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Integration of internal and external facial features in 8- to 10-year-old children and adults

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ABSTRACT

Investigation of whole-part and composite effects in 4- to 6-year-old children gave rise to claims that face perception is fully mature within the first decade of life (Crookes & McKone, 2009). However, only internal features were tested, and the role of external features was not addressed, although external features are highly relevant for holistic face perception (Sinha & Poggio, 1996; Axelrod & Yovel, 2010, 2011). In this study, 8- to 10-year-old children and adults performed a same–different matching task with faces and watches. In this task participants attended to either internal or external features. Holistic face perception was tested using a congruency paradigm, in which face and non-face stimuli either agreed or disagreed in both features (congruent contexts) or just in the attended ones (incongruent contexts). In both age groups, pronounced context congruency and inversion effects were found for faces, but not for watches. These findings indicate holistic feature integration for faces. While inversion effects were highly similar in both age groups, context congruency effects were stronger for children. Moreover, children's face matching performance was generally better when attending to external compared to internal features. Adults tended to perform better when attending to internal features. Our results indicate that both adults and 8- to 10-year-old children integrate external and internal facial features into holistic face representations. However, in children's face representations external features are much more relevant. These findings suggest that face perception is holistic but still not adult-like at the end of the first decade of life.

1. Introduction

Early studies have shown that the most salient characteristic of human face perception is its integrative nature (Yin, 1969; Young, Hellawell, & Hay, 1987). The ability to see faces as unique "wholes" is what makes face perception special, because no other object category exists with comparable perceptual interactions among its parts. In adults, the appearance of facial features such as the eyes, nose or mouth strongly depends on the embedding surround. These features are much easier identified when they appear in their natural face context rather than in isolation (i.e., "whole-part effect", Tanaka & Farah, 1993; Tanaka & Sengco, 1997). Another striking demonstration of the perceptual integration of face parts is the composite face effect (Young et al., 1987). Perceptually, the effect is an illusion: Two identical top halves of a face appear to be different when they are aligned with two different bottom halves of a face (for a demonstration see Rossion & Boremanse, 2008). This effect demonstrates that the upper face halves are not perceived independently from the bottom face halves (i.e., perception is modulated by the lower halves of the face). The fusion of the upper and lower halves as a unified percept impedes comparison of the two upper halves independently of the bottom parts. Hence, the observer sees two different whole faces. Turning the faces upside down reduces this effect, and enables the comparison of the two target halves relatively independently from the influence of the non-target halves (Rossion & Boremanse, 2008). This finding is in line with those that suggest that the specific configuration of facial parts that underlies the unified facial percept is maintained only in an upright position (Yin, 1969) while turning faces upside down enables a piecemeal view where the strong interdependence of facial parts is lost. A comparison of face and non-face objects showed that the composite effect is face specific (Macchi Cassia, Picozzi, Kuefner, Bricolo, Turati, 2009; for a review see Maurer, Le Grand, & Mondloch, 2002). Hence, the strong integration of parts that characterizes faces in the common upright view suggests that faces belong to a unique object category that is perceived *holistically*.

Previous research on the development of face perception found indication of a piecemeal face vision mode in the first decade of life, which is gradually replaced by configural viewing strategies later in adolescence. Although research found that the ability to perceive configural face information appears early in childhood (Cohen & Cashon, 2001; Deruelle & de Schonen, 1998; Turati, Sangrigoli, Ruel, & de Schonen,

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2004) this ability seemingly develops slowly (Mondloch, Le Grand, & Maurer, 2002) reaching the adult-like level of perceptual accuracy in late adolescence (Carey, Diamond, & Woods, 1980; Cohen-Kadosh & Johnson, 2007; Diamond, Carey, & Back, 1983). The correlates of holistic perception, like the whole-part and composite effect, were found to be present but weaker in children compared to adults (Carey & Diamond, 1977, 1994). Additionally, adult expertise is thought to be the result of continuous and accumulating experiences with the perception of faces in the upright view. Developmental neuroimaging studies support this proposal, as results have shown that the fusiform face area (FFA; Kanwisher & Yovel, 2006; Yovel & Kanwisher, 2004) and other face related areas reach adult-like volume and functional specificity at the age of 16, or even later (Golarai, Liberman, Yoon, & Grill-Spector, 2010; Grill-Spector, Golarai, & Gabrieli, 2008; Scherf, Behrmann, Humphreys, & Luna, 2007).

However, a growing body of evidence suggests that at least some capabilities for holistic face perception develop as early as the age of 4 to 6, or even before the age of 4. In several studies the composite effect was examined during the first decade of life and in adulthood. For example, several studies reported an adult-like composite effect for 6-year-old children (Carey & Diamond, 1994; de Heering, Houthuys, & Rossion, 2007; Mondloch, Pathman, Maurer, Le Grand, & de Schonen, 2007). Two studies reported a composite effect for 4-year-old children (de Heering et al., 2007; Macchi Cassia, Picozzi, Kuefner, Bricolo, & Turati, 2009), and evidence exists that a composite effect may exist for 3-month-old infants (Turati, Di Giorgio, Bardi, & Simion, 2010). Similar findings were obtained in research using the whole-part paradigm, in which evidence for holistic integration in face perception was found at the age of 6 (Tanaka, Kay, Grinnell, Stansfield, & Szechter, 1998) and 4 (Pellicano & Rhodes, 2003). Because perceptual integration is the key mechanism that makes face perception special, some researchers have claimed that face perception is fully mature in the first decade of life (Crookes & McKone, 2009; McKone, Crookes, Jeffrey, & Dilks, 2012), or, that the continuous development of face perception mechanisms does not concern the substrates related to holistic perception (Mondloch et al., 2007).

In attempts to access holistic face perception in children the interaction of face parts within the set of *internal* features was tested. However, perceptual integration among only the internal features does not capture the whole scope of the phenomena that make up holistic face perception. Holistic face perception also means that external and internal features are strongly tied to yield one holistic representation of a face. The *Presidential illusion* is a striking demonstration of this holistic integration among external and internal features (Sinha & Poggio, 1996). When the internal features (eyes, eyebrows, nose and mouth) of Bill Clinton are embedded into the external features (head outline, ears and hair) of Al Gore, most observers believe they see Gore, not Clinton. Recent updates of the original example (Andrews & Thompson, 2010; Sinha & Poggio, 2002) showed that very distinct outer features are apt to preclude that observers see the identity of the inner face parts, with the two different holistic impressions overruling the identity of the internal features. Recent neuroimaging studies corroborate that the holistic face representations in face specific brain regions, such as the FFA, are integrated wholes of external and internal features. Using a fMR-adaptation technique (Grill-Spector & Malach, 2001) a release was found from adaptation in the FFA to composite face images when internal features varied and external features remained unchanged. This release from adaptation in the FFA to composite face images is evidence for a holistic response to integrated external and internal facial features. Similar results were obtained when participants judged the face identity of pairwise presented stimuli (Andrews et al., 2010; Axelrod & Yovel, 2010, 2011), while external features (either same or different) were manipulated independently. These studies found that FFA modulations were particularly strong when external features agreed and internal features disagreed, and vice versa. This "congruency effect" vanished when the upper quarter and the lower three quarters of a face were spatially separated (misaligned), which indicates a strong influence of external features on perceived face identity, and on the holistic nature of face representations in the FFA.

Developmental research has not yet focused on the perceptual integration of external and internal features into holistic face representations. Given the strong evidence that external features play a particular role in children's face perception, the lack of research on the development of perceptual integration of external and internal facial features into holistic face representations is an important gap that this study aimed to bridge. Infants prefer external features when attending faces, which gives more weight to external than to internal features when they judge face identity (Turati, Macchi Cassia, Simon, & Leo, 2006). Furthermore, children up to the age of 10 years rely on external features much more than on internal features, even when discriminating highly familiar faces (Campbell, Walker, & Baron-Cohen, 1995; Campbell et al., 1999). Of note, adults are known to place more weight on internal features in this task (Ellis, Shepherd, & Davies, 1979; Young, Hay, McWeeny, Flude, & Ellis, 1985). The shift towards the internal feature preference for faces does not occur during the first decade of life (Campbell et al., 1999). Hence, if external features still play a dominant role in the face representations of children within the first decade of life, and if face perception is holistic at these ages, as indicated by several studies (see above), then the generally higher distinctiveness of external features should become apparent in their holistic face representations. This means that in children, identity and nonidentity of faces with the same internal features should strongly depend on the identity and nonidentity of the external features.

We recently proposed an experimental paradigm designed to reveal holistic face perception by probing the perceptual interaction of external and internal features in face matching tasks (the *context congruency paradigm*; Meinhardt-Injac, Persike, & Meinhardt, 2010, 2011). This paradigm allowed us to measure how the judgment of the identity of internal features is affected by manipulating external features, and vice versa. Comparisons with non-facial control objects demonstrated that the modulatory effects of the unattended features on matching the attended features are face-specific (Meinhardt-Injac, 2013). This finding indicates that the context congruency paradigm captures the interaction between outer and inner face parts that occurs as a result of holistic perceptual integration.

To reveal age-related differences in holistic face representations that comprise perceptual integration of external and internal features we used the context congruency paradigm to compare face and non-face object matching among 8- to 10-year-old children and adults. Non-face objects were included for two reasons: (1) to ascertain that the modulatory effects of unattended features are face-specific in both adults and children, and (2) to confirm that children of that age have the attentional prerequisites to perform a matching task that requires feature-selective attending and ignoring. The results indicate a significant performance advantage for external features for 8- to 10-year-old children, while adults tended to perform better with internal features. In line with expectations, the modulatory effect of unattended external features on matching internal features was substantially larger for children, compared to adults. Results for non-facial con trol objects showed no modulatory effects of unattended features in either age group, and assured that the matching task was in the right difficulty range to be executed by children. These findings confirm that external-internal feature asymmetry still exists at the end of the first decade of life (Campbell et al., 1995, 1999). This asymmetry affects the nature of face representations. While the face representations are holistic, the overall appearance of faces is dominated by the external features. Therefore, face perception is not adult-like, and a transition toward an internal feature preference (which characterizes mature adult face vision) can be expected to occur during further continuous development of face perception mechanisms later in the adolescence.