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Infants' experience-dependent processing of male and female faces: Insights from eye tracking and event-related potentials

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ABSTRACT

The goal of the present study was to investigate infants' processing of female and male faces. We used an event-related potential (ERP) priming task, as well as a visual-paired comparison (VPC) eye tracking task to explore how 7-month-old "female expert" infants differed in their responses to faces of different genders. Female faces elicited larger N290 amplitudes than male faces. Furthermore, infants showed a priming effect for female faces only, whereby the N290 was significantly more negative for novel females compared to primed female faces. The VPC experiment was designed to test whether infants could reliably discriminate between two female and two male faces. Analyses showed that infants were able to differentiate faces of both genders.

The results of the present study suggest that 7-month olds with a large amount of female face experience show a processing advantage for forming a neural representation of female faces, compared to male faces. However, the enhanced neural sensitivity to the repetition of female faces is not due to the infants' inability to discriminate male faces. Instead, the combination of results from the two tasks suggests that the differential processing for female faces may be a signature of expert-level processing.

1. Introduction

Faces are ubiquitous stimuli in our social world, and are particularly salient for infants. Indeed, even newborn infants show a preference for faces and face-like stimuli, compared to other visual objects (Johnson & Morton, 1991; Maurer, 1983; Mondloch et al., 1999; Valenza et al., 1996). Infants' intrinsic preference for face-like stimuli and the pervasiveness of faces in infants' visual environment contributes to a rapid development of face processing abilities over the first few months of life. For example, work by Barrera and Maurer (1981) showed that starting at around 3

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months of age infants are able to distinguish their mother's face from that of another woman in photographs, and are also able to reliably discriminate female faces that are unfamiliar to them.

Around this same age, infants also begin to show the ability to create distinct face categories along different dimensions. Quinn et al. (2002) tested 3 to 4 month old infants using behavioral looking paradigms to examine whether young infants could categorize faces according to the gender of the face. These authors were also interested in whether the experiences accrued with faces influenced infants' behavior, and for this they tested infants who were reared primarily with female or male caregivers. They found that female-reared infants showed a spontaneous preference for female faces, while male-reared infants showed a spontaneous preference for male faces. Analogous to their gender preference, infants as young as 3 months show a preference for faces that belong to the racial/ethnic group that they see most often (Bar-Haim et al., 2006; Kelly et al., 2005). Taken together, these findings show that by 3 months of age infants are already relying on experience with the visual environment to shape their behavior and to form basic categories along different dimensions of face-specific features.

Extensive experience with a specific category of faces also helps infants develop better discrimination abilities for individuals within the same category (Quinn et al., 2002; Scott & Monesson, 2009). Quinn et al. (2002) familiarized 3 to 4 month old "female expert" infants with either a female face or a male face. Successively they tested them with a pair of faces, either females or males, which contained the previously familiarized face and a novel face. They found that these infants showed a significant novelty preference when tested with female faces, but not with male faces, suggesting that they were able to discriminate between female faces, but not between male faces.

The influence of experience on face processing is present throughout the life-span, and gives rise to both behavioral and neural effects. There is an extensive literature documenting differences in the accuracy of identity recognition when adult observers are presented with faces belonging to a racial/ethnic group with which they have little visual experience. For example, observers are better at discriminating between members of the category with which they are more familiar (e.g., Sporer, 2001). Recent studies using event-related potentials (ERP) have also shown that differential experience with face categories produces category-sensitive neural signatures in adults (Balas & Nelson, 2010; Caldara et al., 2003; Stahl et al., 2008; Tanaka & Pierce, 2009).

Despite a relatively extensive literature on the behavioral manifestations of experience in infants (see Pascalis et al., 2005 for a review), less is known about its influence on the neural correlates of face processing. Based on the findings from the adult literature, and the similarities in behavioral effects observed across development, one might predict that in infants, extensive experience with a specific category of faces would produce specific neural signatures in response to the category of expertise. The goal of the present study is to further investigate experience-dependent neural and behavioral responses in the context of face gender in infants using ERPs and a preferential looking paradigm.

With regard to the processing of faces, there are several relevant components that have been identified in infants: the N290, the P400, the Negative Component (NC), and the Positive Slow Wave (PSW). The N290 is a negative component most prominent over posterior electrodes. This component shows an enhanced response to faces starting in infants as young as 3 months (Halit et al., 2004), and by 12 months of age shows a differential response to upright and inverted faces (Halit et al., 2004). The P400 is a positive component strongest over posterior electrodes that shows faster latencies to faces than objects in infants as young as 6 months of age (de Haan & Nelson, 1999). Moreover, this component shows amplitude modulations in response to the picture-plane inversion of faces in infants as young as 3 months of age (de Haan et al., 2002; Halit et al., 2004). The NC is a negative deflection strongest over fronto-central electrodes. With regard to face processing, the NC has been related to the allocation of attention, and it has been shown to differentially respond to an infant's own mother's face, compared to a stranger's face in infants as young as 6 months of age (de Haan & Nelson, 1997). Finally, the PSW is observed over posterior electrodes, and has been associated with the process of creating and updating perceptual representations of faces (de Haan & Nelson, 1999), and it is found in infants as young as 3 months of age.

One might expect that all of the ERP components discussed above may show some degree of experience-dependent modulations based on the behavioral effects observed in infants, but little is known about these changes. One of the few studies that investigated the impact of experience on infants' neural responses was carried out by Moulson et al. (2011). These authors examined the role of experience with a 3-D model of a female face in 3 month olds. They tested infants who either received 1 month of in-home familiarization with a model, or a 1.5-minute in-lab familiarization with a model. During the experiment, the infants were shown pictures of either the model they were familiar with, or a different 3-D model while ERPs were recorded. Moulson et al. (2011) found that infants who were familiarized with a model for a 1 month period showed larger P400 amplitude and a more negative NC to the familiar stimulus compared to the novel stimulus, while the infants who were introduced to a model only during their in-lab visit showed the opposite pattern. These results are consistent with the notion that neural responses are sensitive to experience from an early age.

In another recent study, experience-dependent effects have also been shown at the category-level in infants. Balas et al. (2011) used ERP to test infants' neural responses to faces of either their own race or a different race. These authors tested 9 month-old Caucasian infants using Caucasian and African faces, and found that these infants, who had experience primarily with Caucasian faces, produced a significantly larger N290 in response to Caucasian faces, compared to African faces.

The results of the studies discussed above provide evidence for experience-dependent modulation of neural responses from an early age. However, it has yet to be