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Aberrant pattern of scanning in prosopagnosia reflects impaired face processing

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ABSTRACT

Visual scanpath recording was used to investigate the information processing strategies used by a prosopagnosic patient, SC, when viewing faces. Compared to controls, SC showed an aberrant pattern of scanning, directing attention away from the internal configuration of facial features (eyes, nose) towards peripheral regions (hair, forehead) of the face. The results suggest that SC's face recognition deficit can be linked to an inability to assemble an accurate and unified face percept due to an abnormal allocation of attention away from the internal face region. Extraction of stimulus attributes necessary for face identity recognition is compromised by an aberrant face scanning pattern.

1. Introduction

Prosopagnosia is a rare neurological deficit characterised by an inability to recognise facial identity. A hallmark of the disorder is impaired processing of configural information involving the unique spatial relationships between the facial features. The failure to recognise faces has sometimes been attributed to a complete loss of the configural strategy (Saumier, Arguin, & Lassonde, 2001). Consequently, prosopagnosics are said to perceive faces in terms of analytic processing of facial features in contrast to a more integrated approach using configural information as engaged in normals. It is not known what causes the configural deficit in prosopagnosia. Depending on the nature of damage impaired face identity recognition may manifest at different stages of face processing (Bruce & Young, 1986; Fox, Iaria, & Barton, 2008). Two main subtypes of prosopagnosia have been defined depending on the locus of damage. These include apperceptive and associative forms (Barton, Cherkasova, Press, Intriligator, & O'Connor, 2004; De Renzi, Faglioni, Grossi, & Nichelli, 1991; Sergent & Signoret, 1992b). In apperceptive prosopagnosia the main deficit is in generating an adequate percept of a seen face with which to match against a stored memory. The deficit here is therefore in encoding the facial stimulus. In contrast, in associative prosopagnosia early perceptual processes are considered intact, but the individual incapable of accessing identity-semantic information in response to face stimuli (Bruyer, 1991; De Renzi et al., 1991; Farah, 1991). Impairment in these cases is thought to stem from deficient processing at stages which follow encoding including, matching the sensory representation to a stored representation or an inaccessibility of memory representations, or both.

An individual's visual scanpath record corresponds to the pattern of eye movements or saccades that are made during visual processing and informs as to the nature of information acquired from a scene or stimulus (Gordon et al., 1992; Manor et al., 1999; Norton & Stark, 1971). Scanpath parameters such as the pattern of eye fixations can be used to inform where attention is being allocated (Rayner, 1995). Perception results from the integration of information acquired across eye fixations and as such is governed by the efficiency and distribution of gaze control (Bloom & Mudd, 1991; Henderson & Hollingwort, 1999). Eye movement studies to different stimuli such as scenes and objects have found that the sequence of eye movements or visual exploration pattern is not random (Noton & Stark, 1971; Rayner, 1995). Indeed, face identity recognition in non-patient groups has been linked to a stereotyped sequence of viewing directed towards the internal configuration of facial features including the eyes, mouth and nose respectively, and away from peripheral regions including the hair/hairline and ears (Henderson, Falk, Minut, Dyer, & Mahadevan, 2001; Mertens, Siegmund, & Grusser, 1993; Rizzo, Hurtig, & Damasio, 1987; Schwartz, Rosse, Johri, & Deutsch, 1999; Walker-Smith, Gale, & Findlay, 1977). This visuo-cognitive strategy has been associated with the formation of a unified configural percept involving information from the internal facial features and their configuration. This is thought to be necessary for accurate face identity recognition (Norton & Stark, 1971).

Abnormalities of visual scanning of expressive faces in schizophrenia (Kee, Kern, & Green, 1998; Loughland, Williams, & Gordon, 2002; Manor et al., 1999; Rosse, Schwartz, Johri, & Deutsch, 1998; Schwartz et al., 1999; Streit, Wolwer, & Gaebel, 1997), autism

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(Pelphrey et al., 2002), social phobia (Horley, Williams, Gonsalvez, & Gordon, 2003), and individuals with amygdala damage (Adolphs et al., 2005), have been linked to deficits in emotional recognition in these patient groups. Indeed, compared to non-patient groups the scanpaths tend to be non-focal, more erratic, and undirected, often reflecting the processing of limited internal featural information. As a result, it has been argued in these groups that those stimulus attributes linked to information from the internal face region are not adequately extracted and there is insufficient information to inform an accurate response. While in different patient groups scanpath parameters have been examined with respect to facial expression recognition, similar technology may be used to assess the pattern of scanning during face identity recognition in prosopagnosic patients.

Remarkably, given the interest in visual scanpath data in psychiatric populations, to date, few studies have examined the eye movement pattern of prosopagnosic patients. The results have been mixed. Rizzo et al. (1987) showed that compared to controls there was no deviation in the eye movement pattern during face learning and recognition in two patients tested: saccades, fixation and feature scanning of scenes and faces were normal. The study did however identify individual differences in the mode of scanning familiar compared to unfamiliar faces. This result is comparable to findings of covert recognition in other prosopagnosics using autonomic and behavioural indexes (Barton & Cherkasova, 2003; Barton, Cherkasova, & O'Connor, 2001; Baurer, 1984; de Haan, 1999; Diamond, Valentine, Mayes, & Sandel, 1994; Sergent & Signoret, 1992a; Wallace & Farah, 1992; Young, 1994). Indeed, qualitative differences in information processing of familiar and unfamiliar faces have been proposed in normal subjects. Behavioural studies have found that familiar faces are more accurately recognised from the internal region including the eyes–nose–mouth, than from external features such as the hair and chin, which are more important for initial processing of unfamiliar faces (Bruce & Young, 1998; Clutterbuck & Johnston, 2002; Ellis, Shepherd, & Davies, 1979). The inner face advantage is thought to be associated with the many social attributes that can be inferred from this region which carries greater configural information and is less likely to change with age (Campbell et al., 1999; Want, Pascalis, Coleman, & Blades, 2003).

Le, Raufaste, and Demonet (2003a) investigated face perception in a visual agnosic and prosopagnosic patient, SB, and found a difference in the exploration sequences and fixation number compared to controls (see also, Le, Raufaste, Roussel, Puel, and Demonet (2003b)). SB showed an aberrant scanning pattern, preferentially attending to the hair and hairline. Furthermore, in a subsequent face detection task controls fixated fewer areas of interest, a result linked to the ability to engage configural-holistic processes thought to be unavailable to SB. SB showed no scanpath evidence of covert recognition of overtly unrecognised faces. A similar discrepancy in gaze behaviour, dispersed across the whole face was also found by Schwarzer et al. (2007) in a group of hereditary prosopagnosics.

The presence of covert recognition would support evidence of a face-specific memory deficit in some instances of prosopagnosia and the absence of covert recognition, a deficit that is perceptual in nature (Barton et al., 2001; Newcombe, Young, & de Haan, 1989; Sergent & Signoret, 1992a; Sperber & Spinnler, 2003). Indeed, in both cases tested by Rizzo et al. (1987) the disturbance appeared to be a dysfunction of memory recall/retrieval rather than perception, as evidenced by normal performance on perceptual tests of face processing (see also McNeil and Warrington (1991)). In SB perceptual processing was severely impaired while his scanpath pattern failed to demonstrate covert effects. The presence or absence of evidence of covert recognition in the scanpath pattern may therefore correlate with the locus of the functional impairment.

Here we investigated the pattern of eye movements in a 38-year-old patient, SC, with severe acquired prosopagnosia. The focus of this experiment was on how SC processes visual information from faces during an identity task. The aim was to determine whether abnormalities in exploratory eye movements are associated with impaired face identity recognition. On the basis of the research reviewed above and previous findings of impaired configural processes in SC in identity and expression recognition (Stephan, Breen, & Caine, 2006), it was hypothesised that SC would show scanpath disturbances relative to controls, resulting in fewer fixations to the internal configuration of facial features and a pattern characteristic of a featural-based processing strategy.

2. Methods

2.1. Case description

A detailed description of this patient is presented elsewhere and will only be presented in brief (Stephan et al., 2006). SC is a 38-year-old male with stable prosopagnosia resulting from a motor vehicle accident at 22 years of age. Plain skull X-rays demonstrated a fracture of the right parieto-occipital bone. The Computerised Tomography (CT) scan of the brain showed a haemorrhagic contusion in the left anterior temporal lobe associated with a left sided acute subdural haematoma and ischaemia of the left parietal and occipital lobes. Following evacuation of the subdural haematoma the brain CT scan showed dilatation of the posterior horn of the left lateral ventricle with low attenuation also present in the posterior area of the right occipital lobe.

2.2. Face processing ability

SC was unimpaired on tests of face matching. He performed within normal range on the Benton Facial Recognition Test (43/54) (Benton, Sivan, Hamsher, Varney, & Spreen, 1994), and was able to match both whole faces and isolated face features without error, with 100% correct on all single feature and face feature combinations. In contrast to this preserved ability to perceive and match whole faces and face features, his performance on tasks requiring the association of a face with an identity was catastrophically impaired. In an identity recognition task he was unable to recognise faces previously familiar to him including celebrities and family (0/24 faces correct). However, he was usually able to correctly categorise faces by age and sex, for which purpose he reported relying on facial hair and the hairline.

2.3. Face recognition memory (whole faces versus face parts)

In a face learning and memory task SC could accurately encode and remember target faces suggesting some preservation of the ability to process and discriminate faces from the internal face region and store this information in memory (Stephan et al., 2006). However, his rate of learning was impaired. SC required 9 learning trials to reach the learning threshold whereas controls required an average of only 1.4 learning trials. This suggesting that incomplete or impaired representations of faces may be elaborated through repeated exposure thus leading to improved memory performance. Furthermore, while for controls identity recognition accuracy was differentially affected by information availability, such that availability of the whole internal configuration of facial features maximised recognition performance, followed by the eyes, presented either alone or in combination with the nose and mouth, SC did not show a benefit to recognition accuracy when cued by whole