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Research report

Evidence of an eye movement-based memory effect in congenital prosopagnosia

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ABSTRACT

While extensive work has examined the role of covert recognition in acquired prosopagnosia, little attention has been directed to this process in the congenital form of the disorder. Indeed, evidence of covert recognition has only been demonstrated in one congenital case in which autonomic measures provided evidence of recognition (Jones and Tranel, 2001), whereas two investigations using behavioural indicators failed to demonstrate the effect (de Haan and Campbell, 1991; Bentin et al., 1999). In this paper, we use a behavioural indicator, an ''eye movement-based memory effect'' (Althoff and Cohen, 1999), to provide evidence of covert recognition in congenital prosopagnosia. In an initial experiment, we examined viewing strategies elicited to famous and novel faces in control participants, and found fewer fixations and reduced regional sampling for famous compared to novel faces. In a second experiment, we examined the same processes in a patient with congenital prosopagnosia (AA), and found some evidence of an eye movement-based memory effect regardless of his recognition accuracy. Finally, we examined whether a difference in scanning strategy was evident for those famous faces AA failed to explicitly recognise, and again found evidence of reduced sampling for famous faces. We use these findings to (a) provide evidence of intact structural representations in a case of congenital prosopagnosia, and (b) to suggest that covert recognition can be demonstrated using behavioural indicators in this disorder.

Previous work has reported an eye movement-based memory effect in the viewing of familiar compared to novel stimuli (Althoff et al., 1998; Althoff and Cohen, 1999; Barton et al., 2006). This ''reprocessing effect'' is characterised by fewer fixations and the sampling of fewer regions in repeated items, and has been documented in the viewing of scenes (Ryan et al., 2000) and famous faces (Althoff et al., 1998; Althoff and Cohen, 1999; Barton et al., 2006). Evidence of the eye movement-based memory effect has also been reported in amnesic patients who were asked to view scenes (Ryan et al., 2000) and to recognise familiar faces (Althoff, 1999). Given this evidence of covert recognition, it is pertinent to ask whether the effect can be extended to prosopagnosic patients in the viewing of faces. An extensive literature exists concerning the role of covert processing in acquired prosopagnosia, yet little work has investigated such processes in its congenital equivalent. However, it has been suggested that covert recognition can only be found on autonomic and not behavioural indicators in this condition (Kress and Daum, 2003). In this paper we provide evidence against this claim,

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and show that covert recognition can be demonstrated in a case of congenital prosopagnosia using measures of the visual scanpath.

Although prosopagnosia is more commonly reported following an acquired brain injury, there has been growing interest in people who suffer from face recognition deficits from birth (Ariel and Sadeh, 1996; Avidan et al., 2005; Behrmann and Avidan, 2005; Behrmann et al., 2005; Bentin et al., 1999; Campbell, 1992; de Gelder and Rouw, 2000; de Haan, 1999; de Haan and Campbell, 1991; Duchaine, 2000; Duchaine et al., 2003a, 2004; Duchaine et al., 2006; Galaburda and Duchaine, 2003; Jones and Tranel, 2001; McConachie, 1976; Nunn et al., 2001). This condition has been referred to as 'congenital prosopagnosia', and is characterised by a face processing impairment that has been present from birth, in the context of intact visual and intellectual functions and in the absence of any neurological damage (Jones and Tranel, 2001). Some case studies have reported a familial connection in congenital prosopagnosia (Behrmann et al., 2005; Bentin et al., 1999; de Haan, 1999; Duchaine, 2000; Duchaine et al., 2003b; Kracke, 1994; McConachie, 1976), and a recent study suggests there is a genetic basis for the disorder (Grüeter et al., 2007). The condition is therefore distinguished from the umbrella term 'developmental prosopagnosia', which is used when the condition results from neurological damage at any stage of development, visual deprivation such as infantile cataracts, or from other developmental problems such as autism.

The performance of individuals who present with congenital prosopagnosia is inconsistent, raising the possibility that the condition may not be a unitary disorder (Kress and Daum, 2003). Indeed, some perform relatively well in feature-matching tasks, yet reaction time is often slow and the impairment is revealed when task demands are increased (Kress and Daum, 2003). Similarly, mixed findings have emerged in tasks requiring recognition of famous faces. Some people with congenital prosopagnosia recognise very few, if any, famous faces (Bentin et al., 1999; de Gelder and Rouw, 2000), whereas others appear to show reasonably intact recognition abilities (Duchaine, 2000; Duchaine and Nakayama, 2005; Schwarzer et al., 2007; Temple, 1992). Further, it is also unclear whether the same distinction can be applied across the apperceptive (an impairment in deriving an intact percept of a face) and associative (impairment at the level of semantics) subtypes as reported in acquired prosopagnosia (de Renzi et al., 1991). Indeed, the majority of congenital cases is present with a perceptual impairment, with only three cases in the literature apparently showing the associative form of the disorder (Dr S: Temple, 1992; BC: Duchaine, 2000; TA: Jones and Tranel, 2001).

This sub-classification is particularly important given evidence of a relationship between covert recognition and perceptual impairment. In acquired prosopagnosia, covert recognition has been demonstrated in virtually all patients with an associative impairment but only in some patients with an apperceptive impairment. This finding suggests that some residual capacity to encode face representations is required to demonstrate covert recognition. Some authors have argued against the existence of covert processing in congenital prosopagnosia, because this process relies on sub-threshold activation of previously intact face representations (e.g., Barton et al., 2001). Evidence in support of this statement is mixed. de Haan and Campbell (1991) and Bentin et al. (1999) failed to find evidence of covert recognition in their patients with congenital prosopagnosia (AB and YT) using behavioural measures. However, a recent study has demonstrated covert recognition in a case of congenital prosopagnosia using an autonomic measure (TA: Jones and Tranel, 2001). In this five-year-old boy, skin conductance responses were enhanced during presentations of familiar faces (family and close friends), despite his inability to name any of these people. In line with dual-route models of face recognition (e.g., Breen et al., 2000; Ellis and Lewis, 2001), it has been argued that covert processing can only be found using autonomic and not behavioural indicators in this condition (Kress and Daum, 2003). However, an alternative explanation may lie in the nature of the impairment in these patients. Importantly, AB and YT display perceptual impairments that would classify them as having an apperceptive form of the disorder, whereas TA is more representative of the associative form (see de Renzi et al., 1991). While it is not clear whether these two subtypes map onto congenital prosopagnosia in the same manner as they do in acquired prosopagnosia (Kress and Daum, 2003), it is nevertheless not surprising that behavioural tests of covert recognition did not reveal residual knowledge in AB and YT. According to this hypothesis, we would predict that TA (who presents with an associative impairment) would also show evidence of covert recognition on behavioural measures. Unfortunately, these data were not collected and it remains to be shown whether covert recognition can be demonstrated using behavioural measures in another case of associative congenital prosopagnosia.

The monitoring of eye movements provides another means to observe covert processing (Bruyer, 1991). Indeed, Althoff and colleagues (Althoff et al., 1998; Althoff and Cohen, 1999) present evidence of an eye movement-based memory effect as a means to discriminate between the viewing of famous and novel faces in healthy participants. In comparison to famous faces, the viewing of novel faces was characterised by more fixations, more regions (i.e., facial features) sampled, more fixations made before returning to a previously sampled region, and a greater proportion of fixations elicited to the left side of space and the inner features (i.e., eyes, nose and mouth). Further, these authors used first- and second-order Markov matrices to examine the sequential organization of scanning, and suggested that famous faces were associated with more random scanning sequences than novel faces. Barton et al. (2006) reported a similar distinction between the viewing of famous and novel faces using fixation-based measures (number of fixations and total dwell time), but could not replicate the finding using Markov matrices.

Various measures of the scanpath have been used to provide evidence of covert recognition in neurological patients. Rizzo et al. (1987) used first-order Markov matrices to provide evidence of covert recognition in two patients with acquired prosopagnosia, although they could not replicate this finding in their healthy control participants. Further, two studies have examined the eye movement-based memory effect in patients with amnesia. Ryan et al. (2000) noted a difference in the viewing strategies elicited to repeated and novel scenes in their patients with amnesia, characterised by reduced sampling (i.e., fewer fixations and fewer regions