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The role of inner and outer face parts in holistic processing: A developmental study

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ABSTRACT

The effects of inner–outer feature interactions with unfamiliar faces were investigated in 6- and 10-year-old children and adults (20–30 years) to determine their contribution in holistic face vision. Participants completed a two-alternative forced-choice (2AFC) task under two conditions. The congruent condition used whole, inner-only, and outer-only stimuli. The incongruent condition used stimuli combining the inner features from one face with outer features from a novel face, or vice versa. Results yielded strong congruency effects which were moderated by pronounced feature-type asymmetries specific to developmental stage. Adults showed an inner-feature preference during congruent trials, but no asymmetry for incongruent trials. Children showed no asymmetry for congruent trials, but an outer-feature preference for incongruent trials. These findings concur with recent theoretical developments indicating that adults and children are likely to differ in the types of feature-specific information they preferentially encode in face perception, and that holistic effects are moderated differently in adults and children as a function of feature type.

1. Introduction

Holistic processing suggests that human faces are processed as Gestalt representations, where the sums of the individual parts are processed as an unparsed perceptual whole. This suggests that the interaction between componential (e.g. the eyes, nose, mouth) and relational (e.g. the configuration of components) information is an important factor in face perception (e.g. Farah, Wilson, Drain, & Tanaka, 1998; Tanaka & Farah, 1993; however, see Cabeza & Cato, 2000 for alternative theories). Empirical evidence supporting this hypothesis has documented numerous studies illustrating the importance of holistic processing in both familiar and unfamiliar face recognition (for a review, see Maurer, Le Grand, & Mondloch, 2002). For example, Tanaka and Farah (1993) have demonstrated that individual features of unfamiliar faces are better recognised when they are presented in the context of complete faces, rather than when they are presented in isolation or in unusual contexts (e.g. an inverted or scrambled face), and Yin (1969) has demonstrated that recognising familiar or newly learned faces is significantly impaired when holistic processing is disrupted via 'face inversion' (i.e. when a face is presented upside down; for a review of the inversion effect demonstrated over a variety of experimental conditions, see Rossion & Gauthier, 2002).

Interpretations of the inversion effect centre on the following assumptions. First, when faces are perceived upside down, relational information (a cardinal property of holistic viewing) is substantially disrupted and so processing remains predominantly feature-driven. Second, when faces are perceived upright, viewers are able to exploit holistic vision and so processing is faster and more accurate (Bartlett & Searcy, 1993; Farah, Tanaka, & Drain, 1995; Leder & Bruce, 2000; Maurer et al., 2002; Mondloch, Le Grand, & Maurer, 2002; Rhodes, Brake, & Atkinson, 1993; Rossion & Gauthier, 2002; Tanaka & Sengco, 1997). Holistic processing is therefore thought to involve fast automatic access to whole face representations, whereas access to individual features is achieved through detailed analysis (Tanaka & Farah, 1993). The inversion effect has also been observed to a much greater degree in faces than in other objects (Carey & Diamond, 1977; Diamond & Carey, 1986; Scapinello & Yarmey, 1970; Valentine & Bruce, 1986;

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Yarmey, 1971; Yin, 1969) leading some authors to suggest that faces represent a 'special' class of stimuli (Tanaka & Farah, 1993; Yin, 1969).

Study techniques manipulating 'face parts' have also demonstrated similar effects. Young, Hellawell, and Hay (1987) developed a technique in which they combined the upper and lower halves of different famous faces to create the percept of a new face. Participants' recognition of individual halves was slower when they were horizontally aligned compared to when they were misaligned. Young et al. concluded that the combination of the two halves created a perceptual whole that interfered with the processing of the individual halves — thereby demonstrating the effect of holistic processing, a finding that came to be known as the 'composite effect'. The composite effect has since been replicated (Goffaux & Rossion, 2006), and extended to other lines of enquiry including novel faces (Le Grand, Mondloch, Maurer, & Brent, 2004), unfamiliar faces (Hole, 1994), gender classification (Baudouin & Humphrey's, 2006), emotion recognition (Calder & Jansen, 2005; Calder, Young, Keane, & Deane, 2000), and judgements of facial attractiveness (Abbas & Duchaine, 2008). Interestingly, the composite effect has also been found to diminish when test images are presented upside down, further corroborating the hypothesis that inversion seriously hampers holistic vision (see Rossion, 2008 for a discussion).

Parts of the face that include inner or outer features have also received empirical interest. Inner features include the central area of the face such as the eyes, nose, and mouth, and outer features include the counterpart of the face such as the hair, ears, and facial outline. An example of inner–outer feature interacts in holistic viewing has been demonstrated in studies exploring the 'Presidential Illusion'. In this paradigm, the internal features of famous politicians are removed and replaced by the internal features of different famous politicians. Unless prompted, participants often fail to recognise this important change thus illustrating the strong interdependence between inner and outer features in face perception (Andrews & Thompson, 2010; Sinha & Poggio, 1996, 2002). These observations also correspond with evidence from neuroscience studies indicating a strong interdependence between inner and outer features. For example, the fusiform face area (FFA) has been found to contain intact rather than separate representations of inner and outer features (Andrews, Davies-Thompson, Kingstone, & Young, 2010), and patterns of activation in the FFA have demonstrated that outer features strongly modulate the processing of inner features (Axelrod & Yovel, 2011).

The relative weight of inner–outer features in face processing also seems to vary. Traditional studies investigating feature-asymmetries have focused on the role of face familiarity. Research with adults has demonstrated that familiar faces are recognised more accurately from inner rather than outer features, but vice versa for unfamiliar faces (Ellis, Shepherd, & Davies, 1979; Frowd, Bruce, McIntyre, & Hancock, 2007; Jarudi & Sinha, 2003; Veres-Injac & Persike, 2009; Veres-Injac & Schwaninger, 2009; Young, Hay, & Ellis, 1985; Young, Hay, McWeeny, Flude, & Ellis, 1985). With respect to holistic vision, outer features are often found to be less affected by face inversion than inner features (Barton, Keenan, & Bass, 2001; Malcolm, Leung, & Barton, 2005; Meinhardt-Injac, Meinhardt, & Schwaninger, 2009; Moscovitch & Moscovitch, 2000; Nachson & Shechory, 2002; Phillips, 1979; Rakover & Teucher, 1997; Rhodes et al., 1993). These differences have led some authors to suggest that inner and outer features may be implicated in different sensory routes — with the former stimulating the face recognition system and the latter stimulating the object recognition system. This hypothesis is predicated on the assumption that optimal face processing relies on an interaction between both systems (Moscovitch & Moscovitch, 2000; Moscovitch, Winocur, & Behrmann, 1997).

More recently, Meinhardt-Injac and colleagues have developed a new paradigm to examine inner–outer feature interactions in holistic processing (Meinhardt-Injac, 2013; Meinhardt-Injac, Persike, & Meinhardt, 2010, 2011). Their task requires participants to match two consecutive faces by attending to either the inner or outer features. Task stimuli are manipulated to create congruent vs. incongruent conditions. In the former, faces are either the same or completely different, in the latter, faces have the same inner features but different outer features or vice versa. As with the composite paradigm (Cheung, Richler, Palmeri, & Gauthier, 2008; Richler, Mack, Gauthier, & Palmeri, 2009), performance differences between the two conditions are interpreted as resulting from holistic processing effects, termed the 'context congruency effect'. Interestingly, this effect is moderated by feature-type asymmetries. The interference is stronger when participants attend to inner rather than outer features, thereby illustrating a dominant incongruent outer-feature modulation (corroborating the effects of the Presidential Illusion; Andrews & Thompson, 2010; Sinha & Poggio, 1996, 2002) — further demonstrating the strong interdependence between inner and outer features in holistic vision.

In an attempt to elucidate the temporal course of holistic processing in relation to feature-type asymmetries, Meinhardt-Injac and colleagues also inspected proportion correct as a function of exposure duration. In short, these data illustrate that outer features are matched rapidly and accurately within the first 200 ms and remain relatively unaffected by context (congruent vs. incongruent condition), whereas inner feature matching is much slower and more susceptible to context. Interestingly, with longer duration times (post-200 ms), the effect of conflicting information (incongruent contexts) decreases substantially. However, this decrease remains much more pronounced when matching outer rather than inner features (Meinhardt-Injac et al., 2010). The theoretical motivation behind Meinhardt-Injac et al.'s work originates from early studies showing that the microgenetic evolvement of face perception offers a useful way to examine and understand mechanisms of holistic vision (Bachmann, 1991; Sergent, 1986). According to this model, holistic representations evolve through a sequential process. Low resolution details are initially extracted, and these are followed by finer details characteristic of the inner features. However, the facial representation is hypothesised to remain fully integrated (holistic) throughout this process despite the varied resolution levels. Meinhardt-Injac et al. therefore suggest that the temporal evolution of face perception follows a global to local route characteristic of inner–outer feature asymmetries. Early processing is dominated by global representations inclusive of face shape and outline (outer features) before the inner feature representations start to become established. This hypothesis is supported by face recognition studies illustrating that outer features are often faster and more accurately matched than inner features (De Haan & Hay, 1986; Nachson, Moscovitch, & Umilta, 1995; Young, Hay, & Ellis, 1985), and recent studies predicated on the microgenetic approach illustrating that for adults, global holistic face representations begin to evolve within the first 50 ms of processing (Richler et al., 2009).

1.1. Developmental differences in holistic processing

The face-specific development hypothesis claims that holistic vision capabilities emerge from around 6-years of age and continue to develop well into adolescence (Carey, Diamond, & Woods, 1980; Freire & Lee, 2001; Mondloch, Dobson, Parsons, & Maurer, 2004; Mondloch, Geldart, Maurer, & Le Grand, 2003; Mondloch et al., 2002; Schwarzer, 2002). Sensitivity to holistic viewing is predicted to increase as a function of age, whereas the processing of featural information is predicted to remain age-independent. This approach therefore specifies that maturational differences between children and adults reflect a developmental course in which young children's face processing is predominantly feature-driven, whereas children aged 10-years and above process faces both featurally and holistically (Mondloch et al., 2002, 2003, 2004; Schwarzer, 2000, 2002). However, despite these predictions, holistic capabilities have been observed from infancy onwards. For example, sensitivity to face orientation has been found in newborns (Turati, Macchi Cassia, Simion, & Leo, 2006), infants aged 5- to 6-months (Fagan, 1972), and children aged 3-years (Macchi Cassia, Kuenfer, Picozzi, & Vescovo, 2009; Sangrigoli & de Schonen, 2004), 4, 5, 6, and 10-years (Carey, 1981), and 7-years (Crookes & McKone, 2009; Flin,