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# Behavioral and ERP measures of holistic face processing in a composite task

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## Abstract

Holistic processing of faces is characterized by encoding of the face as a single stimulus. This study employed a composite face task to examine whether holistic processing varies when attention is restricted to the top as compared to the bottom half of the face, and whether evidence of holistic processing would be observed in event-related potentials. Analyses of behavioral data showed that spatial misalignment of the face halves disrupted holistic processing and enhanced detection of repeated attended halves. Effects of misalignment on the N170, VPP and N250 ERP components resembled effects of face inversion. Attention to the top half of the face was associated with faster P1, N170, VPP, and P2 latencies than attending to the bottom, suggesting automatic processing of the eye region. Further, N170 latency effects suggested that structural encoding of the face is facilitated during holistic processing. N250 latency effects reflected task difficulty. Finally, an overall right hemispheric asymmetry was most pronounced when holistic face processing was greatest. Results are discussed in light of recent proposals that holistic face processing is a subtype of configural face processing.



*Keywords:* Faces; Holistic; ERP; Hemispheric asymmetry; Structural encoding; Composite task

## 1. Introduction

Faces, unlike many other types of objects, are processed holistically, which means that they are encoded as one inseparable unit, rather than as a group of individual features or parts (Tanaka & Farah, 1991; Tanaka & Farah, 1993). Evidence of holistic processing can be observed in part-whole paradigms, in which subjects are better able to match or recognize individual facial features that are presented within the context of a whole face than features that are presented alone (Tanaka & Farah, 1993). Evidence of part versus whole effects and holistic processing is observed in adults and in typically developing children as young as four years of age (de Heering, Houthuys, & Rossion, 2007; Pellicano & Rhodes, 2003).

Holistic face processing effects can also be observed in tasks that require the restriction of attention to only one half of the face at a time. In some tasks, composite faces are created by combining the top half of one famous or familiar face with the bottom half of another face, and subjects are then asked to identify only the person depicted in the top or the bottom half of the face (Young, Hellawell, & Hay, 1987). When the two face halves are presented in alignment with one another, they join to form a new face configuration and the stimulus is encoded holistically. In this case, recognition of the individual parts of the face is difficult because the new configuration interferes with the recognition of the individual features within each half. By contrast, a new overall facial configuration does not result when the two halves of the composite face are spatially misaligned with one another. In this case, there is no interference due to holistic encoding of the stimulus and subjects recognize the source images more easily (Young et al., 1987).

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Discrimination of unfamiliar faces is similarly disrupted by holistic processing in composite tasks (Hole, 1994; Hole, George, & Dunsmore, 1999; Le Grand, Mondloch, Maurer, & Brent, 2004). In these tasks, subjects are presented with two composite faces and are asked to make same or different judgments based on only one half of the faces. The unattended halves of the two faces differ on every trial. When the two halves of the composite face are aligned, the face is processed holistically. The new configuration of features that results from pairing identical attended halves with differing unattended halves reduces the probability that subjects will recognize that the attended halves are the same within the trial. However, when the two halves of the composite face are spatially misaligned, holistic processing is disrupted, allowing better selective attention to the attended half of the face, and consequently, better performance in the misaligned relative to the intact condition. Thus, the critical question is the degree to which spatial alignment affects the ability to detect when the attended halves are the *same*. Recognizing that attended halves are different is relatively easy in this task because in this instance both the attended and unattended halves of the face stimuli differ.

In sum, holistic processing is characterized by the encoding of the face as single stimulus, with difficulty attending selectively to individual features or parts of the face. Selective attention to features can be improved by misaligning sections of the face because the misalignment disrupts holistic processing.

### 1.1. Neural signatures of face processing

Event-related potential (ERP) studies of face processing have focused on several components that appear to be face-sensitive, or show different activity for faces compared to other objects. These peaks are also sensitive to information within the face, such as spacing and orientation of features.

The earliest peak is the P1, a positive-going peak around 100 ms post-stimulus. The P1 is observed during many visual tasks, and some studies have reported that this component responds differently to faces than other objects (e.g., Herrmann, Ehlis, Ellgring, & Fallgatter, 2004). The P1, observed in posterior, lateral electrodes, is sensitive to face information, including orientation (Henderson, McCulloch, & Herbert, 2003; Itier & Taylor, 2002; Itier & Taylor, 2004a, 2004b, 2004c; Linkenkaer-Hansen et al., 1998; Taylor, Batty, & Itier, 2004), thatcherization, a technique which inverts the orientation of the eyes and mouth within the face (Milivojevic, Clapp, Johnson, & Corballis, 2003), and changes in the spacing of features and typicality or attractiveness of the face (Halit, de Haan, & Johnson, 2000). However, some studies have failed to find thatcherization effects on the P1 (Boutsen, Humphreys, Praamstra, & Warbrick, 2006), and therefore these effects may be dependent on stimulus or task characteristics.

The N170, a negative-going peak around 170 ms post-stimulus recorded in posterior lateral sites, clearly differentiates faces as a class of stimuli from other visual objects and is therefore considered to index the structural encoding of the face (Bentin, Allison, Puce, Perez, & McCarthy, 1996; Bentin & Deouell, 2000; Itier & Taylor, 2004a, 2004b, 2004c; Rossion et al., 1999; Rossion, Joyce, Cottrell, & Tarr, 2003). This component is highly sensitive to face inversion (Eimer, 2000; Rossion et al., 1999), contrast reversal (Itier & Taylor, 2002), and thatcherization (Carbon, Schweinberger, Kaufmann, & Leder, 2005; Milivojevic et al., 2003). Furthermore, in studies using Mooney faces, which are devoid of individual features but retain the overall configuration of a face, the N170 is larger for stimuli correctly identified as faces than those not perceived as faces, and an inversion effect is present only for stimuli perceived as faces (George, Jemel, Fiori, Chaby, & Renault, 2005). This peak is observed in posterior, lateral electrodes and tends to be faster and larger in the right hemisphere (RH) than the left hemisphere (LH) (Bentin et al., 1996), but this can vary with task and stimulus characteristics. Source-localization studies have localized the generator(s) of the N170 to either the fusiform gyrus, the superior temporal sulcus, or both (Caldara et al., 2003; Itier & Taylor, 2002; Itier & Taylor, 2004a, 2004b, 2004c; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002a; Schweinberger, Pickering, Burton, & Kaufmann, 2002b).

The VPP is a positive going peak that is observed over frontal electrodes at the same latency as the N170. Previous research has shown that the VPP, like the N170, is sensitive to face inversion (Eimer, 2000; Jemel, Pisani, Calabria, Crommelinck, & Bruyer, 2003; Rossion et al., 1999). Some source localization studies conclude that the VPP and N170 components reflect activity from the same neural dipole, probably located in or near the fusiform gyrus (Itier & Taylor, 2002; Joyce & Rossion, 2005; Rossion et al., 1999), while others document differences suggestive of two independent neural generators (Bentin et al., 1996; Botzel, Schulze, & Stodieck, 1995; Eimer, 2000; George et al., 2005).

Later components in the ERP are also sensitive to face information within the context of a task. The P2, a positive-going peak recorded around 200 ms in posterior temporal sites, is sensitive to facial configuration and is larger over the right hemisphere (RH) in response to faces (Halit et al., 2000). It is also affected by thatcherization (Boutsen et al., 2006; Carbon et al., 2005; Milivojevic et al., 2003), familiarity of faces (Caharel et al., 2002), and emotional facial expressions (Stekelenburg & de Gelder, 2004). Many studies suggest that the P2 is involved with processing configural relations between features (Itier & Taylor, 2002; Linkenkaer-Hansen et al., 1998; Milivojevic et al., 2003) or processing of stored representations of familiar faces (Caharel et al., 2002).

The N250, a negative-going peak around 225–250 ms, has been associated with repetition and familiarity in many studies of face perception. This peak shows a RH asymmetry and because it tends to be larger for familiar than unfa-