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Research report

Impaired processing of relative distances between features and of the eye region in acquired prosopagnosia—Two sides of the same holistic coin?

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ABSTRACT

Acquired prosopagnosia (AP) is characterized by impaired recognition of individual faces following brain damage. The nature of the functional impairment(s) underlying AP remains debated. Recent studies have demonstrated deficient processing of diagnostic information in the region of the eyes (Caldara et al., 2005); other studies suggest that patients fail to judge relative distances between facial features (Barton et al., 2002). We hypothesized that these apparently different observations are related to a common cause. More precisely, we suggest that AP arises due to an impairment of a process that reduces uncertainty about the nature/location of the diagnostic cues for face individualization: the ability to perceive multiple elements of a face as a single global representation (holistic processing). Being impaired at processing individual faces holistically, prosopagnosic patients would tend to perform relatively worse for processing facial areas containing multiple elements (i.e., the eyes), and for elements that are widely spaced apart. Here we tested PS, a single case of AP, at matching unfamiliar faces differing either with respect to local features or inter-feature distances, over the upper and lower areas of the face. A pilot study and Experiment 1 confirmed that PS was extremely poor at using information encompassing the eyes, but was also deficient at perceiving relative distances between features. When uncertainty about the location and nature of the diagnostic cue was removed in Experiment 2, PS' performance remained below normal range, but she improved substantially. Most interestingly, her pattern of performance across the different conditions appeared qualitatively identical to that of normal controls. In line with previous observations of PS and other cases of prosopagnosia, our findings indicate that the reduced reliance on the area of the eyes and on relative distances between features in AP may have a common underlying cause—the disruption of holistic processing of the individual face.

1. Introduction

Normal face processing involves adequate perception of different cues that are thought to be diagnostic for face individualization. For instance local shape (Young et al., 1985) and surface (color/texture) (Lee and Perrett, 1997; Russell et al., 2006) information can be derived for this purpose, with the region of the eyes/eyebrows conveying particularly critical

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sources of information (Haig, 1985; Gosselin and Schyns, 2001; Sadr et al., 2003).

The high efficiency with which we generally perceive and recognize faces masks a complexity which becomes apparent when this ability breaks down, as observed in acquired prosopagnosia (AP) (Bodamer, 1947). This rare neurological condition refers to the selective inability to recognize individual faces as a consequence of brain damage to bilateral or right unilateral occipito–temporal regions. Since the first observations (Wigan, 1844; Quaglino et al., 2003; for recent reviews see Barton, 2003; Mayer and Rossion, 2007) the clinical and anatomical conditions of AP have attained considerable notoriety as they provide a means to clarify the neuro-functional mechanisms of normal face processing.

However, despite over 60 years of research on AP, the underlying functional basis of the observable deficits in deriving an adequate representation of an individual face remains a matter of debate.

It has been proposed that AP involves a deficit in processing the face as a global representation, i.e., configural/holistic processing.[1] For instance, based on their assessment of LH, Levine and Calvanio (1989) concluded that prosopagnosia represents a loss of visual ''configural processing'', which they conceptualized as a deficit in visual perception, reflected by the inability to derive an ''*overview of sufficient features to allow structuring or crystallization of a coherent concept*'' (p. 151). This view has been supported by other studies of acquired prosopagnosic patients that used different paradigms to test the interdependence between facial features of the whole face (e.g., Sergent and Villemure, 1989; Saumier et al., 2001; Boutsen and Humphreys, 2002). However, the different paradigms used and the variability among patients tested has hindered true significant progress with respect to validation of this hypothesis and thus of our understanding of the nature of this configural/holistic processing view of AP. Furthermore, the fact that different authors conceptualize configural/holistic processing differently (e.g., Farah et al., 1998; Maurer et al., 2002), poses additional problems.

More recent studies indicate that prosopagnosia involves a deficit restricted to the processing of certain localized features of the face. Caldara et al. (2005) tested the acquired prosopagnosic patient PS (Rossion et al., 2003) by means of a learning paradigm followed by an identification task of faces revealed through random apertures (''Bubbles'', Gosselin and Schyns, 2001). Compared to normal observers, PS required much more information to achieve the same performance level and relied mostly on the mouth rather than on the eyes. In the same vein, Bukach et al. (2006) showed that the prosopagnosic patient LR was able to detect diagnostic changes in the mouth region, but was strikingly impaired at making such judgments based on the eyes of faces (see also Bukach et al., 2008; Rossion et al., 2009).

Also recently, other authors have reported several patients who were impaired at discriminating faces that differed with respect to distances between features (e.g., mouth-nose distance, inter-ocular distance, ...) but could apparently process local features (e.g., eye color) efficiently (Barton et al., 2002; Joubert et al., 2003; Barton and Cherkasova, 2005). Barton et al. (2002) therefore concluded that the perception of the relative distances between features of faces is impaired in patients with prosopagnosia, in particular when their lesions involve the right fusiform gyrus, and that this deficit contributes directly to their prosopagnosia.

These last two hypotheses differ from the proposed holistic/configural hypothesis of AP described above. They suggest that prosopagnosia arises from the inability to process a certain *type* of information—local information conveyed by the eyes (Caldara et al., 2005; Bukach et al., 2006) or the relative distances between facial features in general (Barton et al., 2002)—rather than from an impaired mode of processing (i.e., holistic, as opposed to analytical).

One the one hand, it is tempting to attribute these different observations to the functional variability among acquired prosopagnosic patients (Sergent and Signoret, 1992; Schweich and Bruyer, 1993), and to acknowledge that the main impairment observed in prosopagnosia—the inability to process faces at the individual level efficiently—has several different manifestations, which would presumably rely on the specific localization of a patient's lesion(s). On the other hand, another way to conceptualize these observations is to integrate all of them into a single theoretical framework. That is, while acknowledging the functional variability among prosopagnosic patients in terms of associated deficits, it may be that all of these patients share a common disrupted process, which characterizes their prosopagnosia.

In line with previous studies and our interpretation of the observations made for the patient PS, we hypothesized that the primary *cause* of AP lies in the inability to process faces holistically/configurally. More precisely, all patients suffering from AP would be unable (or significantly less able) to ''*integrate the multiple features of an individual face simultaneously, into a unified perceptual representation*'' (Tanaka and Farah, 1993; Rossion, 2008a). Consequently, they would have to process a face feature-by-feature, analytically, or over a small spatial window at a time. Since the region of the eyes contains several elements (two eyes and two eyebrows, at least), a disruption of the ability to process these elements as a whole would be particularly detrimental for the diagnosticity of this facial region. In the same vein, processing a distance between features requires the processing of at least two elements over a wider spatial range than processing a localized single feature. Hence, the loss of the ability to process both the eye region of the face (Caldara et al., 2005; Bukach et al., 2006; Rossion et al., 2009) and the relative distances between features (Barton et al., 2002; Barton and Cherkasova, 2005) may not reflect distinct fundamental aspects of AP, but rather represent mere *consequences* of a single cause: a defective holistic processing mode.

[1] These terms have been used interchangeably in the face processing literature, even though a number of authors have used the term ''configural'' to refer specifically to the processing of relative distances between features that would be diagnostic of someone's identity (e.g., Rhodes, 1988; Carey, 1992; Maurer et al., 2002). Here we will use the term ''holistic'' or ''configural'' to refer to a process, not to specific cues of the stimulus. In line with earlier proposals (Farah et al., 1998), this process can be defined as the ''*ability to perceive the multiple elements of a(n) (upright) face simultaneously, as an integrated representation*'' (Rossion, 2008a, 2008b). Its empirical manifestation is characterized by the interdependence between facial features.