stands to reason that infants would be sensitive to the frequency differences between female and male faces as well as between own-race and other-race faces. We now proceed to a discussion of how infant looking behavior is affected by these experiential asymmetries.

Spontaneous Preference

Visual preference procedures allow investigators to ask whether infants look more at exemplars from one class over instances of another class. A typical procedure involves one or more face pairs presented in a left-right arrangement with the members of each pair chosen from each of the contrasted categories. Given that individual infants may have tendencies to look more in one direction versus another, such procedures typically have at least two trials, with the left-

right positioning of the instances from the contrasting categories counterbalanced across infants on the first trial and reversed on successive trials.

Race

In the initial study measuring how infants allocate looking time between own- and other-race faces, Caucasian newborns and 3-month-olds were tested with Caucasian faces contrasted with African, Asian, or Pakistani faces (Kelly et al., 2005). The newborns were on average only 3 days old, and did not display a looking time advantage for own- over other other-race faces. Although one might wonder whether this null effect simply reflects poor vision at birth (e.g., Dobson & Teller, 1978) and hence the inability to discriminate among the faces from the different races, Pascalis and de Schonen (1994) have shown that Caucasian newborns can discriminate among Caucasian faces. Given that the differences in faces from different races are arguably going to be as large as the differences in faces from the same race (if not larger given differences in facial physiognomy across races, e.g., Le, Farkas, Ngim, Levin, & Forrest, 2002), it stands to reason that newborn infants possess the sensitivity to discriminate between faces from different races even though they do not display preferences for one over another race. By contrast, at 3 months of age, the Caucasian infants looked more to Caucasian over African, Asian, and Pakistani faces. These findings suggest that approximately 100 days of experiencing over 90% own-race faces is sufficient to induce a visual preference for own-race faces.

A skeptic could argue that an experiential account of the own-race preference is premature. For example, the own-race preference could arise from maturation, and there is also the possibility that Caucasian faces could simply be more salient than contrasting other-race face classes, or both could be at work. To defeat these alternative explanations, one needs to document that infants from another race also display an own-race preference. In this regard, Bar-Haim, Ziv, Lamy, and Hodes (2006) reported that African 3-month-olds reared in Ethiopia and

exposed primarily to African faces preferred African over Caucasian faces. Also, Kelly et al. (2007a) reported that Asian 3-month-olds reared in China and exposed nearly exclusively to Asian faces preferred Asian faces over Caucasian, African, and Pakistani faces. These additional results support the argument that 3 months of experience with a predominance of own-race faces can induce an own-race preference. Further strengthening the experiential account is the finding of a null preference for own- versus other-race faces in a group of Ethiopian 3-month-olds exposed to both African and Caucasian faces (Bar-Haim et al., 2006).

The most recent studies on race-based face preference have been examining whether there is developmental change beyond 3 months of age. Two different studies, one conducted with Caucasian infants exposed primarily to Caucasian faces (contrasting Caucasian with African faces), and the other conducted with Chinese infants exposed to nearly all Asian faces (contrasting Asian with Caucasian faces), have revealed that the own-race preference at 3 months gives way to a null preference at 6 months followed by a reversal to an other-race preference at 9 months (Fassbender, Teubert, & Lohaus, 2016; Liu et al., 2015b). A preference for faces from racial minority groups has also been reported in 11-month-olds (Singarajah et al., 2017).

One interpretation of the reversal in preference is that it reflects a more general age-based transition (one that includes responding to non-face objects) from familiarity to novelty preference (e.g., Hunter & Ames, 1988). A non-mutually exclusive account is that processing efficiency or fluency for own-race faces is improving because of increasing experience with such faces, with the consequence that more attention can be allocated to other-race faces (Fassbender et al., 2016; Liu et al., 2015b). The finding that older infants display more holistic processing for own-race faces relative to other-race faces (Ferguson, Kulkofsky, Cashon, & Casasola, 2009) is consistent with this account.

An alternative account of the reversal in preference is that infants are beginning to respond to faces as a social class of stimuli (Singarajah et al., 2017). This account embraces arguments from the social psychology literature regarding intergroup relations. In particular, it maintains that smaller groups are more likely to be salient and hence targeted for out-grouping (Bigler & Liben, 2007). The preference for other-race faces in 9-month-old infants might thus reflect greater attention to "odd" other-race faces that pop out against a predominant background of own-race faces. The finding that a single other-race face located amidst a background of seven own-race faces attracts 9-month-old infant attention, but a single own-race face amidst a background of seven other-race faces does not, is consistent with this account (Hayden, Bhatt, Zieber, & Kangas, 2009).

Gender

Over the first three months, infants display gender-based looking time preferences to faces that correspond with those observed for face race. In particular, although newborns do not show a preference between female versus male faces, 3- to 4-month-olds with female primary caregivers look longer at female relative to male faces (Hillairet de Boisferon, Uttley, Quinn, Lee, & Pascalis, 2014; Quinn et al., 2008, 2010). An experiential basis for this effect is indicated by the finding that 3-month-olds with male primary caregivers look longer at male relative to female faces (Quinn, Yahr, Kuhn, Pascalis, & Slater, 2002).

As was the case for face race, some recent studies on gender-based face preferences have been examining developmental change beyond 3 months. These studies suggest that infants at 6 months still look more to female over male faces, but that infants at 9 months divide attention between female and male faces (Liu et al., 2015a; Tham, Bremner, & Hay, 2015; but see Kim, Johnson, & Johnson, 2015, and Quinn, 2002). The decline in the female face preference has been interpreted by Liu et al. (2015a) in terms of a threshold model. That is, when male face

experience surpasses some threshold amount between 6 and 9 months, infants no longer prefer female faces. The threshold model contrasts with a proportional ratio model in which a consistent ratio favoring female faces would be expected to preserve the female face preference. Because Liu et al. (2015a) observed that the ratio of female to male face experience was consistently close to 2:1 from 3 to 9 months, the change in the gender preference from female to null between 6 and 9 months was interpreted in accord with the threshold model. However, it should be acknowledged that Kim et al. (2015) and Quinn (2002) observed a female preference in infants from 3 to 10 months, so these results would be more in accord with a proportional ratio model.

Recognition

Face recognition abilities have been studied using a paired-comparison procedure in which infants are familiarized with a face of a given race or gender and then subsequently tested with the familiar face and a novel face from the same category. A looking-time preference for the novel face allows one to infer that infants encoded the familiarized face and can discriminate between it and the novel face (Fantz, 1964). To make the test less of an image matching task and more of a face recognition task, some studies have varied the view of the face (full vs. ¾) from familiarization to test.

Race

Paired-comparison procedures have revealed that Caucasian 3-month-olds exposed primarily to Caucasian faces and Chinese 3-month-olds exposed almost exclusively to Asian faces displayed positive recognition abilities for both Asian and Caucasian faces as well as for African faces. However, between 6 and 9 months, while discrimination among familiar own-race faces was maintained, discrimination of faces from within other-race categories declined (Kelly et al., 2007b; Kelly et al., 2009). The findings suggest that the well known other-race effect in which both child and adult observers have greater difficulty telling apart faces from within other

races than faces from within one's own race (Meissner & Brigham, 2001; Sangrigoli & de Schonen, 2004) takes root in infancy (see Sugden & Marquis, 2017, for a recent meta-analysis).

The same pattern of change in response to experiential asymmetry has also been reported for language, i.e., native vs. non-native speech (Werker & Tees, 1984). It has become known as narrowing and interpreted to support a model of perceptual development in which experience is needed to maintain abilities that arise as a consequence of the initial settings of the perceptual system (Gottlieb, 1981).

If the decline in recognition of faces from within races reflects an experientially-driven falloff in ability, then it should be possible to prevent narrowing from occurring by providing experience with exemplars from the relevant category, in this case, instances of other-race faces. To this end, Heron-Delaney et al. (2011) had parents of Caucasian 6-month-olds take home picture books of named Asian faces and present their infants with these faces for a 12-week period between 6 and 9 months. The faces were presented every day for the first week, every other-day during the next week, and at least once a week for the next 10 weeks. At 6 months, the infants were able to recognize both Caucasian and Asian faces, thus verifying that the training was begun at a time when narrowing had not yet taken effect. At 9 months, following training, the infants continued to recognize both Caucasian and Asian faces, thereby establishing that the picture book experience with Asian faces prevented narrowing from occurring. This conclusion was additionally supported by the finding that a control group of Caucasian infants who received picture book training with Caucasian faces did display the decline in recognition for Asian faces from 6 to 9 months that is consistent with narrowing.

One can also ask whether experience with other-race faces can undo narrowing after it has already occurred. To answer this question, Anzures et al. (2012) investigated a group of Caucasian 8- to 10-month-olds who were found not to discriminate between Asian faces. The

parents of these infants agreed to present to their infants a daily video of Asian faces introducing themselves by name. After three weeks of everyday exposure to the faces on the video, the infants displayed above-chance discrimination of Asian faces. This outcome indicates that narrowing of recognition for other-race faces can be undone with experience with faces from the other-race category. Moreover, the findings of both Heron-Delaney et al. (2011) and Anzures et al. (2012) strengthen the interpretation of narrowing of face race as an experientially-driven development.

Gender

Narrowing of recognition has been reported for face gender, although the evidence is more subtle and tenuous; one needs to compare results across several studies to reach this conclusion. Perhaps, though, this is as one would expect, given that the statistics of face gender (7:3 or 2:1) are not as asymmetrical as they are for face race (9:1). At 3 months, infants familiarized with one face and then tested with that face and a novel face from the same gender display a preference for the novel face regardless of whether the faces are male or female (Quinn et al., 2002). Equivalent discrimination of both male and female faces in paired-comparison procedures has also been observed in 7-month-olds (Righi, Westerlund, Congdon, Troller-Renfree, & Nelson, 2014). Positive evidence for discrimination among male faces and among female faces using the paired-comparison procedure has additionally been reported in 10-, 14-, and 16-month-olds (Rennels et al., 2017).

Based on the data described thus far, one would conclude that there is no evidence for narrowing of face gender. However, Rennels et al. (2017) reported on an additional visual search task in which infants were familiarized with one face and then tested with the familiarized face and 3 novel faces of the same gender, with each of the four test faces appearing in a given quadrant of a square 2 x 2 array. The key finding was that infants at 10, 14, and 16 months were

more likely to fixate the familiarized face in female- than male-arrays. Given that the infants were more likely to locate the female than male face and because the effect was observed in infants 10 months of age and older, a time window in which narrowing has been observed for face race, the effect of gender on visual search was interpreted by Rennels et al. (2017) in terms of narrowing. One could question this interpretation inasmuch as comparable performance for female and male faces in the same task was not reported for infants younger than 10 months of age. Nevertheless, a broader take away that the effect is experientially driven is supported by the findings that the visual search advantage for female faces was only observed among infants with a female primary caregiver; among infants with caregiving that was more distributed across mother and father, the familiar face was located on an above-chance basis regardless of whether it was male or female.

Given the timing between the developmentally early appearance of preferences for own-race and female faces at 3 months and the subsequent decline in recognition among other-race and male faces it seems reasonable to suggest that there is a relation between the two processes. In particular, greater experience with a particular face class may initially bring about increased attention to exemplars of that category and decreased attention to exemplars of less experienced classes. That decreased attention could in turn lead to shallower encoding, thereby producing the decline in recognition. Studies examining the relation between individual differences in preference for own-race and female faces in early infancy and individual differences in recognition of other-race and male faces in later infancy are needed to evaluate this proposal.

Scanning

The eye movements that observers make when scanning visual images have long been been theorized as an important mechanism by which internal representations of objects are constructed (Hebb, 1949). Use of eye tracking to measure infant visual fixations has been around

since the 1970s (e.g., Maurer & Salapatek, 1976), but the development of commercially available eye-tracking systems that can be used with infants has created a resurgence of interest in this investigative tool. Eye tracking allows one to determine where on a stimulus an infant is fixating. In the case of a face, are infants fixating the internal features such as the eyes, nose, and mouth? One can also use eye tracking to study, for example, developmental change in which face regions are being fixated and the sequence in which fixations are executed. By examining the timing relations between developmental change in visual scanning behavior and developmental change in processes such as recognition, researchers can make more informed inferences about how eye movements are associated with visual processing.

Race

The first study of how infants scan faces based on race reported a developmental change in the way that Chinese infants exposed almost entirely to Asian faces fixated the internal features (eyes, nose, and mouth) of own- versus other-race (Caucasian) faces (Liu et al., 2011). Specifically, between 4 and 9 months, while fixation time on the internal features of own-race faces was maintained, fixation time on the internal features of other-race faces decreased. This outcome corresponds well with the maintenance of recognition for own-race faces and decline in recognition for other-race faces observed over this same time frame (Kelly et al., 2007b, 2009). If recognition of identity is tied to the processing of differences in the shape and size of the internal features, as well as their spacing relations, and infants are decreasingly likely to fixate such features in other-race faces, it follows that recognition ability for such faces will decline. The decline in holistic processing for other-race faces that has been reported in this same developmental window (Ferguson et al., 2009) is additionally consistent with the decline in fixations on the internal features of these faces.

Other aspects of infant scanning behavior for own- versus other-race faces are less in accord with a maintenance model, and more in agreement with an attunement model of perceptual development (Aslin, 1981). Xiao, Quinn, Pascalis, and Lee (2014) examined sequences of fixations between internal features in 6- and 9-month-old Caucasian infants presented either with Caucasian or Asian faces. At 6 months, the similarities of scan paths across infants did not differ for own- versus other-race faces; however, at 9 months, there was greater similarity in scan paths across infants for own-race faces relative to other-race faces. This trend was also observed in a reanalysis of scanning performance of the Chinese infants from the Liu et al. (2011) study.

The increase in similarity of scan path with increased age for own- but not other-race faces indicates that infant face perception is becoming more enhanced or attuned to the category of frequent experience. The findings also suggest that as own-race faces become increasingly familiar, the sequence of fixations used to scan such faces is becoming more systematic, perhaps reflecting greater efficiency in extracting information diagnostic of identity and stronger top-down control of scanning (Hadley, Rost, Fava, & Scott, 2014). Greater efficiency in scanning of own-race faces in 9-month-olds would presumably allow for rapid processing, a suggestion that is consistent with the explanation of the reversal in preference to other-race faces at this age because of the ability to deploy more attentional resources to such faces (Liu et al., 2015b).

Gender

To our knowledge and surprise, there is only one study that has reported differential scanning of male versus female faces in infants. Gredeback, Eriksson, Schmitow, Laeng, and Stenberg (2012) reported that 14-month-olds displayed a broader distribution of fixations on male faces relative to female faces. By itself, this finding can be interpreted in different ways. A broader distribution of fixations could be considered as being consistent with more holistic

processing for male faces. However, that interpretation would be inconsistent with female faces being the category of greater experience and hence the stronger candidate for holistic processing. An alternative interpretation, one that we favor and consistent with what was observed in the scan path data for face race, is that the broader distribution of fixations on male faces may reflect more expansive exploration of the less familiar male faces. The more familiar female faces may elicit a more focused set of fixations, possibly reflecting more knowledge of the likely location of information diagnostic of identity.

Category Formation

Category representations or concepts are crucial for organizing our experiences in memory and responding to novel objects as if they are familiar. In the absence of category representations, each entity that we know about would be unrelated to every other entity, and much of our time would be spent learning responses for the novel entities we encounter on an everyday basis. Category representations were once thought to be formed during childhood and later, reflecting the influence of language, the learning of logic, and the acquisition of instruction (e.g., Fodor, 1972; Hull, 1920; Leach, 1964). However, in the 1970s, it was recognized that categories are marked by attribute correlations, e.g., dogs have four legs and fur, birds have two legs and feathers (Mervis & Rosch, 1981). Infant work would soon follow investigating whether infants could form categories based on extraction of attribute correlations from perceptual experience (Cohen & Younger, 1983).

Children and adults demonstate their categories in patterns of naming, for example, labeling a cat as a “cat”, generalizing this label to other instances of cats, and differentially labeling different instances of dogs with the label “dog”. These behaviors entail the signature evidence that a category has been formed: equivalent responding to different members of the category and differential responding to instances from a different category. To measure category

formation in infants, researchers have made two modifications in the procedure used to measure recognition in infants. First, different instances from the same category are presented during familiarization. Second, during the preference test, two novel instances are presented, one is a novel instance from the familiarization category and the other is a novel instance from a novel category. Generalization of looking time responsiveness from the familiarization instances to the novel instance of the familiarization category and differential responding to the novel instance from the novel category (in the form of increased looking time) are taken as evidence that a category has been formed.

Race

Given that differences in facial physiognomy and skin tone perceptually mark faces from different races, e.g., Caucasian faces are marked by light skin color, thin lips, and narrow noses relative to African and Asian faces (Farkas, Forrest, & Litsas, 2000; Le et al., 2002), two studies have examined whether infants can form categories based on face race. The first study asked whether Caucasian 6- and 9-month-olds could represent the categories of own-race Caucasian faces versus other-race Asian faces (Anzures, Quinn, Pascalis, Slater, & Lee, 2010). The 6-month-olds responded differently depending on familiarization category. When familiarized with Asian faces, there was generalization to novel Asian faces and differential responding to Caucasian faces. This pattern suggests that the younger infants formed a category of Asian faces that included novel Asian faces, but excluded Caucasian faces. However, with familiarization to Caucasian faces, there was generalization to both novel Caucasian faces and novel Asian faces.

How can the asymmetrical pattern of responding of the 6-month-olds be explained? An accounting in terms of spontaneous preference for own-race faces facilitating a novel category preference for own-race faces after familiarization with other-race faces and interfering with a novel category preference for other-race faces after familiarization with own-race faces seems

unlikely given that 6-month-olds have been reported not to have an own-race preference (Fassbender et al., 2016; Liu et al., 2015b). A more likely explanation has to do with within-category variation. Anzures et al. (2010) found that even at 6 months the Asian faces were less discriminable than the Caucasian faces, indicating that perceptual narrowing of recognition had already begun. This finding indicates that category formation for the other-race faces was likely achieved through categorical perception, where the perception is of similar exemplars that are difficult to discriminate (Harnad, 1987) rather than through categorization, where the categories are formed despite the ability to individuate the instances within the categories. Moreover, the greater variation among the Caucasian faces may have made them more difficult to group together into a common category representation (Quinn, Eimas, & Rosenkrantz, 1993; Valentine & Endo, 1992). These considerations thus suggest a way in which narrowing of recognition and category formation may be related: lessened discriminability may be associated with enhanced category formation. It also carries the implication that category representations for other-race faces may precede category representations for own-race faces in infancy. Such a developmental ordering, even though counterintuitive, could be a precursor of the other-race categorization advantage in adults, a phenomenon in which other-race faces are more rapidly categorized relative to own-race faces (Ge et al., 2009).

We are still left with the question of how the older infants in Anzures et al. (2010), the 9-month-olds, responded to the category distinction between own- and other-race faces. Whether presented with Asian or Caucasian faces, these infants generalized to novel instances of the familiarization category, and responded differentially to novel instances of the novel category. This outcome suggests that infants by 9 months represent own- and other-race faces as distinct categories. However, there is a caveat. Because infants have been shown to spontaneously prefer other-race faces at 9 months (Fassbender et al., 2016; Liu et al., 2015b), it is possible that the

novel category preference for other-race faces after familiarization with own-race faces was driven largely, if not exclusively, by the spontaneous preference (i.e., it would have been present even without familiarization with own-race faces). While spontaneous preference for one category (i.e., other-race faces) over another (i.e., own-race faces) by itself provides evidence of systematic differentiation between instances from two categories, it falls short of demonstrating category formation because we do not have firm evidence that the infants generalized responsiveness from the category instances shown during familiarization to the novel instance of the familiarization category shown on the test trials. Thus, at 9 months, while there is good evidence for an other-race face category (that excludes own-race faces), the evidence for an own-race face category (that excludes other-race faces) is fragile. On the one hand, given that infants have strong tendencies to form categories (Quinn, 2011) and the perceptual differences between Asian and Caucasian faces, the lack of evidence for a category of own-race faces may be surprising. On the other hand, given the extensive experience that infants have with own-race faces, it could be that the recognition of such faces as individuals overrides any tendency to group them together into a category (Tanaka, 2001). Such behavior may foreshadow the own-race recognition advantage observed in adults (Ge et al., 2009).

Quinn, Lee, Pascalis, and Tanaka (2016) inquired further into the abilities of infants to form categories based on face race by examining how infants represent different classes of other-race faces. This work gets at the question of whether, for example, it matters to a Caucasian infant if an other-race face is African or Asian. Caucasian infants at 6 and 9 months were familiarized with African or Asian faces and then tested with a novel African versus novel Asian face. The 6-month-olds displayed novel category preferences regardless of whether they were familiarized with African or Asian faces. This result indicates that the 6-month-olds were forming category representations for different classes of other-race faces. Given lack of

experience with other-race face classes, infants were likely using the perceptual differences between the classes based on facial physiognomy and skin tone to form the categories.

At 9 months, a surprising result was obtained: the infants did not display novel category preferences after familiarization with African or Asian faces. On its own, this finding is ambiguous because it is consistent with infants forming no categories or infants forming a broad category of other-race faces, one inclusive of multiple classes of other-race faces. To disentangle these possibilities, an additional study was conducted in which Caucasian 9-month-olds were tested on the category contrast of own-race Caucasian faces versus other-race African or Asian faces. Infants familiarized with Caucasian faces showed novel category preferences for both African and Asian faces. Perhaps more importantly, infants familiarized with either African or Asian faces displayed a novel category preference for Caucasian faces. This latter finding, coupled with the null outcome in the initial study of Quinn et al. (2016), indicates that infants at 9 months form a broad category of other-race faces that includes faces from multiple other-race classes, but excludes own-race faces. For Caucasian infants, this other-race category includes at least African and Asian faces, but excludes Caucasian faces. With regard to a category of own-race faces, the evidence remains fragile. As was the case in the Anzures et al. (2010) study, the novel category preference for other-race faces after familiarization with own-race faces could have arisen because of an a priori preference (Fassbender et al., 2016; Liu et al., 2015b).

Overall, then, at 9 months, infants encode own-race faces as individuals, but encode other-race faces as members of a wide-ranging “other” or not-Caucasian category. Because the other-race face category of these older infants is filtering out the perceptual differences between different other-race face classes (African vs. Asian for a Caucasian infant), its inclusiveness might be regarded as less perceptual and more social. By this view, the 9-month-old representation of other-race faces (relative to the 6-month-old representation of other-race face

categories where the boundaries followed perceptual differences) may represent the initial beginnings of an out-grouping of faces. In particular, at 9 months, the out-group may consist of faces that do not match the faces of predominant experience. This suggestion corresponds with the interpretation of the other-race preference at 9 months as a response to an out-group (Singarajah et al., 2017). That differences in the frequency of experience may drive the formation of an "other" category is supported by the finding of decreasing distance between African and Asian faces in a computational model learning Caucasian, African, and Asian faces in an 8:1:1 ratio (Balas & Quinn, 2015).

Gender

Two studies investigating the abilities of infants to form category representations based on face gender have revealed an asymmetric pattern of results (Leinbach & Fagot, 1993; Quinn et al., 2002). In particular, infants from 3 to 12 months familiarized with male faces generalized looking time responsiveness to novel female faces and preferred male faces; however, same aged infants familiarized with female faces generalized looking time responsiveness to both novel female and male faces (Leinbach & Fagot, 1993; Quinn et al., 2002). This pattern of responsiveness is consistent with the spontaneous preference for female faces that has been reported in younger infants (Kim et al., 2015; Quinn et al., 2002) as well as in older infants in some studies (Kim et al., 2015; Quinn, 2002; but see Tham et al., 2015 and Xiao et al., 2015a). After familiarization with male faces, a spontaneous preference for female faces and a novel category preference for female faces would combine to yield a strong preference for female faces. However, after familiarization with female faces, a spontaneous preference for female faces would interfere with a novel category preference for male faces, thus producing a null preference.

The possibility that a spontaneous preference for female faces is influencing performance in a gender category task makes it difficult to conclude that distinct categories for male and

female faces are being formed. For each familiarization category, we have only half of the evidence needed to conclude that a category is present. That is, when the familiarization category is male, there is generalization to novel male faces, but the differential response to female faces would have been present even without familiarization with male faces. When the familiarization category is female, there is generalized responding to novel female faces, but there is no differential responding to male faces. The spontaneous preference for female over male faces independently provides evidence that infants can systematically differentiate male and female faces, but drawing a firm conclusion about category representations for male versus female faces is more problematic.

Association with Emotional Valence

Although at least younger infants look more to the face categories of greater experience, own-race and female, such a looking time advantage does not necessarily imply that infants have greater liking for own-race and female faces (Liberman, Woodward, & Kinzler, 2017; Shutts, 2015). However, there is the well-established finding that greater frequency of exposure to objects results in more favorable attitudes toward those objects (Zajonc, 1968), and several recent studies with adults have shown that familiar faces are viewed as happier, more attractive, and more trustworthy than unfamiliar faces (Batres, Kannan, & Perrett, 2017; Carr, Brady, & Winkielman, 2017; Dotsch, Hassin, & Todorov, 2016). These considerations have led to investigations into whether such familiar=positive associations would emerge even in infants and whether positive valence would be associated with more frequently experienced own-race and female faces.

Race

Xiao et al. (2017a) developed a procedure to determine whether infants associate familiar own-race faces with positive emotion and unfamiliar other-race faces with negative emotion. Infants from 3 to 9 months (i.e., 3-month-olds, 6-month-olds, and 9-month-olds) were presented

with a series of faces (shown individually) that alternated with a sequence of musical excerpts (i.e., Face 1, Musical Excerpt 1, Face 2, Musical Excerpt 2, and so on). The faces could be own-race or other-race and the musical excerpts were happy or sad, leading to four different between-subjects conditions in which two were congruent (own-race/happy and other-race/sad) and two were incongruent (own-race/sad and other-race/happy). Given that infant attention is maintained more by audio-visual congruence than incongruence (e.g., Walker et al., 2010), the expectation was that infant attention would be stronger for the congruent than incongruent face-music combinations.

The findings were that while 3-month-olds showed no differential attention among the conditions, with age, infants increasingly attended to the congruent conditions, such that by 9 months, infants attended longer in the own-race/happy and other-race/sad conditions relative to the own-race/sad and other-race/happy conditions. These outcomes suggest that older infants associate familiar own-race faces with positive emotional valence and unfamiliar other-race faces with negative emotional valence. In accord with the suggestion that older infants are more likely to associate differential emotional valence to own- versus other-race faces is the finding that infants in the age range between 8 and 17 months were less likely to approach other-race versus own-race strangers (Feinman, 1980). Data showing that preference for fair versus unfair distributors in 15-month-olds is affected by whether the distributions benefit own- versus other-race individuals (Burns & Sommerville, 2014) is additionally consistent with the suggestion that older infants associate own- versus other-race faces with differential valence.

Gender

Although we are unaware of a gender analogue to the Xiao et al. (2017a) study with race, Bayet et al. (2015b) reported that 3.5-month-old infants preferred a happy to a neutral female facial expression, but preferred a neutral to a happy male facial expression. In addition, 7- to 19-

month-olds showed less stranger anxiety for females versus males (Lewis & Brooks-Gunn, 1974) and 9- to 12-month-olds responded less positively (with fewer smiles) to male relative to female faces (Brooks-Gunn & Lewis, 1981). The set of findings taken together is consistent with the idea that infants are more likely to associate positive emotion with female faces.

Selective Learning

A rapidly expanding literature on the early development of social learning is examining how infants learn differentially or selectively from adults who vary in attributes such as expertise and reliability (e.g., Stenberg, 2012; Tummeltshammer, Wu, Sobel, & Kirkham, 2014). Of significance is the finding that 14-month-olds were more likely to imitate the action of an in-group adult who spoke in the infant's native language than an out-group adult who spoke a foreign language (Buttelmann, Zmyj, Daum, & Carpenter, 2013). In addition, preschool children trust familiar over unfamiliar informants (Corriveau & Harris, 2009), and are more trusting with a lack of consensus among own- than other-race individuals (Chen, Corriveau, & Harris, 2013). Based on these findings, it became of interest to investigate whether infants would show advantages in learning from own-race and female faces relative to other-race and male faces.

Race

Two recent studies have examined how infants use gaze cues from own- versus other-race adults to learn about objects (Pickron, Fava, & Scott, 2017; Xiao et al., 2017b). In Xiao et al. (2017b), 7-month-old infants were presented with a rectangular display in which the gaze of a centrally located own- or other-race female model predicted the subsequent location of an animal that appeared in one of the four corners of the display. There were three different between-subject conditions in which the accuracy of the model in predicting the animal's location varied: 100% (complete reliability), 50% (uncertain reliability), and 25% (chance reliability). The infants learned to use the gaze of both the own- and other-race adults when they were 100% reliable and

did not learn to use the gaze of either adult when each was at chance reliability (25%). However, in the uncertain context in which the adults were partially reliable (50%), the infants were more likely to learn the gaze cues of the own-race relative to the other-race adult to anticipate the appearance of the animal. It was as if the infants granted benefit when there was doubt more so to an own-race adult than to an other-race adult.

Pickron et al. (2017) also used a gaze-cuing procedure with 5- and 10-month-olds, although with a centrally located own- or other-race model (that was male or female) looking to one of two objects located on the model's left and right. When the objects subsequently appeared without the model, the infants looked more to the non-cued object, but only when the model was own-race (and female). This looking pattern was interpreted as evidence that the infants learned about the cued object (thus rendering it as familiar and making the non-cued object appear as novel) just when the model was own-race (and female). The results of the Xiao et al. (2017b) and Pickron et al. (2017) studies, taken together, suggest that infants learn more readily from own- relative to other-race adults.

Gender

Pickron et al. (2017) reported that 5- and 10-month-olds learned about objects that were cued by the gaze of females, but did not learn about objects cued by the gaze of males. In addition, in social referencing situations, 12-month-olds were more likely to consult the reactions of mothers than fathers (Hirshberg & Svejda, 1990). Moreover, a possible correspondent effect that has been observed in the language domain is that 7-month-olds have been shown more likely to respond to female relative to male vocalizations with their own vocalizations (Johnson, Caskey, Rand, Tucker, & Vohr, 2014). All of these results suggest stronger learning effects with the more familiar gender.

Continuity Beyond Infancy?

Do the events taking place in infancy have consequences beyond it? Although theories embracing discontinuity have a lengthy history in developmental psychology (Piaget, 1952; Kagan, 2008), recent empirical efforts suggest substantial continuity at least between infancy and childhood in domains such as spatial cognition and theory of mind (Lauer & Lourenco, 2016; Thoermer, Sodian, Vuori, Perst, & Kristen, 2012; Yamaguchi, Kuhlmeier, Wynn, & VanMarle, 2009). It therefore seems reasonable to ask whether a case can be made for continuity in how infants and children as well as adults respond to the social categories of gender and race. Although we do not know of any longitudinal studies assessing whether individual differences on one or another measure of infant response to race or gender are preserved in childhood responses for these same categories (but see Hadley, Pickron, & Scott, 2015, for a report indicating that individuation training with monkey faces for infants between 6 and 9 months of age was associated with more rapid recognition of human faces in 4- to 6-year-olds) we will argue that there is at least consistency in the directionality of responding (i.e., in favor of own-race and female) beyond infancy. In making this argument, we will contend in a couple of cases that the tasks used to assess infant responding may be construed as infant equivalents of the tasks used to investigate responding in children and adults.

Race

As noted, the findings that older infants have greater difficulty distinguishing between faces from within other-race classes relative to faces from within one's own-race class (Kelly et al., 2007b, 2009) presage demonstrations of the other-race effect of recognition in children (Sangrigoli & de Schonen, 2004) and adults (Meissner & Brigham, 2001). Our view is that the way in which recognition is measured in infancy (familiarization with one face and then testing

with that face versus a novel face) approximates the way in which recognition is measured in older participants (familiarization with one face and then testing with that face versus one or more novel faces). The other-race effect reported in infants may thus represent an infant analogue of equivalent behavior reported in children and adults.

That older infants respond more favorably to own- over other-race faces (with greater recognition of individuality, more efficiency in scanning, association with positive emotional valence, and selective learning) also leads one to ask whether such responding could be related to social biases favoring own-race individuals that have been observed in children as young as 3 years of age (e.g., Qian et al., 2016). Some theorists have argued that perception may contribute substantially to the formation of intergroup bias on the grounds that intergroup bias is more likely to be observed in contexts where there are appearance differences between groups and where there are also proportional size differences between groups with smaller groups being targets of out-grouping (Bigler & Liben, 2007). These conditions clearly exist for the infants we have been describing in this article, and the infant behaviors we have documented suggest that infants are sensitive to both appearance and frequency differences between own- and other-race face classes.

Are there infant analogues to the way racial bias is measured in young children? In this regard, we believe that a parallel can be drawn between the way implicit racial bias is measured in children (Qian et al., 2016) and the association between face race and emotional valence that has been reported in Xiao et al. (2017a). For example, Qian et al. (2016) measured implicit racial bias in children by presenting an own- or other-race face in the center of a touchscreen display, with line drawings of a smile face and a frown face presented at the bottom corners of the display. On congruent trials, children are asked to touch the smile face in the presence of an own-race face or touch the frown face in the presence of an other-race face. On incongruent trials, children are asked to touch the frown face in the presence of an own-race face or touch the smile

face in the presence of an other-race face. Association of own-race faces with positive emotion and other-race faces with negative emotion is inferred if children are faster on the congruent relative to the incongruent trials. Importantly for us, this logic of using differential responding on congruent versus incongruent trials to infer association between face race and emotional valence in children in Qian et al. (2016) is the same logic used to infer association between face race and emotional valence in infants in Xiao et al. (2017a). We would add that both ways of measuring implicit racial bias in developmental populations correspond with the classic way in which implicit racial bias has been measured in adults, i.e., via strength of association of own-race with positive attributes and other-race with negative attributes (Banaji & Greenwald, 2013). We therefore believe that there is at least a functional equivalence between the responding observed in infants, children, and adults as it pertains to the association between race and valence.

Gender

For gender, predominant female experience in infancy transitions to predominant same-sex friendships in childhood. This change suggests continuity of experience for females and discontinuity of experience for males. For example, in the case of recognition, projecting beyond infancy, assuming that female face experience from same-sex friendships in girls would only reinforce the female face experience of infants with female primary caregivers, one would predict a continuing recognition advantage for female over male faces in girls and women. By the same reasoning, on the assumption that male face experience from same-sex friendships in boys would interfere with (or neutralize) the female face experience of infants with female primary caregivers, one would predict no recognition advantage for female over male faces in boys and men. A recent meta-analysis confirmed these predictions (Herlitz & Loven, 2013), thus providing support for our experiential account of recognition ability in the case of face gender.

Can the differential affective responses of infants to male and female faces (i.e., greater stranger anxiety for males, more smiling to female faces, and more looking at females with happy expression) be linked with gender biases beyond infancy? Such infant behaviors do seem to foreshadow findings that children and adults are more likely to classify a face as male when that face depicts a negative facial expression (Bayet et al., 2015a) and also the "women are wonderful" effect in which women are evaluated more positively than men on a variety of attitudinal measures (Eagly, Miadinic, & Otto, 1991). As noted in the prior paragraph, one needs to be mindful of continuity between female face experience in infancy and same-sex friendships for girls and the discontinuity between female face experience in infancy and same-sex friendships for boys. On this basis, one would predict stronger gender bias favoring female in girls and women relative to boys and men. Studies examining implicit gender bias in children and adults support this prediction (Cvencek, Greenwald, & Meltzoff, 2011; Dunham, Baron, & Banaji, 2016; Nosek & Banaji, 2001). Overall, then, we believe that the association observed between female faces and positive affect in infancy is consistent with what is observed in childhood and adulthood, although the association can be modified by the same-sex experience of boys and men.

On the Emergence of Perceptual-Social Linkage

In prior sections of the paper, we have described how infants come to respond differently to own- versus other-race faces and female versus male faces based on unequal experience. Some aspects of this differential responding can be explained with traditional models of perceptual development (Aslin, 1981; Gottlieb, 1981). For example, narrowing of recognition for other-race and male faces is consistent with experience being needed to maintain initial ability, and the increased efficiency in scanning for own-race and female faces is in accord with attunement of initial abilities by experience. However, other aspects of the differential responding to face race

and gender in infants, such as the linkage of more positive affect with own-race and female faces and more negative affect with other-race and male faces seem to extend beyond models of perceptual development. This consideration calls for a framework that conjoins perceptual with social and emotional development (Timeo, Farroni, & Maass, 2017).

Recent work coming from adult vision science suggests that the most basic differential response to different face types is approach versus avoidance (Jack et al., 2014), and it seems reasonable to suggest that a contrast such as this (or engagement versus withdrawal) might provide a more comprehensive accounting of how infants are responding to own- versus other-race and female versus male. This framework is consistent with the differential responses both adults and infants display for stimuli associated with positive versus negative affect (Cacioppo et al., 1999; Lewis, 2016). It is also in accord with arguments that perceived relevance or importance motivate differential responding to different social categories (Hugenberg et al., 2011). A proxy for perceived importance during infancy could be frequency information (Balas & Quinn, 2015; Quinn et al., 2016).

How do infants come to attach differential affect with different social categories? We believe that there are a number of candidate mechanisms that could be interrelated. They include familarity (Zajonc, 1968), processing fluency (Reber, Winkielman, & Schwarz, 1998), caregiver displays of positive expression (Malatesta & Haviland, 1982), caregiver reliability (Sroufe, Egeland, Carlson, & Collins, 2005), heightened stranger anxiety for males and other-race members (Brooks Gunn & Lewis, 1981; Feinman, 1980; Lewis & Brooks Gunn, 1974), and association of more positive attributions with individuals and more negative attributions with categories (Banaji & Greenwald, 2013).

One could envision these different mechanisms working as follows. Majority group infants reared by female primary caregivers in mono-racial contexts experience own-race over

other-race faces in a 9 to 1 or higher ratio, and female over male faces in a 2 to 1 or higher ratio (Rennels & Davis, 2008; Sugden et al., 2014; Xiao et al., 2015a). Such frequency differences could be anticipated to produce greater liking and trust for own-race and female faces (Corriveau & Harris, 2009; Dotsch et al., 2016; Zajonc, 1968), although as we note below, exposure differences may not be sufficient. The greater experience that infants have with own-race and female faces may allow infant scanning of such faces to be more efficient (Gredeback et al., 2012; Xiao et al., 2015b). Such efficiency may translate into greater processing fluency, which could enhance liking of own-race and female faces (Reber et al., 1998).

The maintenance of recognition for individuals from own-race and female categories and decline in recognition of individuals from other-race and male categories (Kelly et al., 2007b, 2009; Rennels et al., 2017), combined with the observations that attitudes towards individuals tend to be more positive, whereas attributions towards categories tend to be more negative (Banaji & Greenwald, 2013), would provide yet another basis by which infants could attach more positive affect to own-race and female faces. Our view is that maintaining the recognition of individuals in frequently experienced categories may be critically important in the attachment of positive affect to these categories. It follows that training to individuate members of less frequently experienced categories for which recognition has otherwise been lost due to narrowing may be crucial in removing the attachment of negative affect to these categories.

In the case of race, training adults to individuate other-race faces reduces implicit racial bias for those faces (Lebrecht, Pierce, Tarr, & Tanaka, 2009). More importantly for us, such training has been shown to be effective in children as young preschoolers (Xiao et al., 2015), and mere exposure to such faces without the individuation aspect of the training was not effective (Qian et al., 2017b). The individuation training disrupts the tendency to respond to other-race

faces categorically, a mode of responding that is positively related to implicit bias (Setoh et al., 2017).

That individuation training is especially effective when used to reduce racial bias in young children, a population for whom the bias has not had a chance to become deep-rooted, is underscored by the recent finding that the effect of such training has a lasting duration in reducing bias of up to 8 weeks (Qian et al., 2017a). The long-lasting nature of the bias reduction achieved through individuation training in children is particularly noteworthy given that bias reduction efforts in adults have not had success achieving long-term change (Lai et al., 2016). The individuation training may also have significant translational value given that it can be administered to children in countries with racial demographics that would not allow direct access to members of other-race classes.

That a majority of primary caregivers are female and own-race, and respond to their infants with positivity and reliability, may provide another developmental pathway by which positive affect becomes attached to female and own-race. Positivity and reliability are known to enhance trust (Harris & Corriveau, 2011; Lane, Wellman, & Gelman, 2013) and attachment (De Wolff & van Ijzendoorn, 1997; Sroufe et al., 2005). Given physiognomic differences between female versus male faces and own- versus other-race faces, generalization of positive characteristics from a female, own-race caregiver to other females and own-race individuals seems more likely than generalization of those characteristics to males and other-race individuals (Scherf & Scott, 2012). The positive affect attached to females and own-race individuals might also be enhanced by the contrast with the negative affect attached to males and other-race individuals as is evidenced, for example, in the heightened anxiety infants display for male and other-race strangers (Feinman, 1980; Lewis & Brooks-Gunn, 1974). That these proposed developmental pathways can be disrupted is evidenced in the finding that implicit racial bias can

be reduced in children as young as 5 years of age by the presentation of positive portrayals of other-race individuals (Gonzalez, Steele, & Baron, 2017).

Unanswered Questions

We finish by highlighting some of the questions we have about how infants respond to social categories. With regard to race, it is important to note that the participants we have reported on have generally been either Caucasians being reared in Europe or North America or Asians being reared in China. In both cases, the race of faces seen within the family will be the same race of faces seen outside the home in the broader community.

What about infants being reared in contexts where the race of faces seen in the home differs from the race of faces seen in the broader community? This would be the case for African infants being reared in an African family in Europe or North America. Would such infants be less likely to favor one's own race? There are small bits of evidence on this question, for example, the finding that African infants experiencing both Caucasian and African faces do not prefer African over Caucasian faces (Bar-Haim et al., 2006), although as noted, even when such preferences are present, they are subject to change during the course of the first year (Fassbender et al., 2016; Liu et al., 2015b; see also Singarajah et al., 2017), and hence cannot be construed as proxies for social liking. There is also the finding that Black American children do not show implicit racial bias against Whites (Newheiser & Olson, 2012), which would fit with an analysis in which the greater frequency of white faces encountered in the broader population can interfere with the greater frequency of black faces in the home. However, this analysis is confounded by socioeconomic status differences of Black and White Americans. Overall, then, we need to know more about infants reared in environments where there is not a match between the racial composition of the family home and broader community.

A second question regarding race concerns the role of language in the development of the positive=own-race linkage. We would conjecture that a majority of own-race individuals encountered by an infant are labeled with individual names, whereas a majority of other-race individuals are either labeled by category or not labeled. Such a multimodal perspective on face experience has been proposed to account for narrowing of recognition (Pascalis et al., 2014). Moreover, as described previously, data with infants indicate that individuation experience with other-race faces can prevent or undo narrowing (Anzures et al., 2012; Heron-Delaney et al., 2011) and evidence with young children indicates that individuation experience with other-race faces can reduce racial bias (Qian et al., 2017a; Xiao et al., 2015). In all of these cases of individuation training, participants learned a different label for each other-race face. Furthermore, when children were presented with other-race faces with a common label, racial bias was not reduced (Qian et al., 2017b). Given the potency of different labels in object individuation and the strength of a common label in promoting the formation of object categories (Waxman & Gelman, 2010), it may be that differential versus common labeling is a critical variable in the success of individuation versus exposure training in reducing racial bias.

With regard to gender, the vast majority of the participants we have reported on were reared with female primary caregivers. We have just a smidgeon of evidence on infants reared by male primary caregivers. For example, there was the reversal of the preference for female faces to male faces with male caregivers (Quinn et al., 2002). However, as was the case for race, a looking time advantage does not equate with social preference. The difficulty in recruiting infants with male caregivers has led some researchers to begin studying infants being reared in countries with more permissive parental leave policies such as Sweden (e.g., Rennels et al., 2017). However, even in Sweden, the majority of fathers do not take their leave until infants are older and after breast-feeding has concluded.

We also do not know in the case of gender if the individuation training or positive portrayals that have been successful in reducing implicit bias against other-race could be applied to reduce implicit bias against males. Overall, given the closer ratio of males to females (Rennels & Davis, 2008; Sugden et al., 2014), the discontinuity from infancy to childhood (at least in boys) created by same-sex friendships, the development of area-specific gender stereotypes favoring males in children as young as 6 years (Cvencek, Meltzoff, & Greenwald, 2011), and changes in face processing occurring at puberty (Picci & Scherf, 2016), the developmental course of responding to male versus female faces is likely more nuanced than that for responding to own- versus other-race faces and may require a more complex accounting.

One may also wonder how the account offered here for race and gender applies to other social categories such as age and species. As was mentioned earlier, our analysis focused on race and gender because data were available for a number of different behaviors related to these categories. Nevertheless, there are aspects of infant responding to face age and species that fit with our analysis. For example, in the case of age, infants experience over 75% adult faces relative to other-age faces (Rennels & Davis, 2008; Sugden et al., 2014), and a preference for adult over infant faces has been observed at 3.5 and 6 months (Heron-Delaney et al., 2017). In addition, younger infants (i.e., 3-month-olds) discriminate among familiar adult faces, and among less familiar infant faces, whereas older infants (i.e., 9- to 10-month-olds) continue to discriminate adult faces, but show difficulty discriminating among infant faces (Cassia, Bulf, Quadrelli, & Proietti, 2014). Also, infants between 9 and 12 months of age come to form different categories for adult, child, and infant faces (Damon, Quinn, Heron-Delaney, Lee, & Pascalis, 2016). Finally, with regard to selective learning, children favor adults over peers (Rakoczy, Hamann, Warneken, & Tomasello, 2010). Likewise, in the case of species, even 2.5-day-old infants prefer human over monkey faces (Heron-Delaney, Wirth, & Pascalis, 2011), and

infants in the age range between 3 and 9 months will display narrowing of recognition for other-species faces (i.e., monkey, sheep) relative to human faces (Pascalis, de Haan, & Nelson, 2002; Simpson, Varga, Frick, & Fragaszy, 2011). However, there are other aspects of infant responding to face age and species that fit less well with our analysis. For example, it seems unlikely that infants would disengage from infant faces and the faces of some animal species (i.e., those that become pets). In these cases, the operation of a baby schema (Borgi, Cogliati-Dezzi, Brelsford, Meints, & Cirulli, 2014) may offset any tendency to withdraw from these less frequently experienced categories.

Another question that will require further investigation is: What neural changes are associated with the development of differential responding to social categories? Investigators have reported neural correlates for the perceptual aspects of differential responding, including the decline in other-race recognition in infancy (Balas, Westerlund, Hung, & Nelson, 2011; Vogel, Monesson, & Scott, 2012). Understanding functional connectivity between brain regions has assumed increasing importance in understanding behavioral development (Nelson, 2016). In this regard, there is evidence for stronger connectivity between posterior (occipital cortex) and anterior regions (frontal cortex) in processing own-race faces relative to other-race faces with increased age (Ding, Fu, & Lee, 2014; Zhou, Liu, Ding, Fu, & Lee, 2016).

There is, however, no work of which we are aware investigating the neural correlates of the emergence of social bias in older infants and young children. Work with adults has revealed that increased connectivity between the fusiform face area and amygdala is associated with the processing of out-group faces (Molapour, Golkar, Navarette, Haaker, & Olsson, 2015). Connectivity between these areas has also been theorized to play an important role in the development of social perception (Schultz, 2005). As neuroimaging methods continue to evolve for use with younger and younger participants (Deen et al., 2017) it will be of interest to learn if

such greater connectivity can be observed in tasks measuring bias against male and other-race faces in older infants and young children.

It will also be informative to determine if computational models of learning can enrich our understanding of the development of differential responding to social categories. As mentioned earlier, a computational model learning Caucasian, African, and Asian faces in an 8:1:1 ratio (Balas & Quinn, 2015) displayed evidence of forming an "other" category inclusive of multiple classes of other-race faces. In addition, our interpretation of narrowing of recognition based on face race has been enhanced by computational work showing that predominant exposure to variation within and among own-race faces that increases recognition of faces from within one's own race does not apply well to recognizing other-race faces (Balas, 2012). However, computational work on the learning of implicit race and gender bias is completely lacking, even in adults, although computational frameworks for understanding implicit bias have been proposed (Huebner, 2016).

It would further be of interest if more could be revealed about the developmental relation between the processing of emotion and differential responding to social categories (Quinn et al., 2011). For many years, it was commonly believed that processing of facial identities and categories (e.g., race) operated independently from the processing of facial expressions of emotion (e.g., Bruce & Young, 1986). However, subsequent behavioral studies have demonstrated interaction of these dimensions. In one pertinent study in adults, changing other-race faces so that they depicted angry instead of neutral expressions improved recognition of those faces (Ackerman et al., 2006). As noted by Hugenberg et al. (2011), "facial expressions…can create the motive to individuate cross-race faces" (p. 252). This interpretation is consistent with recent arguments that facial expressions function as communicative signals (Jack et al., 2014), but we do not know of comparable developmental work investigating whether, for example, facial expressions can affect perceptual

narrowing. Positive findings would be theoretically important in suggesting that not only does perceptual processing of faces have social consequences (as we have contended in much of this article), but also that social processing of faces can have perceptual consequences.

However the questions raised in this concluding section are to be resolved, the findings reviewed here indicate that differential experience with own- versus other-race faces and female versus male faces affects perceptual operations (visual preference, recognition, and scanning) as well as more cognitive and social processes (category formation, selective learning, and association with positive versus negative emotion or valence). The existing evidence thus points to a model of social category development in which perceptual-cognitive and social-emotional mechanisms conjoin in infancy and provide a foundation for the intergroup behaviors observed in children and adults.

References

Ackerman, J. M., Shapiro, J. R., Neuberg, S. L., Kenrick, D. T., Becker, D. V., Griskevicius, V.,…Schaller, M. (2006). They all look the same to me (unless they're angry): From outgroup homogeneity to outgroup heterogeneity. *Psychological Science, 17,* 836-840.

Anzures, G., Quinn, P. C., Pascalis, O., Slater, A. M., & Lee, K. (2010). Categorization, categorical perception, and asymmetry in infants' representation of face race. *Developmental Science*, *13,* 553-564.

Anzures, G., Wheeler, A., Quinn, P. C., Pascalis, O., Slater, A. M., Heron-Delaney, M., Tanaka, J. W., & Lee, K. (2012). Brief daily exposures to Asian females reverses perceptual narrowing for Asian faces in Caucasian infants. *Journal of Experimental Child Psychology*, *112,* 484-495.

Aslin, R. N. (1981). Experiential influences and sensitive periods in perceptual development: A unified model. In R. N. Aslin, J. R. Alberts, & M. R. Petersen (Eds.), *Development of perception: Psychobiological perspectives* (Vol. 2, pp. 45-93). New York: Academic Press.

Balas, B. (2012). Bayesian face recognition and perceptual narrowing in face-space. *Developmental Science*, *15,* 579-588.

Balas, B., & Quinn, P. C. (2015, March). Simulating classification of face race by infants: Similarities and differences between model and infant looking performance. In L. Scott (Organizer), *General and specific influences on learning in infancy*. Symposium conducted at the meeting of the Society for Research in Child Development, Philadelphia, PA.

Balas, B., Westerlund, A., Hung, K., & Nelson, C. A. III. (2011). Shape, color and the other-race effect in the infant brain. *Developmental Science, 14,* 892-900.

Banaji, M. R., & Greenwald, A. G. (2013). *Blindspot: The hidden biases of good people.* New York: Delacorte Press.

Bar-Haim, Y., Ziv, T., Lamy, D., & Hodes, R. M. (2006). Nature and nurture in own-race face processing. *Psychological Science, 17,* 159-163.

Batres, C., Kannan, M., & Perrett, D. I. (2017). Familiarity with own population's appearance influences facial preferences. *Human Nature, 28,* 344-354.

Bayet, L., Pascalis, O., Quinn, P. C., Lee, K., Gentaz, E., & Tanaka, J. W. (2015a) Angry facial expressions bias gender categorization in children and adults: behavioral and computational evidence. *Frontiers in Psychology, 6*: 346. doi:10.3389/fpsyg.2015.00346

Bayet, L., Quinn, P. C., Tanaka, J. W., Lee, K., Gentaz, E., & Pascalis, O. (2015b). Face gender influences the looking preference for smiling expressions in 3.5-month-old human infants. *PLoS ONE, 10*(6): e0129812. doi:10.1371/journal.pone.0129812

Bigler, R., & Liben, L. S. (2007). Developmental intergroup theory: Explaining and reducing children's stereotyping and prejudice. *Current Directions in Psychological Science, 16,* 162-166.

Borgi, M., Cogliati-Dezza, I., Brelsford, V., Meints, K., & Cirulli, F. (2014). Baby schema in human and animal faces induces cuteness perception and gaze allocation in children. *Frontiers in Psychology, 5,* 411.

Brooks-Gunn, J., & Lewis, M. (1981). Infant social perception: responses to pictures of parents and strangers. *Developmental Psychology, 17,* 647-649.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*, 305–327.

Burns, M. P., & Sommerville, J. (2014). "I pick you": The impact of fairness and race on infants' selection of social partners. *Frontiers in Psychology, 5,* 93. doi:10.3389/fpsyg.2014.00093

Buttelmann, D., Zmyj, N., Daum, M., & Carpenter, M. (2013). Selective imitation of in-group over out-group members in 14-month-old infants. *Child Development, 84,* 422-428.

Cacioppo, J. T., Gardner, W. L., & Berntson, G. G. (1999). The affect system has parallel and integrative processing components: Form follows function. *Journal of Personality and Social Psychology, 76,* 839-855.

Carr, E., Brady, T. F., & Winkielman, P. (2017). Are you smiling or have I seen you before? Familiarity makes faces look happier. *Psychological Science, 28,* 1087-1102.

Cassia, V. M., Bulf, H., Quadrelli, E., & Proietti, V. (2014). Age-related face processing bias in infancy: Evidence of perceptual narrowing for adult faces. *Developmental Psychobiology, 56,* 238-248.

Cassia, V. M., Turati, C., & Simion, F. (2004). Can a nonspecific bias toward top-heavy patterns explain newborns' face preference? *Psychological Science, 15,* 379-383.

Chen, E. E., Corriveau, K. H., & Harris, P. L. (2013). Children lose trust in a consensus composed of outgroup members--but do not retain that trust. *Child Development, 84,* 269-282

Cohen, L. B., & Cashon, C. (2001). Do 7-month-old infants process independent features or facial configurations. *Infant and Child Development, 10,* 83-92.

Cohen, L. B., & Younger, B. A. (1983). Perceptual categorization in the infant. In E. Scholnick (Ed.), *New trends in conceptual representation* (pp. 197-220). Hillsdale, NJ: Erlbaum.

Cordes, S., & Brannon, E. M. (2009). The relative salience of discrete and continuous quantity in young infants. *Developmental Science, 12,* 453-463.

Corriveau, K., & Harris, P. L. (2009). Choosing your informant: weighing familiarity and recent accuracy. *Developmental Science, 12,* 426-437.

Cvencek, D., Greenwald, A. G., & Meltzoff, A. N. (2011). Measuring implicit attitudes of 4-year-olds: The Preschool Implicit Association Test. *Journal of Experimental Child Psychology, 109,* 187-200.

Cvencek, D., Meltzoff, A. N., & Greenwald, A. G. (2011). Math-gender stereotypes in elementary school children. *Child Development, 82,* 766-779.

Damon, F., Quinn, P. C., Heron-Delaney, M., Lee, K., & Pascalis, O. (2016). Development of category formation for faces differing by age in 9- to 12-month-olds: An effect of experience with infant faces. *British Journal of Developmental Psychology*, *34,* 582-597.

Deen, B., Richardson, H., Dilks, D. D., Takahashi, A., Keil, B., Wald, L. L., Kanwisher, N., & Saxe, R. (2017). Organization of high-level visual cortex in human infants. *Nature Communications*, *8*:13995.

De Wolff, M. S., & van Ijzendoorn, M. H. (1997). Sensitivity and attachment: a meta-analysis of antecedents of infant attachment. *Child Development, 68,* 571-591.

Ding, X. P., Fu, G., & Lee, K. (2014). Neural correlates of own-and other-race face recognition in children: a functional near-infrared spectroscopy study. *Neuroimage, 85,* 335-344.

Dobson, V., & Teller, D. Y. (1978). Visual acuity in human infants: a review and comparison of electrophysiological and behavioral studies. *Vision Research, 18,* 1469-1483.

Dotsch, R., Hassin, R. R., & Todorov, A. (2016). Statistical learning shapes face evaluation. *Nature Human Behaviour, 1*, 0001.

Dunham, Y., Baron, A. S., & Banaji, M. (2016). The development of implicit gender attitudes. *Developmental Science, 19,* 781-789.

Eagly, A. H., Miadinic, A., & Otto, S. (1991). Are women evaluated more favorably than men? *Psychology of Women Quarterly, 15*, 203-216.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science, 164,* 668-670.

Farkas, L. G., Forrest, C. R., & Litsas, L. (2000). Revision of neoclassical facial canons in young adult Afro-Americans. *Aesthetic Plastic Surgery, 24,* 179-184.

Fassbender, I., Teubert, M., & Lohaus, A. (2016). The development of preferences for own-race versus other-race faces in 3-, 6- and 9-month-old Caucasian infants. *European Journal of Developmental Psychology, 13,* 152-165.

Feinman, S. (1980). Infant response to race, size, proximity, and movement of strangers. *Infant Behavior and Development, 3,* 187-204.

Ferguson, K. T., Kulkofsky, S., Cashon, C. H., & Casasola, M. (2009). The development of specialized processing of own-race faces in infancy. *Infancy, 14,* 263-284.

Fodor, J. A. (1972). Some reflections on L. S. Vygotsky's "Thought and Language." *Cognition, 1,* 83-95.

Gauthier, I., & Nelson, C. A. (2001). The development of face expertise. *Current Opinion in Neurobiology, 11,* 219-224.

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

Gonzalez, A. M., Steele, J. R., & Baron, A. S. (2017). Reducing children's implicit racial bias through exposure to positive out-group exemplars. *Child Development, 88,* 123-130.

Gottlieb, G. (1981). Roles of early experience in species-specific perceptual development. In R. N. Aslin, J. R. Alberts, & M. R. Petersen (Eds.), *Development of perception: Psychobiological perspectives* (Vol. 1, pp. 5-44). New York: Academic Press.

Gredeback, G., Eriksson, M., Schmitow, C., Laeng, B., & Stenberg, G. (2012). Individual differences in face processing: Infants' scanning patterns and pupil dilations are influenced by the distribution of parental leave. *Infancy, 17,* 79-101.

Hadley, H., Rost, G. C., Fava, E., & Scott, L. S. (2014). A mechanistic approach to understanding cross-domain perceptual narrowing in the first year of life. *Brain Sciences, 4,* 613-634.

Hadley, H., Pickron, C., & Scott, L. S. (2015). The lasting effects of process-specific versus stimulus-specific learning during infancy. *Developmental Science, 18,* 842-852.

Harnad, S. (Ed.). (1987). *Categorical perception*: *The groundwork of cognition.* New York: Cambridge University Press.

Harris, P. L., & Corriveau, K. H. (2011). Young children's selective trust in informants. *Philosophical Transactions of the Royal Society B, 366,* 1179-1187.

Hayden, A., Bhatt, R. S., Zieber, N., & Kangas, A. (2009). Race-based perceptual asymmetries underlying face processing in infancy. *Psychonomic Bulletin & Review, 16,* 270-275.

Hebb, D. O. (1949). *The organization of behavior*. New York: Wiley.

Herlitz, A., & Loven, J. (2013). Sex differences and the own-gender bias in face recognition: A meta-analytic review. *Visual Cognition, 21,* 1306-1336.

Heron-Delaney, M., Anzures, G., Herbert, J. S., Quinn, P. C., Slater, A. M., Tanaka, J. W., Lee, K., & Pascalis, O. (2011). Perceptual training prevents the emergence of the other race effect during infancy. *PLoS ONE*, *6*(5): e19858.

Heron-Delaney, M., Damon, F., Quinn, P. C., Meary, D., Xiao, N. G., Lee, K., & Pascalis, O. (2017). An adult face bias in infants that is modulated by face race. *International Journal of Behavioral Development, 41,* 581-587.

Heron-Delaney, M., Wirth, S., & Pascalis, O. (2011). Infants' knowledge of their own species. *Philosophical Transactions of the Royal Society B: Biological Sciences, 366,* 1753-1763.

Hillairet de Boisferon, A., Uttley, L., Quinn, P. C., Lee, K., & Pascalis, O. (2014). Female face preference in 4-month-olds: The importance of hairline. *Infant Behavior & Development, 37,* 676-681.

Hirshberg, L. M., & Svejda, M. (1990). When infants look to their parents: I. Infants' social referencing of mothers compared to fathers. *Child Development, 61,* 1175-1186.

Huebner, B. (2016). Implicit bias, reinforcement learning, and scaffolded moral cognition. In M. Brownstein & J. Saul (Eds.), *Implicit bias & philosophy: Volume I, metaphysics and epistemology* (pp. 47-79). Oxford: Oxford University Press.

Hugenberg, K., Young, S. G., Sacco, D. F., & Bernstein, M. J. (2011). Social categorization influences face perception and face memory. In A. J. Calder, G. Rhodes, M. H. Johnson, & J. V. Haxby (Eds.), *The Oxford handbook of face perception* (pp. 245-261). Oxford, UK: Oxford University Press.

Hull, C. L. (1920). Quantitative aspects of the evolution of concepts. *Psychological Monographs, XXVIII.*

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 5, pp. 69-95). Norwood, NJ: Ablex.

Jack, R. E., Garrod, O. G. B., & Schyns, P. G. (2014). Dynamic facial expressions of emotion transmit an evolving hierarchy of signals over time. *Current Biology, 24,* 187-192.

Johnson, M. H., Senju, A., & Tomalski, P. (2015). The two process theory of face processing: modifications based on two decades of data from infants and adults. *Neuroscience & Biobehavioral Reviews, 50,* 169-179.

Johnson, K., Caskey, M., Rand, B. A., Tucker, R., & Vohr, B. (2014). Gender differences in adult-infant communication in the first months of life. *Pediatrics, 134,* 1-8.

Kagan, J. (2008). In defense of qualitative changes in development. *Child Development, 79,* 1606-1624.

Kelly, D. J., Liu, S., Ge, L., Quinn, P. C., Slater, A. M., Lee, K., Liu, Q., & Pascalis, O. (2007a). Cross-race preferences for same-race faces extend beyond the African versus Caucasian contrast in 3-month-old infants. *Infancy, 11,* 87-95.

Kelly, D. J., Liu, S., Lee, K., Quinn, P. C., Pascalis, O., Slater, A. M., & Ge, L. (2009). Development of the other-race effect in infancy: Evidence towards universality? *Journal of Experimental Child Psychology, 104,* 105-114.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Gibson, A., Smith, M., Ge, L., & Pascalis, O. (2005). FAST TRACK REPORT: Three-month-olds, but not newborns, prefer own-race faces. *Developmental Science, 8,* F31-F36.

Kelly, D. J., Quinn, P. C., Slater, A. M., Lee, K., Ge, L., & Pascalis, O. (2007b). The other-race effect develops during infancy: Evidence of perceptual narrowing. *Psychological Science, 18,* 1084-1089.

Kirkham, N. Z., Slemmer, J. A., & Johnson, S. P. (2002). Visual statistical learning in infancy. *Cognition, 83,* B35-42.

Kim, H. I., Johnson, K. L., & Johnson, S. P. (2015). Gendered race: are infants' face preferences guided by the intersectionality of sex and race? *Frontiers in Psychology, 6*: 1330.

Lai, C. K., Skinner, A. L., Cooley, E., Murrar, S., Brauer, M., Devos, T., . . . Nosek, B. A. (2016). Reducing implicit racial preferences: II. Intervention effectiveness across time. *Journal of Experimental Psychology: General, 145,* 1001–1016.

Lane, J. D., Wellman, H. M., & Gelman, S. A. (2013). Informants' traits weigh heavily in young children's trust in testimony and in their epistemic inferences. *Child Development, 84,* 1253-1268.

Lauer, J. E., & Lourenco, S. F. (2016). Spatial processing in infancy predicts both spatial and mathematical aptitude in childhood. *Psychological Science, 27,* 1291-1298.

Le, T. T., Farkas, L. G., Ngim, R. C. K., Levin, L. S., & Forrest, C. R. (2002). Proportionality in Asian and North American Caucasian faces using neoclassical facial canons as criteria. *Aesthetic Plastic Surgery, 26,* 64-69.

Leach, E. (1964). Anthropological aspects of language: Animal categories and verbal abuse. In E. H. Lenneberg (Ed.), *New directions in the study of language* (pp. 23-63). Cambridge, MA: MIT Press.

Lebrecht, S., Pierce, L. J., Tarr, M. J., & Tanaka, J. W. (2009). Perceptual other-race training reduces implicit racial bias. *PLoS ONE, 4,* e4215. doi:10.1371/journal.pone.0004215

Leinbach, M. D., & Fagot, B. I. (1993). Categorical habituation to male and female faces: Gender schematic processing in infancy. *Infant Behavior and Development, 16,* 317-332.

Leo, I., & Simion, F. (2009). Face processing at birth: a Thatcher illusion study. *Developmental Science, 12,* 492-498.

Lewis, M. (2016). The emergence of human emotions. In L. F. Barrett, M. Lewis, & J. M. H. Jones (Eds.), *Handbook of emotions*, 4th ed. (pp. 272-292). New York: Guilford.

Lewis, M., & Brooks-Gunn, J. (1974). Self, other, and fear: Infants' reactions to people. In M. Lewis & L. A. Rosenblum (Eds.), *The origins of fear* (pp. 195-227). New York: Wiley.

Liberman, Z., Woodward, A. L., & Kinzler, K. D. (2017). The origins of social categorization. *Trends in Cognitive Sciences, 21,* 556-568.

Liu, S., Quinn, P. C., Wheeler, A., Xiao, N., Ge, L., & Lee, K. (2011). Similarity and difference in the processing of same- and other-race faces as revealed by eye-tracking in 4- to 9-month-old infants. *Journal of Experimental Child Psychology, 108,* 180-189.

Liu, S., Xiao, N. G., Quinn, P. C., Zhu, D., Ge, L., Pascalis, O., & Lee, K. (2015a). Asian infants show preference for own-race but not other-race female faces: The role of infant caregiving arrangements. *Frontiers in Psychology, 6*:593. doi: 10.3389/fpsyg.2015.00593

Liu, S., Xiao, W. S., Xiao, N. G., Quinn, P. C., Zhang, Y., Chen, H., Ge, L., Pascalis, O., & Lee, K. (2015b). Development of visual preference for own- versus other-race faces in infancy. *Developmental Psychology, 51,* 500-511.

Malatesta, C. Z., & Haviland, J. M. (1982). Learning display rules: The socialization of emotion expression in infancy. *Child Development, 53,* 991-1003.

Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child Development, 47,* 523-527.

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

Mervis, C. B., & Rosch, E. (1981). Categorization of natural objects. *Annual Review of Psychology, 32,* 89-115.

Molapour, T., Golkar, A., Navarrete, C. D., Haaker, J., & Olsson, A. (2015). Neural correlates of biased social fear learning. *Neuroimage, 121,* 171-183.

Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: a two-process theory of infant face recognition. *Psychological Review, 98,* 164-181.

Nakabayashi, K., & Liu, C. H. (2014). Development of holistic vs. featural processing in face recognition. *Frontiers in Human Neuroscience, 8,* 831.

Nelson, C. A. (2016). Introduction to special issue on the role of connectivity in developmental disorders: Genetic and neural network approaches. *Developmental Science, 19,* 523.

Newheiser, A. K., & Olson, K. R. (2012). White and black American children's implicit intergroup bias. *Journal of Experimental Social Psychology, 48,* 264-270.

Nosek, B. A., & Banaji, M. (2001). The go/no-go association task. *Social Cognition, 19,* 625-664.

Pascalis, O., de Haan, M., & Nelson, C. A. (2002). Is face processing species-specific during the first year of life. *Science, 296,* 1321-1323.

Pascalis, O., & de Schonen, S. (1994). Recognition memory in 3- to 4-day-old human neonates. *Neuroreport, 5,* 1721-1724.

Pascalis, O., Loevenbruck, H., Quinn, P. C., Kandel, S., Tanaka, J. W., & Lee, K. (2014). On the linkage between face processing, language processing, and narrowing during development. *Child Development Perspectives*, *8*, 65-70.

Piaget, J. (1952). *The origins of intelligence in children*. New York: Norton.

Picci, G., & Scherf, K. S. (2016). From caregivers to peers: Puberty shapes human face perception. *Psychological Science*, *27,* 1461-1473.

Pickron, C. B., Fava, E., & Scott, L. S. (2017), Follow my gaze: Face race and sex influence gaze-cued attention in infancy. *Infancy*, *22,* 626-644.

Pun, A., Birch, S. A. J., & Baron, A. S. (2016). Infants use relative numerical group size to infer social dominance. *Proceedings of the National Academy of Sciences of the United States of America*, *113,* 2376-2381.

Qian, M., Quinn, P. C., Heyman, G. D., Pascalis, O., Fu, G., & Lee, K. (2017a). A long-term effect of perceptual individuation training on reducing implicit racial bias in preschool children. *Child Development*. doi: 10.1111/cdev.12971 [Epub ahead of print]

Qian, M. K., Heyman, G. D., Quinn, P. C., Messi, F. A., Fu, G., & Lee, K. (2016). Implicit racial biases in preschool children and adults from Asia and Africa. *Child Development*, *87,* 285-296.

Qian, M., Quinn, P. C., Heyman, G. D., Pascalis, O., Fu, G., & Lee, K. (2017b). Perceptual individuation training (but not mere exposure) reduces implicit racial bias in preschool children. *Developmental Psychology*, *53,* 845-859.

Quinn, P. C. (2002). Beyond prototypes: Asymmetries in infant categorization and what they teach us about the mechanisms guiding early knowledge acquisition. In R. Kail & H. Reese (Eds.), *Advances in child development and behavior* (Vol. 29, pp. 161-193). San Diego: Academic Press.

Quinn, P. C. (2010). The acquisition of expertise as a model for the growth of cognitive structure. In S. P. Johnson (Ed.), *Neoconstructivism: The new science of cognitive development* (pp. 252-273). New York: Oxford University Press.

Quinn, P. C. (2011). Born to categorize. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development,* 2nd ed. (pp. 129-152). Oxford, UK: Wiley-Blackwell.

Quinn, P. C., Anzures, G., Izard, C. E., Lee, K., Pascalis, O., Slater, A. M., & Tanaka, J. W. (2011). Looking across domains to understand infant representation of emotion. *Emotion Review* (Special section on Infant Emotional Development), *3,* 197-206.

Quinn, P. C., Conforto, A., Lee, K., O'Toole, A. J., Pascalis, O., & Slater, A. M. (2010). Infant preference for women's faces extends to girl prototype faces. *Infant Behavior & Development, 33,* 357-360.

Quinn, P. C., Eimas, P. D., & Rosenkrantz, S. L. (1993). Evidence for representations of perceptually similar natural categories by 3- and 4-month-old infants. *Perception, 22,* 463-475.

Quinn, P. C., Lee, K., Pascalis, O., & Tanaka, J. W. (2016). Narrowing in categorical responding to other-race face classes by infants. *Developmental Science, 19,* 362-371.

Quinn, P. C., & Slater, A. (2003). Face perception at birth and beyond. In O. Pascalis & A. Slater (Eds.), *The development of face processing in infancy and early childhood: Current perspectives* (pp. 3-11). Huntington, NY: Nova Science Publishers.

Quinn, P. C., Tanaka, J. W., Lee, K., Pascalis, O., & Slater, A. M. (2013). Are faces special to infants? An investigation of configural and featural processing for the upper and lower regions of houses in 3- to 7-month-olds. *Visual Cognition, 21,* 23-37.

Quinn, P. C., Uttley, L., Lee, K., Gibson, A., Smith, M., Slater, A. M., & Pascalis, O. (2008). Infant preference for female faces occurs for same- but not other-race faces. *Journal of Neuropsychology* (Special Issue on Face Processing), *2,* 15-26.

Quinn, P. C., Yahr, J., Kuhn, A., Slater, A. M., & Pascalis, O. (2002). Representation of the gender of human faces by infants: A preference for female. *Perception, 31,* 1109-1121.

Rakoczy, H., Hamann, K., Warneken, F., & Tomasello, M. (2010). Bigger knows better: Young children selectively learn rule games from adults rather than from peers. *British Journal of Developmental Psychology, 28,* 785-798.

Reber, R., Winkielman, P., & Schwarz, N. (1998). Effects of perceptual fluency on affective judgments. *Psychological Science, 9,* 45-48.

Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017). The human fetus preferentially engages with facelike stimuli. *Current Biology, 27,* 825-828.

Rennels, J. L., & Davis, R. E. (2008). Facial experience during the first year. *Infant Behavior & Development, 31,* 665-678.

Rennels, J. L., Juvrud, J., Kayl, A. J., Asperhold, M., Gredeback, G., & Herlitz, A. (2017). Caregiving experience and its relation to perceptual narrowing of face gender. *Developmental Psychology, 53,* 1437-1446.

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

Rule, N. O. (2017). Introduction to the special issue on face perception. *Current Directions in Psychological Science, 26,* 211.

Sangrigoli, S., & de Schonen, S. (2004). Effect of visual experience on face processing: A developmental study of inversion and non-native effects. *Developmental Science, 7,* 74-87.

Scherf, K. S. & Scott, L. S. (2012). Connecting developmental trajectories: Biases in face processing from infancy to adulthood. *Developmental Psychobiology, 54,* 643-663.

Schultz, R. T. (2005). Developmental deficits in social perception in autism: The role of the amygdala and fusiform face area. *International Journal of Developmental Neuroscience*, *23*, 125-141.

Setoh, P., Lee, K. J. J., Zhang, L., Qian, M. K., Quinn, P. C., Heyman, G. D., & Lee, K. (2017). Racial categorization predicts implicit racial bias in preschool children. *Child Development*. doi: 10.1111/cdev.12851 [Epub ahead of print]

Shutts, K. (2015). Young children's preferences: Gender, race, and social status. *Child Development Perspectives, 9,* 262-266.

Simion, F., & Di Giorgio, E. (2015). Face perception and processing in early infancy: Inborn predispositions and developmental changes. *Frontiers in Psychology, 6,* 959.

Simpson, E. A., Varga, K., Frick, J. E., & Fragaszy, D. M. (2011). Infants experience perceptual narrowing for nonprimate faces. *Infancy, 16,* 318-330.

Singarajah, A., Chanley, J., Gutierrez, Y., Cordon, Y., Nguyen, B., Burakowski, L., & Johnson, S. P. (2017). Infant attention to same- and other-race faces. *Cognition, 159,* 76-84.

Sroufe, L. A., Egeland, B., Carlson, E., & Collins, W. A. (2005). *The development of the person: The Minnesota study of risk and adaptation from birth to adulthood*. New York: Guilford.

Stenberg, G. (2012). Why do infants look at and use positive information from some informants rather than others in ambiguous situations? *Infancy, 17,* 642-671.

Sugden, N. A., & Marquis, A. R. (2017). Meta-analytic review of the development of face discrimination in infancy: Face race, face gender, infant age, and methodology moderate face discrimination. *Psychological Bulletin, 143,* 1201-1244.

Sugden, N. A., Mohamed-Ali, M. I., & Moulson, M. C. (2014). I spy with my little eye: Typical, daily exposure to faces documented from a first-person infant perspective. *Developmental Psychobiology, 56,* 249-261.

Tanaka, J. W. (2001). The entry point of face recognition: Evidence for face expertise. *Journal of Experimental Psychology: General*, 130, 534-543.

Tham, D. S. Y., Bremner, J. G., & Hay, D. (2015). In infancy the timing of emergence of the other-race effect is dependent on face gender. *Infant Behavior & Development, 40*, 131-138.

Thoermer, C., Sodian, B., Vuori, M., Perst, H., & Kristen, S. (2011). Continuity from an implicit to explicit understanding of false belief from infancy to preschool age. *British Journal of Developmental Psychology, 30,* 172-187.

Timeo, S., Farroni, T., & Maass, A. (2017). Race and color: Two sides of one story? Development of biases in categorical perception. *Child Development, 88,* 83-102.

Tummeltshammer, K. S., Wu, R., Sobel, D. M., & Kirkham, N. Z. (2014). Infants track the reliability of potential informants. *Psychological Science, 25,* 1730-1739.

Valentine, T., & Endo, M (1992). Towards an exemplar model of face processing: The effects of race and distinctiveness. *The Quarterly Journal of Experimental Psychology, 44A,* 671-703.

Vogel, M., Monesson, A., & Scott, L. S. (2012). Building biases in infancy: The influence of race on face and voice emotion matching. *Developmental Science, 15,* 359-372.

Walker, P., Bremner, J. G., Mason, U., Spring, J., Mattock, K., Slater, A., & Johnson, S. P. (2010). Preverbal infants' sensitivity to synaesthetic cross-modality correspondences. *Psychological Science, 21,* 21–25.

Waxman, S. R., & Gelman, S. (2010). Different kinds of concepts and different kinds of words: What words do for human cognition. In: D. Mareschal, P. C. Quinn, & S. E. G. Lea (Eds.), *The making of human concepts* (pp. 101–130). Oxford, NY: Oxford University Press.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development, 7,* 49-63.

Xiao, N. G., Quinn, P. C., Liu, S., Ge, L., Pascalis, O., & Lee, K. (2017a). Older but not younger infants associate own-race faces with happy music and other-race faces with sad music. *Developmental Science*.

Xiao, N. G., Wu, R., Quinn, P. C., Liu, S., Tummeltshammer, K. S., Kirkham, N., Ge, L., Pascalis, O., & Lee, K. (2017b). Infants rely more on gaze cues from own-race than other-race adults for learning under uncertainty. *Child Development*.

Xiao, W. S., Fu, G., Quinn, P. C., Qin, J., Tanaka, J., Pascalis, O., & Lee, K. (2015). Individuation training with other-race faces reduces preschoolers' implicit racial bias: A link between perceptual and social representation of faces in children. *Developmental Science*, *18,* 655-663.

Xiao, W. S., Quinn, P. C., Pascalis, O., & Lee, K. (2014). Own- and other-race face scanning in infants: Implications for perceptual narrowing. *Developmental Psychobiology* (Special Issue on Perceptual Narrowing), *56,* 262-273.

Yamaguchi, M., Kuhlmeier, V. A., Wynn, K., & vanMarle, K. (2009). Continuity in social cognition from infancy to childhood. *Developmental Science, 12,* 746-752.

Zajonc, R. B. (1968) Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9,* 1-27.

Zhou, G., Liu, J., Ding, X. P., Fu, G., & Lee, K. (2016). Development of effective connectivity during own- and other-race face processing: A Granger causality analysis. *Frontiers in Human Neuroscience, 10,* 474.