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Brief report

Holistic processing in mother's face perception for infants

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ABSTRACT

In this study, we created composite faces using mothers' faces to examine holistic face processing in infants aged 5–8 months. The composite-face effect occurred only in infants aged 7–8 months, suggesting that infants older than 7 months are able to process familiar faces holistically.

Infants' recognition of their mothers' faces is important in the development of their social communication. Several studies on face perception have demonstrated that infants discriminated between their mothers' faces and those of strangers (Barrera & Maurer, 1981; Bushnell, 1982). Even newborns preferred their mother's face over strangers' faces (Bushnell, 2001; Bushnell, Sal, & Mulhn, 1989; Pascalis, de Schonen, Morton, Deruelle, & Fabre-Grenet, 1995). As shown in behavioral studies involving infants, studies using event-related potentials (ERP) (de Haan & Nelson, 1997) and near-infrared spectroscopy (Nakato et al., 2011) revealed that brain activation differed according to whether infants aged approximately 6–7 months processed their mothers' or unfamiliar faces. Therefore, infants' processing of their mothers' faces differed to that of strangers' faces.

Furthermore, studies investigating infants' emotion perception suggest that infants' sensitivity to expressions may be facilitated by their mother's face. For example, infants aged 3.5 months could only detect the correspondence between vocal and facial emotional expressions in their mothers when compared with unfamiliar women (Kahana-Kalman & Walker-Andrews, 2001). Similarly, Montague and Walker-Andrews (2002) found that infants aged 3.5 months looked longer at their mothers' happy faces when they heard happy or sad voices, whereas they did not show preferences for the faces of their fathers, unfamiliar men, and unfamiliar women. In another ERP study, Hoehl, Wahl, Michel, and Striano (2012) found that objects looked at by the mother's eye gaze elicited less ERP response in infants than objects looked by a stranger's eye gaze. This indicates that an infant's mother's eye gaze has stronger effects on the infant's object processing compared with a stranger's eye gaze. These studies suggest that the mother's face may enhance an infant's processing of face, expression, and eye gaze cues.

As shown in infants, it is generally accepted that adults' processing of familiar faces differs from that of unfamiliar faces. More specifically, the processing of familiar faces depends on internal facial features, whereas the processing of unfamiliar faces relies on external features, as shown by studies using cropped or blurred images (Campbell et al., 1999; Ellis, Shepherd, & Davies, 1979; Young, Hay, McWeeny, Flude, & Ellis, 1985). In these studies, facial images were cropped or blurred for only the required type of feature to selectively show either internal or external features.

Young, Hellawell, and Hay (1987) assessed the role of internal facial features in processing familiar faces in a composite-face experiment, which involved two types of combined facial stimulus: composite and non-composite. Composite faces were created by aligning the top half of a famous face with the bottom half of another famous face, and non-composite faces were created by shifting the bottom half of a composite face to the right or left. Young et al. (1987) demonstrated that adults experienced difficulty in identifying the top half of famous faces within composite faces. The integrated top and bottom halves of composite faces were

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perceived as novel faces and interfered with identification of the top halves of famous faces. The integration of internal facial features into a Gestalt or a whole is referred to as holistic face processing (Maurer, Le Grand, & Mondloch, 2002). The results of Young et al. (1987) suggested that adults engaged in holistic processing in the perception of familiar faces. Since Young et al.'s (1987) study was conducted, composite-face experiments have been used widely for familiar and unfamiliar faces (e.g., review by Rossion, 2013). The composite-face effect has been observed in the recognition of both familiar and unfamiliar faces.

Recently, Turati, Di Giorgio, Bardi, and Simion (2010) examined holistic face processing in newborns, 3-month-old infants, and adults, using a composite-face experiment. The results indicated that both adults and 3-month-old infants were capable of processing faces holistically and indicated that holistic face processing emerged with exposure to unfamiliar faces during infancy.

There were two differences between the study conducted by Turati et al. (2010) and the present study: first, the present study used the preferential looking technique, while Turati et al. (2010) used the habituation method; second, infants' own mothers' faces were presented as stimuli in the present study, while Turati et al. (2010) presented unfamiliar faces. Originally, Young et al. (1987) demonstrated that the composite-face effect occurred in the perception of familiar faces, and other studies examining the composite-face effect in adults have used familiar faces as stimuli (Ramon & Rossion, 2012). We sought to determine whether the composite-face effect occurred with familiar (mothers') faces in infants.

Our study was based on infants' preference for their mothers' faces as demonstrated by Yamashita, Kanazawa, and Yamaguchi (2014). They used facial image transformation and found that among infants aged 7 months, preference for their mothers' faces declined when facial images were stretched horizontally or sheared, but not when they were stretched vertically. Vertical stretching maintains the shape of internal facial features more than horizontal stretching. Tolerance for spatial distortions in face recognition indicates that configural or global facial information is used as a basis for face recognition (Hole, George, Eaves, & Rasek, 2002). Therefore, Yamashita et al. (2014) suggested that only infants aged 7 months develop adult-like face recognition, and attributed this to configural or holistic processing.

Based on the results of Yamashita et al.'s (2014) study, the present study included infants aged 7–8 months, in addition to those aged 5–6 months. We hypothesized that infants aged 7–8 months would prefer their mothers' faces in the non-composite condition, but not in the composite condition, while infants aged 5–6 months would show no preference for their mothers' faces in either condition.

With regard to holistic processing of unfamiliar faces during infancy, Cashon and Cohen (2004) examined holistic processing of upright faces using the visual habituation switch task. They created switch faces by combining the internal features of one face (the region of the eyes, nose, and mouth) with the external features of another. The results showed that infants aged 3, 4, and 7 months were able to process faces holistically, whereas 6-month-old infants were not. Therefore, Cashon and Cohen's (2004) study provided evidence for different developmental patterns in holistic face processing during infancy.

Bhatt, Bertin, Hayden, and Reed (2005) investigated the development of sensitivity to first- and second-order face processing information among infants aged 3 and 5 months. They reported that only 5-month-old infants discriminated changes in spatial relationships among facial features (such as the distance between the eyes) that are thought to underlie holistic face processing. This suggests that 5-month-old infants exhibited evidence of holistic processing. Another study examined holistic processing during infancy using eye-tracking (Oakes & Ellis, 2013). Those authors investigated developmental changes in eye-movements when looking at upright and inverted faces in infants aged 4.5, 6.5, 8, and 12.5 months. The results indicated that on an upright face, infants aged 4.5 and 6.5 months focused more on the eye region, whereas infants aged 8 and 12.5 months focused more broadly on the non-eye region. Therefore, holistic face processing may emerge during infancy from age 5–8 months.

The findings of Cashon and Cohen (2004) and Oakes and Ellis (2013) imply that 7- to 8-month-old infants were able to process unfamiliar faces holistically, whereas 6-month-old infants were not. In addition, Yamashita et al. (2014) showed that 7-month-old infants' preferred their mothers' faces only in the presentation of vertical stretching, whereas 6-month-old infants showed no preference. Therefore, a developmental shift from featural to holistic processing of both familiar and unfamiliar faces may emerge between the ages of 6 and 7 months. The present study included infants in two age groups, 5–6 months and 7–8 months, to determine when holistic processing of familiar faces occurred in a composite-face experiment.

Few studies have directly tested holistic face processing for familiar faces in infants, even though the processing of familiar faces relies on internal facial features in adults (Campbell et al., 1999) as well as infants (Pascalis et al., 1995; Yamashita et al., 2014). Adults have demonstrated difficulty in identifying famous faces within composite rather than non-composite faces (Young et al., 1987). Based on the results of Young et al.'s (1987) study, if infants were able to process familiar faces holistically, they would fail to identify their mothers' faces within composite faces. In particular, we predicted that infants' preference for their mothers' faces would be absent for composite facial stimuli and present for non-composite facial stimuli.

Considering previous findings that holistic face processing relies on low spatial frequencies (Goffaux & Rossion, 2006), and holistic processing is more efficient in categorizing faces (Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007), holistic processing may contribute to detecting familiar faces more quickly. However more needs to be known about what kinds of processes underlying the perception of mothers' faces when infants look their mothers' faces. For infants' perception of the mothers' faces, no previous research has directly examined infants' holistic processing of their mothers' faces. It is important to examine the development of an infant's perception of their mother's face because a mother's face may enhance her infant's processing of face, expression, and eye gaze cues (de Haan & Nelson, 1997; Hoehl et al., 2012; Kahana-Kalman & Walker-Andrews, 2001; Montague & Walker-Andrews, 2002; Nakato et al., 2011).

We aimed to explore how infants integrated internal facial featural information when they looked at their mother's face. Therefore, the present study sought to determine whether holistic face processing occurred in infants aged 5–8 months while perceiving familiar (their mother's) faces using a composite-face experiment. We compared infants' preference for their mothers' faces