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Impaired holistic coding of facial expression and facial identity in congenital prosopagnosia

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ABSTRACT

We test 12 individuals with congenital prosopagnosia (CP), who replicate a common pattern of showing severe difficulty in recognising facial identity in conjunction with normal recognition of facial expressions (both basic and 'social'). Strength of holistic processing was examined using standard expression composite and identity composite tasks. Compared to age- and sex-matched controls, group analyses demonstrated that CPs showed weaker holistic processing, for both expression and identity information. Implications are (a) normal expression recognition in CP can derive from compensatory strategies (e.g., over-reliance on non-holistic cues to expression); (b) the split between processing of expression and identity information may take place after a common stage of holistic processing; and (c) contrary to a recent claim, holistic processing of identity is functionally involved in face identification ability.

1. Introduction

People with congenital prosopagnosia (CP; also referred to as developmental prosopagnosia) have severe, life-long deficits recognising the identity of familiar people from their faces despite intact low-level vision and general cognitive abilities (Behrmann & Avidan, 2005; Lee, Duchaine, Wilson, & Nakayama, 2010). As many as 2.5% of the educated population can be classified as a CP (Bowles et al., 2009; Kennerknecht et al., 2006), and some of these cases run in families (Duchaine, Germine, & Nakayama, 2007; Grueter et al., 2007; Lee et al., 2010; Schmalzl, Palermo, & Coltheart, 2008). Face recognition deficits in CP appear to be associated with smaller anterior fusiform volumes (Behrmann, Avidan, Gao, & Black, 2007), reduced grey matter volume in brain regions that respond to faces, such as the mid-fusiform gyrus (Garrido et al., 2009), and compromised white matter tracts in occipito-temporal cortex (Thomas et al., 2009).

Despite profound impairments in facial identity recognition, many, although not all, CPs are adept at labelling the basic facial expressions of happiness, anger, disgust, fear, sadness and surprise (Kress & Daum, 2003; Nunn, Postma, & Pearson, 2001; Schmalzl et al., 2008), even when the display of these basic expressions is subtle and difficult to categorise (Duchaine, Parker, & Nakayama, 2003; Humphreys, Avidan, & Behrmann, 2007). CPs are also typically able to recognise subtle social emotions conveyed by the eyes, such as playfulness and regret (Duchaine et al., 2003, 2007; Lee et al., 2010). In the present study we test 12 CPs showing this pattern of impaired identity recognition with no discernable deficit in facial expression recognition, and examine the strength of holistic processing for face expression information (in all 12 participants) and face identity information (in a subset of nine participants), in order to address three theoretical questions regarding the role of holistic processing in their patterns of face processing abilities.

Holistic processing, defined as the "simultaneous perception of multiple features of an individual face, that are integrated into a single global representation" (Rossion, 2008, p. 275), is a core perceptual mechanism in the processing of faces. The most widely accepted measure of holistic processing is the composite effect. Assessing holistic coding of identity typically involves participants identifying the top (or bottom) half of a face paired with the bottom (or top) half of another person's face. The composite effect is the robust finding that participants are slower, and less accurate, when the face halves are vertically *aligned* (forming the illusion of a

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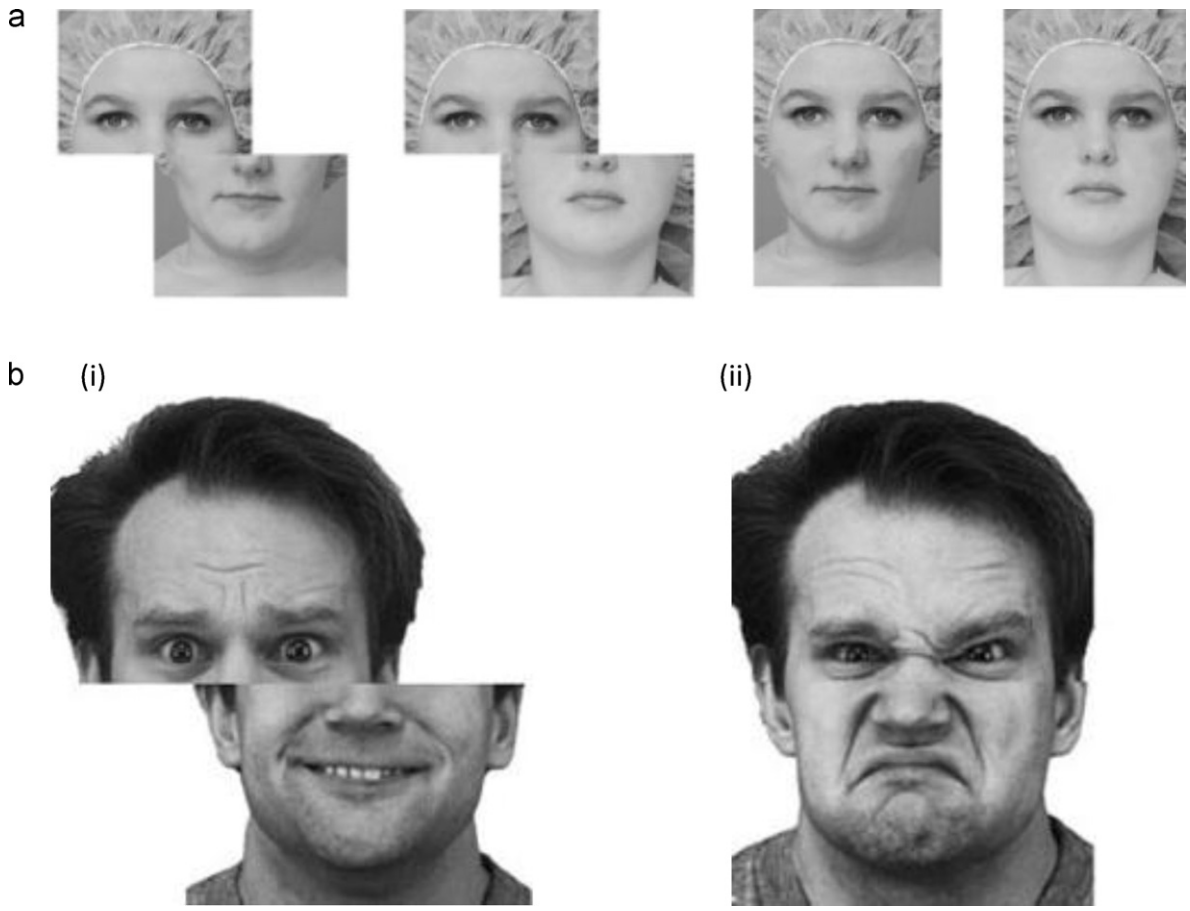

Fig. 1. (a) *Identity composite task*. Pairs of faces were shown sequentially and participants judged whether the top halves of the faces were either the "same" or "different". In this example the top halves were the "same" in both the unaligned (left) and aligned (right) pairs. The bottom halves were always of a different individual to the top individual. Reprinted with kind permission from Le Grand et al. (2004). (b) *Expression Composite task*. Examples of unaligned (left) and aligned (right) composite expressions in which participants judged the expression from either the (i) top (fear) or (ii) bottom (disgusted) halves of the face. The other half of the face was always of a different expression. Face images are from the KDEF (Lundqvist et al., 1998).

new face) compared to when they are spatially *unaligned* so they do not resemble a whole face (e.g., McKone, 2008; Young, Hellawell, & Hay, 1987; e.g., Fig. 1a). In the expression version, participants judge the expression on one half of the face (e.g., anger) while trying to ignore an inconsistent expression on the other half (e.g., happiness) (Calder & Jansen, 2005; Calder, Young, Keane, & Dean, 2000; White, 2000; e.g., Fig. 1b). Composite effects for both types of information occur for upright faces (where identity and expression recognition is typically also good) but not inverted faces (where recognition is poorer).

The first question we address in the current study is whether the normal levels of expression recognition ability in our CPs derive from normal use of perceptual mechanisms, as opposed to reliance on other compensatory strategies. Patient H.J.A., who acquired prosopagnosia at age 61 following a stroke, demonstrated a relatively normal ability to recognise facial expressions despite displaying no expression composite effect, implying the use of compensatory strategies (perhaps a reliance on local part cues) (Baudouin & Humphreys, 2006). This implies that there is no guarantee that normal expression recognition ability in CP is achieved via the same perceptual mechanisms used by typically developing adults. Here we test whether our CPs may rely less on holistic processing (and therefore more on other contributory mechanisms) than controls.

The second question concerns the stage of processing from which the dissociation between identity and expression recognition derives. Common theories place the point of split between processing of identity and expression information quite early in perceptual/cognitive processing, with the split occurring before the stage of view-independent 'structural descriptions' in the cognitive model of Bruce and Young (1986), and before processing in the lateral fusiform gyrus (identity) and superior temporal sulcus (expression) in the anatomical model of Haxby, Hoffman, and Gobbini (2000). However, Calder and Young's (2005) review argued that much of the evidence for an early split was not as strong as often assumed. Here, we address the question of whether a split has occurred by the perceptual stage of holistic processing. We consider two models. In the first (Model A, Fig. 2), there are two distinct types of holistic coding, one for coding expression and another for coding information about identity. In support of this model, Calder et al. (2000) found that participants could selectively attend to holistic information specific to identity or expression (i.e., participants took no longer to judge the facial expression of a composite whether they were composed of the same or different identity and vice versa), suggesting that holistic coding of identity and expression were independent. However, as this data can also be modelled within a single multi-dimensional system, there may not be an absolute dissociation between the composite effect for expression and identity (Calder and Young, 2005). Alternatively then, there could be a common stage of holistic coding, which feeds into both expression and identity recognition (Model B, Fig. 2). In support of this model, Calder and Jansen (2005) note that composite effects for both identity and expression are sensitive to inversion but not photographic negative, suggesting a common level of perceptual processing.

In the current study, we assess whether holistic expression and identity processing go together, or dissociate, in our CPs. Model