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Effects of configural processing on the perceptual spatial resolution for face features

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ABSTRACT

Configural processing governs human perception across various domains, including face perception. An established marker of configural face perception is the face inversion effect, in which performance is typically better for upright compared to inverted faces. In two experiments, we tested whether configural processing could influence basic visual abilities such as perceptual spatial resolution (i.e., the ability to detect spatial visual changes). Face-related perceptual spatial resolution was assessed by measuring the just noticeable difference (JND) to subtle positional changes between specific features in upright and inverted faces. The results revealed robust inversion effect for spatial sensitivity to configural-based changes, such as the distance between the mouth and the nose, or the distance between the eyes and the nose. Critically, spatial resolution for face features within the region of the eyes (e.g., the interocular distance between the eyes) was not affected by inversion, suggesting that the eye region operates as a separate ‘gestalt’ unit which is relatively immune to manipulations that would normally hamper configural processing. Together these findings suggest that face orientation modulates fundamental psychophysical abilities including spatial resolution. Furthermore, they indicate that classic psychophysical methods can be used as a valid measure of configural face processing.

1. Introduction

It is typically harder to recognize visual stimuli and differentiate between them when they are presented in an inverted, 180° rotated orientation, compared to the processing of the same stimuli in their standard, upright orientation. However, this inversion effect is much more pronounced for faces compared to other objects (Yin, 1969). It has been argued that the rotation of a face along the picture plain impairs its configural normal processing style (Farah, Wilson, Drain, & Tanaka, 1998; Freire, Lee, & Symons, 2000; Riesenhuber & Wolff, 2009; Rossion, 2008, 2009; Sergent, 1984; Tanaka & Farah, 1993; Yovel, 2009). As a result, inverted faces are processed in a piecemeal, analytic processing style, largely based on the identity of single face features rather than on their overall configuration. Hence, it is assumed that facial inversion impairs the sensitivity to changes in the spatial relations *between* features to a much greater extent compared to the sensitivity to changes in the shape of single features (Barton, Keenan, & Bass, 2001; Freire et al., 2000; Leder, Candrian,

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Huber, & Bruce, 2001; Rossion, 2008). We note that the terms configural and holistic processing are sometimes used interchangeably in the literature to refer to a non-analytic, Gestalt processing style (Piepers & Robbins, 2012). In the context of the current study, participants were explicitly asked to judge distances between facial features, and hence, to avoid confusion, throughout the paper, we will use the term "configural" to refer to such non-analytic, holistic processing style (see Rossion, 2009; but see Maurer, Grand, & Mondloch, 2002 for a different view).

The fact that a mere rotation in the pictorial plain results in a dramatic change in the way faces are processed provides compelling evidence for the notion that faces are represented in a unique manner compared to other objects (e.g., Ellis, 1975). Supporting evidence for this notion also comes from several neuroimaging studies suggesting that facial inversion results in a qualitatively different pattern of brain activation compared to the effect of inversion of other objects (Aguirre, Singh, & D'Esposito, 1999; Haxby et al., 1999; Pitcher, Duchaine, Walsh, Yovel, & Kanwisher, 2011; Sadeh, Goldberg, Avni, Pelleg, & Yovel, 2011; Yovel & Kanwisher, 2005).

Neuropsychological evidence also converges to the idea that a configural processing style, which mediates normal face perception, is largely disrupted when processing inverted faces. For example, there is evidence that patients with acquired prosopagnosia, who suffer from severe difficulties in face processing due to lesions in occipito-temporal cortex, are less affected by face inversion compared to controls (Busigny & Rossion, 2010; Farah, Wilson, Maxwell Drain, & Tanaka, 1995; Marotta, McKeeff, & Behrmann, 2002). Interestingly, similar findings were also observed in individuals with congenital prosopagnosia (Avidan, Tanzer, & Behrmann, 2011; Behrmann, Avidan, Marotta, & Kimchi, 2005). Other studies have also suggested that acquired prosopagnosia patients, who specifically suffer from lesions in the right fusiform area, show impairments in detecting changes in the spatial location of facial features (Barton, Press, Keenan, & O'Connor, 2002), thus implying that configural processing of faces is largely impaired in these individuals. Consistent with this account, these patients do not show a normal inversion effect (Busigny & Rossion, 2010), thus further supporting the notion that inverted faces are not processed in a configural fashion, similar to faces in their standard, upright orientation.

Although it is widely accepted that in normal participants, facial inversion leads to robust impairments in performance, the mechanisms involved in such impairments are debated. For example, it has been suggested that the inversion of the horizontal and vertically-based features of the face disproportionally affects performance. In particular, Goffaux and Rossion (2007) proposed that inverting a face impairs the perception of vertical metric distances to a much greater extent compared to the horizontal distances (also see, Goffaux, 2008). This approach has been criticized, however, by others who argued that the horizontal-vertical model is limited by the fact that changes in the horizontal plain are usually restricted to changes within the region of the eyes (i.e., eyes, eyebrows or both). It could therefore be argued that the distinction between vertical and horizontal metric planes was confounded by attentional demands naturally associated with the region of the eyes. Specifically, it has been suggested that inversion disproportionally affects performance to features within the region of the eyes due to their high saliency compared to other features of the face rather than to vertically as opposed to horizontally-based face features (Sekunova & Barton, 2008).

A parsimonious account for these findings refers to the size of the perceptual field. Specifically, Rossion (2009) suggested that when looking at an inverted compared to an upright face, our "perceptual field" is smaller, consequently making the utilization of distant configural information less efficient during processing. Therefore, the larger perceptual field for upright faces allows for more affective, simultaneous processing of a large number of features (see also Van Belle, Lefèvre, & Rossion, 2015). This effect can be modulated by the fixation pattern (Hills, Cooper, & Pake, 2013; Hills, Ross, & Lewis, 2011). In particular, assuming that fixation is mandatorily directed to the region of the eyes for both upright and inverted faces, there should be a smaller, or even no advantage for upright compared to inverted faces when participants are asked to judge this particular part of the image (Rossion, 2009).

Previous research that looked at the effect of facial inversion used different approaches and methodologies to compare the processing of upright and inverted faces. Most of these methodologies included memory-based recognition tests (Civile, McLaren, & McLaren, 2013), or same/different perceptual classification tests (Barton et al., 2002; Busigny & Rossion, 2010; Farah et al., 1995; Goffaux & Rossion, 2007; Jacques, d'Arripe, & Rossion, 2007). Although empirically sound, one limitation of these methods is that they typically only provide a general measure of performance such as percentage accuracy or average reaction time for a given condition. They do not allow, however, a precise, fine-grained quantification of the effect of inversion on face perception. The main purpose of the present study was to provide such a basic measure of performance using classic psychophysical tools. We propose that a basic attribute of configural face processing can be indexed by the ability to detect spatial variations along the metric distances between facial features. For example, sensitivity to the slightest variation in the distance between the eyes and the nose can be considered as a characteristic of one's ability to process faces in a configural manner.

To reiterate, our basic assumption is that faces are processed in a configural manner, and hence multiple sets of facial features are processed automatically even when the task at hand does not explicitly require such processing. Consequently, the ability to compute the veridical distance between any given set of features (or reference points) within a face would always be affected by other features, or reference points within that face, thus facilitating a more accurate perception. To illustrate this point, computing the distance between the eyes and nose would be more efficient if one would simultaneously take into account other relevant distances within the face, such as the distances between the nose and the mouth, the eyes and the mouth and so forth (Tanaka & Sengco, 1997); In order to partial out general configural effects from those that are face-specific, we tested whether and how facial inversion affects participants' resolution for distances

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