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Visual expertise for horses in a case of congenital prosopagnosia

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ABSTRACT

A major question in the domain of face perception is whether faces comprise a distinct visual category that is processed by specialized mechanisms, or whether face processing merely represents an extreme case of visual expertise. Here, we examined O.H, a 22 years old woman with congenital prosopagnosia (CP), who despite her severe deficits in face processing, acquired superior recognition skills for horses. To compare the nature of face and horse processing, we utilised the inversion manipulation, known to disproportionally affect faces compared to other objects, with both faces and horses. O.H's performance was compared to data obtained from two control groups that were either horse experts, or non-experts. As expected, both control groups exhibited the face inversion effect, while O.H did not show the effect, but importantly, none of the participants showed an inversion effect for horses. Finally, gaze behaviour toward upright and inverted faces and horses was indicative of visual skill but in a distinct fashion for each category. Particularly, both control groups showed different gaze patterns for upright compared to inverted faces, while O.H presented a similar gaze pattern for the two orientations that differed from that of the two control groups. In contrast, O.H and the horse experts exhibited a similar gaze pattern for upright and inverted horses, while non-experts showed different gaze patterns for different orientations. Taken together, these results suggest that visual expertise can be acquired independently from the mechanisms mediating face recognition.

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1. Introduction

1.1. Characteristics of face perception

Faces have distinctive evolutionary and social significance and, therefore, they have long been considered a unique object category. The unique properties of face perception have often been attributed to holistic processing. Namely, perception which relies not only on processing of the features comprising the face, but also on the gestalt of these features (Maurer et al., 2002). Holistic processing have been investigated using a number of well-known experimental manipulations including the inversion effect (Farah et al., 1995; Freire et al., 2000; Yin, 1969), part-whole effect (Gauthier and Tarr, 2002; Tanaka and Farah, 1993) and the composite effect (Boutet et al., 2002; Farah et al., 1998; Young et al., 1987; Gauthier et al., 2003). Of most relevance for the present study is the face inversion effect, indicating the disproportional decrement in perception (Haxby et al., 1999), recognition (Brooks and Goldstein, 1963) and memory (Goldstein, 1965; Hochberg and Galper, 1967; Yin, 1969) for inverted, compared to upright faces relative to the effect of inversion on processing other object categories. The common interpretation of this finding is that while upright faces are processed in a holistic, efficient manner which emphasises the invariant structure of the identity of the face, inverted faces are processed in a featural, piecemeal manner leading to the typical reduced performance observed in this condition (Barton et al., 2001; Farah et al., 1995; Rhodes et al., 1993; Rossion, 2009, 2008, but see Susilo et al. (2013)). It has been often argued that other objects are less prone to the inversion manipulation because their processing relies less heavily on holistic perception, compared to faces. Note however that some researchers argue that the face inversion effect does not necessarily index holistic processing (Murray, 2004; Richler et al., 2011; Richler and Gauthier, 2014; Sekuler et al., 2004). Rather, they suggest that while inverted faces are processed less efficiently than upright faces, this cost in performance is quantitative rather than qualitative in nature. We will return to this claim in Section 4 in relation to our results.

An additional and important measure for assessing the nature of face processing is gaze behaviour and eye movement patterns. Many studies revealed that when looking at human faces, normal individuals tend to fixate on the eyes and the nose more than on other features comprising the face (e.g., mouth, cheeks, and chin), a pattern that was attributed to a holistic processing strategy (Belle et al., 2010; Schwarzer et al., 2005, 2007). In contrast, an analytical strategy yields more fixations towards the specific informative regions of the face, which are dependent on the task's

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requirements (Schwarzer et al., 2005). This result is consistent with findings showing atypical gaze behaviour in individuals with disrupted holistic face perception due to Autism (Dalton et al., 2005), acquired prosopagnosia (Bukach et al., 2006a), or congenital prosopagnosia (CP). Pertinent to the present study are findings showing that individuals with CP exhibit reduced gaze preference towards the eyes (Schmalzl et al., 2008), and tend to rely more heavily on external and dispersed regions of the face (Schwarzer et al., 2007).

Based on the wealth of behavioural and neural findings, it is often assumed that faces comprise a unique object category, however despite much research, this issue is still contentious. Specifically, some researchers claim that faces are processed by "domain specific" distinct cognitive and neural systems which are different from those devoted to other object categories (Kanwisher, 2000; McKone and Robbins, 2007; Weiner and Grill-Spector, 2013; Yovel and Kanwisher, 2004) and may even be innate (Goren et al., 1975; McKone et al., 2007). In contrast, others have proposed the opponent, "expertise hypothesis" according to which face perception and representation is not unique, but rather, represents an extreme case of visual expertise (Bukach et al., 2006a; Gauthier and Bukach, 2007; McGugin et al., 2012), hence implicating that processing faces and objects of expertise depend on the same cognitive and neural mechanisms.

In the current study, we present a case study of an individual, O. H, who has congenital prosopagnosia (CP), a life-long impairment in face processing despite normal sensory vision and normal intelligence and in the absence of neurological history, who nevertheless reported having an expertise for horses. The goal of this study is to test whether this individual indeed presents visual expertise in a visual category not related to faces, and if so, whether such expertise would be associated with holistic processing, as has been suggested in other studies (see below). These unique circumstances, in which face perception is impaired while visual expertise naturally emerged in a different visual domain, allow us to disentangle the cognitive mechanisms mediating visual expertise.

1.2. Processing objects of expertise

As outlined above, some researchers have suggested that faces represent a special case of acquisition of visual expertise (Bukach et al., 2006a; Gauthier and Bukach, 2007). According to this view, one would expect that other objects of expertise would share some common characteristics with faces related to the underlying mechanisms mediating expertise. Below, characteristics of face processing will be compared to those of objects of expertise as they appear in several studies, and subsequently, some evidence for a possible dissociation between face processing and processing objects of expertise will be presented.

1.2.1. Holistic processing for objects of expertise

Given the centrality of holistic processing in face perception, a major question is whether objects of expertise are also processed holistically. This question has been addressed in a number of studies and the results thus far are conflicting. For example, in a study conducted by (Diamond and Carey, 1986), subjects who were dog experts (i.e., breeders and judges in dogs' competitions) exhibited an inversion effect when presented with pictures of dogs, while in contrast, non-experts exhibited no difference in performance between upright and inverted photos of dogs. Another study that examined holistic processing for natural objects of expertise, documented the composite effect for cars, in car experts, and the effect was correlated with the extent of expertise (Gauthier et al., 2003). Along similar lines, Wong et al. (2009) showed that even in expertise that was acquired in a short period of laboratory training (in contrast to real-life expertise), participants acquired holistic processing as evident by a composite effect obtained for the artificial, trained objects ("Ziggerins"). Another study by Gauthier and Tarr (1997) attempted to show configural processing for another category of artificial objects ("greebles") following training, however, this study only revealed configural sensitivity to the greebles, but did not find other "signature" holistic effects such as the "part-whole" or "inversion" effects in greeble experts compared to novices. A different set of studies used a basic-level detection task to examine possible commonalities between faces and objects of expertise. These studies showed interference for face detection in the presence of objects of expertise, regardless of their task-relevance (Hershler and Hochstein, 2009; McGugin et al., 2010), suggesting a common, holistic search mechanism for both stimuli.

In contrast to the findings described above, Robbins and McKone (2007) also investigated face-like processing in dog experts and novices but did not find any evidence for holistic processing in neither experts nor novices (no inversion or composite effect). Furthermore, a study by Harel and Bentin (2013) undermined the necessity of holistic processing, typically mediated by low spatial frequencies for objects of expertise, by showing an advantage for processing images of cars containing only high spatial frequencies in cars experts. Another study by the same group (Golan et al., 2013) have demonstrated better visual detection of cars by cars experts compared to non-experts, as opposed to similar performance for faces by CP individuals (who may be considered face novices) and a control group, implying different mechanisms for detecting faces and objects of expertise.

Finally, several studies used eye tracking to examine the underlying mechanisms of expertise (Manning et al., 2006; Donovan and Litchfield, 2013). In these studies radiologists were required to search for a pathological finding in a chest x-ray. Expert radiologists used less dispersed fixations, focusing on the regions with higher probability for locating abnormality, compared to novices. This may imply a local, but yet, more efficient search strategy for experts.

1.2.2. Dissociation between the perception of faces and objects of expertise

In addition to studies which examined the extent of similarity between the mechanisms underlying processing of faces and objects of expertise, some studies reported dissociations between face perception and objects of expertise in cases of visual agnosia or acquired prosopagnosia (AP). For example, an AP patient who showed preserved recognition ability for cars despite his severe deficit in face recognition (Sergent and Signoret, 1992), a farmer who lost his ability to recognise his cows, but retained his face recognition ability, following a lesion in occipital–temporal regions (Assal et al., 1984), and an AP patient who became a farmer following his brain injury, and developed expertise for sheep, while having impairments in face perception (McNeil and Warrington, 1993). Other studies described experimental training manipulations that attempted to train AP (Behrmann et al., 2005a, 2005b; Bukach et al., 2012; Rezlescu et al., 2014) and CP (Duchaine et al., 2004) individuals to acquire expertise in a new category in spite of their impaired face processing abilities, thus indicating a distinction between face recognition and the ability to acquire expertise in a different visual category. Note though, that Bukach et al. (2012) suggested that the expertise acquired by the AP patient they trained, was accomplished through more analytic mechanisms and not the holistic mechanisms normally used for face perception, which are impaired in this patient. Taken together, these case studies illustrate a possible dissociation between performance associated with face perception, and acquired or maintained abilities in other domains of visual expertise, and therefore suggest that different behavioural mechanisms may be involved in face perception compared to the processing of other objects of expertise.

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