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Impaired holistic processing in congenital prosopagnosia

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ABSTRACT

It has long been argued that face processing requires disproportionate reliance on holistic or configural processing, relative to that required for non-face object recognition, and that a disruption of such holistic processing may be causally implicated in prosopagnosia. Previously, we demonstrated that individuals with congenital prosopagnosia (CP) did not show the normal face inversion effect (better performance for upright compared to inverted faces) and evinced a local (rather than the normal global) bias in a compound letter global/local (GL) task, supporting the claim of disrupted holistic processing in prosopagnosia. Here, we investigate further the nature of holistic processing impairments in CP, first by confirming, in a large sample of CP individuals, the absence of the normal face inversion effect and the presence of the local bias on the GL task, and, second, by employing the composite face paradigm, often regarded as the gold standard for measuring holistic face processing. In this last task, we show that, in contrast with controls, the CP group perform equivalently with aligned and misaligned faces and was impervious to (the normal) interference from the task-irrelevant bottom part of faces. Interestingly, the extent of the local bias evident in the composite task is correlated with the abnormality of performance on diagnostic face processing tasks. Furthermore, there is a significant correlation between the magnitude of the local bias in the GL and performance on the composite task. These results provide further evidence for impaired holistic processing in CP and, moreover, corroborate the critical role of this type of processing for intact face recognition.

1. Introduction

Face recognition presents one of the most demanding perceptual challenges to the visual system. Not only is a multiplicity of dimensions such as emotional expression and gaze direction conveyed via the face, but the individual identity of each face must be rapidly and accurately established. Despite this apparent complexity, humans are expert at face recognition and the robustness of this ability is further attested to by the fact that recognition remains remarkably accurate even under relatively poor lighting conditions, under changes in view of the face, and with changes in the age and appearance of the face (for example, with changes of facial hair). Surprisingly, however, there are a number of conditions under which normal face recognition is adversely impacted. Common to many, if not all, of these conditions is that there is a disruption of the configural or holistic processing of the face. Consequently, the observer resorts to relying on the featural information rather than on the configural information, in which the relations among the features of the face rather than just the features themselves, are represented (Maurer, Le Grand, & Mondloch, 2002; Tanaka & Farah, 1993).

1.1. Configural processing in face recognition

Given that all faces share the same local internal components (eyes, nose and mouth), the claim is that deriving a rapid and accurate representation of the face requires disproportionate reliance on the configuration of the features relative to that required for non-face object recognition (Maurer et al., 2002). Any manipulation that disrupts the configuration of the face, then, would be predicted to affect face processing disproportionately. Evidence to support this prediction comes from a number of experimental paradigms. For example, it is now well-known that face processing is adversely affected by changes in orientation: when the face is inverted, recognition is adversely affected to a greater degree, relative to upright, than is true for other classes of objects (Farah, Tanaka, & Drain, 1995; Freire, Lee, & Symons, 2000; Leder & Bruce, 1998; Malcolm, Leung, & Barton, 2004; Searcy & Bartlett, 1996). It is also the case that face perception benefits from the presence of the entire face, compared with the presence of just some components of the face and this whole vs. part advantage holds to a greater degree for faces than for other objects (Gauthier & Tarr, 2002; Tanaka & Farah, 1993).

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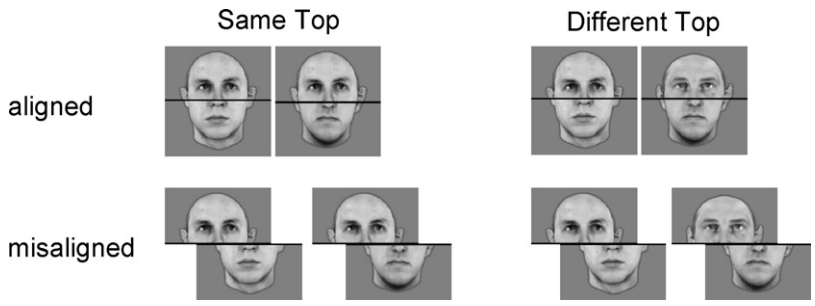

Fig. 1. Composite experiment: examples of the stimuli used in the experiment showing the aligned (top row) and misaligned (bottom row) conditions.

Interestingly, the derivation of the configuration of the face is apparently so automatic that even when instructed to attend selectively to only some parts of a face, normal observers cannot help but be sensitive to the entire face (Amishav & Kimchi, 2010). Data to support this claim comes from a well-established paradigm using composite faces (Boutet, Gentes-Hawn, & Chaudhuri, 2002; Farah, Wilson, Drain, & Tanaka, 1998; Gauthier, Curran, Curby, & Collins, 2003; Le Grand, Mondloch, Maurer, & Brent, 2004; Young, Hellawell, & Hay, 1987). In the version of this paradigm used here (Fig. 1), individuals view two consecutively presented composite faces, and make same/different decisions based only on the top part of the face (Le Grand et al., 2004). The bottom part of the face is to be ignored. The two faces are created such that the two top parts could either be the same or different while the bottom part is always different. Additionally, the top and bottom parts of a single face can be either aligned or misaligned. Due to the holistic nature of face processing, even when instructed to judge only the top halves of aligned faces and to ignore the bottom parts, normal observers exhibit significant interference induced by the presence of the task-irrelevant bottom half of the composite face (which is always different). Thus, erroneously, they tend to judge two faces with identical tops as 'different' rather than 'same' (i.e. make false alarms). This interference from the task-irrelevant bottom of the face is substantially reduced when configural information is disrupted, as in the misaligned condition (Fig. 1, bottom row) (Young et al., 1987) and also when the faces are inverted (Hole, 1994; Hole, George, & Dunsmore, 1999).

1.2. Disrupted configural processing in prosopagnosia

If it is indeed the case that individuals with prosopagnosia are impaired at configural processing, one direct prediction is that their judgments about the top parts of faces will be impervious to the (different) bottom part of faces, even in the especially taxing aligned condition. That is, they will not process the task-irrelevant lower part of the face automatically.

Considerable empirical evidence supports the notion that a breakdown in configural processing is related to the impairment in face processing (for review see Barton, 2009; Rivest, Moscovitch, & Black, 2009). For example, individuals with prosopagnosia were substantially impaired, relative to matched controls, when deciding which of 3 faces was 'odd' when the interocular distance or the distance between the nose and mouth were altered (Barton, Press, Keenan, & O'Connor, 2002). Based on these findings, the authors argued that the need to represent the spatial relations between the features (and they note that the distance between the eyes is especially important) is integral to the ability to process faces. Moreover, PS, a well-characterized patient with acquired prosopagnosia but no deficits in other perceptual domains, exhibited abnormal holistic processing on several behavioral tests, including the composite face paradigm (Ramon, Busigny, & Rossion, 2010).

This disruption in configural processing skills appears to be true not only of individuals with acquired prosopagnosia (Barton, 2009) but also of individuals with congenital prosopagnosia (CP) (Lobmaier, Bolte, Mast, & Dobel, 2010). CP is an apparently lifelong deficit in face processing that occurs along with intact sensory visual abilities, normal intelligence and adequate opportunity to acquire face recognition skills (Behrmann & Avidan, 2005). Although there is some evidence that CP is related to a difficulty in deriving the configural or holistic relations between the features of a face, this claim is still controversial.

On the one hand, CP individuals, similar to individuals with AP (Busigny & Rossion, 2010), are minimally (if at all) affected by face inversion and a few even show better performance for inverted than upright faces (the "inversion" superiority effect) but this latter effect is not very common in either forms of prosopagnosia (Behrmann, Avidan, Marotta, & Kimchi, 2005; Busigny & Rossion, 2010; Farah et al., 1995) (and see also Table 2 in the present study). Additionally, these same individuals show a bias for local processing of elemental features, even for non-face stimuli. Thus, shown hierarchical, compound Navon stimuli, these individuals are faster at local than global letter identification and, when the letter identities are inconsistent at the two levels, show no interference from global to local letter identification, a pattern markedly discrepant from that of normal observers (Behrmann et al., 2005; Kimchi, 1992; Navon, 2003) (and see also Table 2, Fig. 2 and Supplementary Fig. 1 in the present study). Finally, along similar lines, Palermo et al. (2011) recently showed reduced holistic processing (i.e. reduced interference indicating atypical configural processing) in a group of 12 individuals with CP on the composite task.

This apparent trend towards featural or elemental processing may not be ubiquitous, however. For example, Duchaine (2000) tested a congenital (or 'developmental') prosopagnosic on three tests from the Kit of Factor-Referenced Cognitive Tests and showed that this individual performed normally on these gestalt completion tasks. More pertinent perhaps and contrary to our findings, Duchaine, Yovel, and Nakayama (2007) tested a group of 14 developmental prosopagnosia participants on the global/local task and did not find a local processing bias in these individuals. Additionally, Le Grand et al. (2006) employed the composite face task and found abnormal performance in only one out of 8 CP participants. We return to the discrepancies among these studies, as well as others, and offer a possible, albeit tentative, resolution in Section 4.

To explore further whether CP individuals do indeed evince an impairment in holistic processing, here, we conduct 3 experiments, all of which are designed to tap configural processing, in a relatively large group of 14 well-characterized CP individuals. We expect to replicate the lack of an inversion effect and the local bias in the global/local task, both of which we reported previously in smaller groups of participants, and, furthermore, predict that the very same individuals should be less affected by the incongruency effects afforded by the discrepant bottom parts of aligned faces in the composite task. In other words, and counterintuitively, in this