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Research report

When the brain remembers, but the patient doesn't: Converging fMRI and EEG evidence for covert recognition in a case of prosopagnosia

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ABSTRACT

The role of the occipito-temporal cortex in visual awareness remains an open question and with respect to faces in particular, it is unclear to what extent the fusiform face area (FFA) may be involved in conscious identification. An answer may be gleaned from prosopagnosia, a disorder in which familiar faces are no longer recognized. This impairment has sometimes been reported to be associated with implicit processing of facial identity, although the neural substrates responsible for unconscious processing remain unknown. In this study, we addressed these issues by investigating the functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) responses to familiar and unfamiliar faces in a well-known prosopagnosic patient (P.S.). Our fMRI results show that faces known prior to the onset of prosopagnosia produce an increase in activation in the lateral fusiform gyrus encompassing the FFA, as well as the right middle frontal gyrus, when compared to unknown faces. This effect is not observed with photographs of celebrities dating after the onset of prosopagnosia. Furthermore, electrophysiological responses show that previously familiar faces differ from unfamiliar ones at around 550 msec.

Since covert processing of familiarity is associated with activation in FFA, this structure does not appear to be sufficient to produce awareness of identity. Furthermore, the results support the view that FFA participates in face individuation.

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1. Introduction

Prosopagnosia – or face agnosia – is an impairment in the recognition of faces that can occur following bilateral, and occasionally unilateral lesions in the right occipito-temporal territories (acquired prosopagnosia, see Damasio et al., 1982; Farah, 1990). Due to the variability in the location and extent of the lesions, the neuropsychological deficits often extend to other functions, including colour vision or object recognition, whilst sensory, cognitive and intellectual abilities are largely spared. Prosopagnosic patients fail to identify faces of persons they know (including relatives) and do not experience any sense of familiarity when seeing them, although they maintain the capacity to identify the individuals through alternate means or modalities, using for example voice or gait (Sergent and Signoret, 1992). In these patients, the impairment affects overt behavioural tests of face recognition. However, growing evidence suggests that some degree of covert, non-conscious processing may occur.

Covert recognition of familiar individuals has been demonstrated using a broad set of methods, particularly in patients who present no configurational deficits for faces (Schweinberger and Burton, 2003). Evidence for this has been obtained using behavioural measures based upon perceptual and/or learning approaches (Cole and Perez-Cruet, 1964; Bruyer et al., 1983; Sergent and Poncet, 1990), as well as through electrodermal measures (Bauer, 1984; Tranel and Damasio, 1985), eye movement monitoring (Rizzo et al., 1987) and event-related potential recordings (Renault et al., 1989). These studies demonstrated that, even though overt knowledge about the stimuli was absent, familiar and unfamiliar faces gave rise to different response times, somatic reactions, patterns of visual exploration and electrical brain responses, thus indicating differential processing for familiarity and/or identity without awareness. However, despite these reports evidencing covert processing of familiarity in prosopagnosics, the neuroanatomical underpinnings underlying this ability remain unclear. In particular, the role of the occipito-temporal face pathway in awareness is still debated.

In healthy controls, several functional magnetic resonance imaging (fMRI) studies, in which visual awareness of faces (Tong et al., 1998; Kleinschmidt et al., 1998) or facial identities (Grill-Spector et al., 2004; Rotshtein et al., 2005) were manipulated, showed that conscious perception of either faces or specific identities was linked to the activation of face-selective regions. It therefore appears that for conscious identification of a face to occur, activation of some areas included in the core system for face processing (Haxby et al., 2000) might be necessary. These are generally agreed to include the fusiform face area (FFA) medially (Kanwisher et al., 1997), and the occipital face area (OFA e.g., Gauthier et al., 2000) lying laterally in the inferior occipital gyrus.

However, this view has been called into question by several recent investigations. For example, Morris et al. (2007) observed that a briefly masked face could also produce BOLD activation in the FFA even without the participants' awareness. Using a masked face priming paradigm, another fMRI study demonstrated an adaptation effect in the FFA following the repetition of a face, effect that was present even when the subjects were unaware of the initial face prime (Kouider et al., 2009). Another event-related fMRI design using a different masking procedure showed that the OFA was involved in the detection of changes in identity when faces were concerned. Of particular interest is the fact that a similar level of activation was present whether or not the change in facial identity was subjectively reported (Large et al., 2008). Hence, despite the fact that the facial identities were not consciously perceived, parts of the core face processing system were found to be differentially activated when previously encountered faces were displayed.

The putative role of the extrastriate visual areas in awareness of identity may be substantiated by investigating covert processing of familiarity in prosopagnosics. Since these patients lack awareness of familiarity, activation of extrastriate face areas in response to the presentation of familiar faces should constitute evidence that these areas are not sufficient for conscious identification. However, the number of neuroimaging studies of patients with acquired prosopagnosia patients remains low to date [i.e., to our knowledge, only three have been studied: Rossion et al. (2003) – on the current patient P.S. – Marotta et al. (2001) and Steeves et al. (2006)]. In these prosopagnosics, fMRI suggested a normal activation of FFA in response to faces, thus leading to the hypothesis that functional integrity of both the FFA but also the OFA in the same hemisphere (the right[1]) is the necessary condition to achieve overt familiarity detection (Rossion et al., 2003; Rossion, 2008).

Although the contributions of these first studies on prosopagnosic patients were essential in delineating the cortical areas involved in face processing, none of them addressed the question of possible covert face recognition. Nevertheless, attempts have been made to determine whether faces, when presented repeatedly, produce the decrease in the fMR response that occurs in healthy participants, as demonstrated by the well-known paradigm called the suppression or fMR-adaptation effect (Grill-Spector and Malach, 2001). Both Schiltz et al. (2006) and Dricot et al. (2008) with patient P.S. and Steeves et al. (2006) with another patient investigated the response in functionally defined face preferential areas and demonstrated a lack of adaptation of the right FFA during multiple exposures to the same face. This was interpreted as the manifestation of the face-recognition deficit in patients. Unfortunately, no attempt has been made to search for residual correlates of face identification in prosopagnosic patients by means of tasks that are less biased towards short-term memory representations, but rely on longer-term exposure to the faces and therefore on previously well-established familiarity.

In this study, we investigated the processing of facial identity in an acquired prosopagnosic patient, P.S. in order to assess whether or not the brain responses for familiar, famous

[1] As noted below in the Materials and Methods section, patient P.S. suffers from a right OFA lesion. Hence the disruption of the OFA/FFA pathway is obvious within the right hemisphere and has been hypothesised to explain P.S.'s impairments in face identification by Rossion et al. (2003). By contrast, patient D.F. from Steeves et al. (2006) exhibits bilateral damage extending well into OFA, the relative contribution of each hemisphere in this patient's impairment is therefore not possible to ascertain.