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Does acquisition of Greeble expertise in prosopagnosia rule out a domain-general deficit?

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ABSTRACT

According to the expertise account of face specialization, a deficit that affects general expertise mechanisms should similarly impair the expert individuation of both faces and other visually homogeneous object classes. To test this possibility, we attempted to train a prosopagnosic patient, LR, to become a Greeble expert using the standard Greeble expertise-training paradigm (Gauthier & Tarr, 2002). Previous research demonstrated that LR's prosopagnosia was related to an inability to simultaneously use multiple features in a speeded face recognition task (Bukach, Bub, Gauthier, & Tarr, 2006). We hypothesized that LR's inability to use multiple face features would manifest in his acquisition of Greeble expertise, even though his basic object recognition is unimpaired according to standard neuropsychological testing. Although LR was eventually able to reach expertise criterion, he took many more training sessions than controls, suggesting use of an abnormal strategy. To further explore LR's Greeble processing strategies, we assessed his ability to use multiple Greeble features both before and after Greeble training. LR's performance in two versions of this task demonstrates that, even after training, he relies heavily on a single feature to identify Greebles. This correspondence between LR's face recognition and post-training Greeble recognition supports the idea that impaired face recognition is simply the most visible symptom of a more general object recognition impairment in acquired prosopagnosia.

1. Introduction

Patients with prosopagnosia are characterized as showing a disproportional impairment in recognizing faces as compared to other types of objects, however, the specificity of this impairment is a matter of some debate. On the one hand, some researchers suggest that prosopagnosia involves damage to mechanisms that are specific to faces (e.g., Duchaine, Yovel, Butterworth, & Nakayama, 2006; Farah, Levinson, & Klein, 1995). Under this account, damage to face-specific mechanisms should leave recognition ability for all other object classes intact. On the other hand, other researchers suggest that the apparent face-selectivity associated with prosopagnosia is due to factors such as the insensitivity of the methods used to assess object recognition and the (typically) greater demands of face individuation both in the laboratory and in everyday life (e.g., Damasio, Damasio, & Van Hoesen, 1982; Gauthier, Behrmann, & Tarr, 1999). In particular, the expertise account of face-specificity (Diamond & Carey, 1986; Gauthier & Tarr, 1997) hypothesizes that face recognition is a particular example of more domain-general mechanisms that potentially support expert-level within-category individuation across most visually homogeneous object categories. Under this account, impairments of the mechanisms that are necessary for expert face recognition should also affect the acquisition of expertise for non-face homogeneous object classes. The nature and specificity of category-selective deficits such as prosopagnosia therefore provides some constraints for theories of normal object recognition. Here, we scrutinize the specificity of impairment in one case of acquired prosopagnosia – with a deficit that appears specific to faces as assessed by standard neuropsychological tests – and find that similar deficits are present for faces and for non-face objects of expertise.

By definition, individuals with prosopagnosia have a disproportionate impairment in recognizing faces compared to other types

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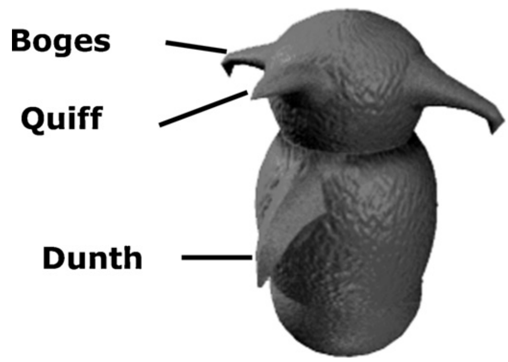

Fig. 1. Image of a Greeble with Boges, Dunth, and Quiff parts labeled.

of objects. From the earliest reported cases, the disproportionate deficit in face recognition has been interpreted as evidence for neural mechanisms that are specific to faces (e.g., Bodamer, 1947 as cited by Ellis, 1996). However, some researchers have questioned the specificity of the impairment, pointing out that face recognition requires within-class discrimination of individual exemplars that are visually similar, whereas most other types of objects require only between-class discrimination of visually dissimilar objects (Damasio et al., 1982; Faust, 1955, as cited by Hecaen, 1981). The evidence for face-specificity in prosopagnosia has been quite mixed, with several cases reported to have completely spared within-class discrimination (Bruyer et al., 1983; Busigny, Graf, Mayer, & Rossion, 2010; de Renzi, 1986; Farah et al., 1995; McNeil & Warrington, 1993; Riddoch, Johnston, Bracewell, Boutsen, & Humphreys, 2008), and several others reported to have impaired within-class discrimination (Blanc-Garin, 1984; Bornstein, 1963; Bornstein, Sroka, & Munitz, 1969; Damasio et al., 1982; Gauthier, Behrmann, et al., 1999; Gloning & Quatember, 1966; Lhermitte & Pillon, 1975). Recently, a novel approach that used preserved semantic knowledge to estimate pre-morbid car expertise levels of six prosopagnosic participants found that all six had car recognition impairments compared to matched controls (Barton, Hanif, & Ashraf, 2009).

Studies of neurologically typical individuals have likewise produced mixed evidence for the specificity of face recognition (for a recent review, see Bukach & Peissig, 2010). Supporting the face-specificity stance, faces recruit an area in the fusiform gyrus more than any other class of objects (Kanwisher, McDermott, & Chun, 1997), show an N170 component greater for faces than for other types of objects (Bentin, Allison, Puce, Perez, & McCarthy, 1996), and show more evidence of holistic and relational processing than other types of objects (Leder & Carbon, 2006; Young, Hellawell, & Hay, 1987). Supporting a more general expertise stance, studies of real-world expertise (such as car, bird, and fingerprint experts) show patterns of neural and behavioral markers similar to those seen for faces (e.g., Bukach, Phillips, & Gauthier, 2011; Busey & Vanderkolk, 2005; Gauthier, Curran, Curby, & Collins, 2003; Gauthier, Skudlarski, Gore, & Anderson, 2000; Righi, Tarr, & Kingon, in press; Tanaka & Curran, 2001; Xu, 2005).

Most saliently, much of the support for the expertise hypothesis has relied on data from the acquisition of expertise using "Greebles" (Gauthier & Tarr, 1997): novel homogeneous objects that share a common configuration of parts – a property that according to Diamond and Carey (1986), makes faces distinct from other object classes. Like faces, which have eyes above nose above mouth, Greebles also have three primary parts in a stable configuration: Boges above Quiff above Dunth (Fig. 1).[1] Identification of individual objects with a common overall configuration of parts is thought to recruit more metric aspects of shape as well as their second order spatial relationships.

Greebles can be classified at a "family" level as well as an "individual" level. In the typical training paradigm with Greebles (Gauthier & Tarr, 2002), subjects practice both levels of classification until response times for individual judgments (typically slow to begin with) are statistically equivalent to response times to family level judgments. This criterion is based on findings that experts tend to be as fast to make a subordinate level judgment as a more superordinate level judgment (Tanaka, 2001). Greeble studies have found that, as expertise is acquired, subjects show similar behavioral and neural patterns as those thought to be specific to face recognition, including holistic and relational processing, recruitment of the FFA, and a strong N170 when viewing novel Greeble exemplars not used during training (Gauthier & Tarr, 1997; Gauthier & Tarr, 2002; Gauthier, Tarr, Anderson, & Gore, 1997; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier, Williams, Tarr, & Tanaka, 1998; Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002). Thus, there is some evidence that Greeble expertise recruits computational and neural mechanisms that are common to those mechanisms recruited by face recognition.

This correspondence between Greeble expertise and face recognition has been questioned on the basis that a developmental prosopagnosic patient, Edward, was able to individuate Greebles after training (Duchaine, Dingle, Butterworth, & Nakayama, 2004; Duchaine et al., 2006). Duchaine et al. reported that Edward met criterion in sessions one, three, four, six and eight. Unfortunately, there were several differences in data analysis that make it difficult to conclude whether in fact Edward reached criterion according to the traditional standard used in earlier studies.[2] Nonetheless, it is clear that Edward's learning trajectory was within normal age-matched limits, and had training continued, he may have reached the stricter criterion used in previous studies. However, we hold that this finding alone is insufficient to invalidate the conclusions of previous expertise studies and to conclude that face recognition and Greeble recognition rely on separate mechanisms as Duchaine et al. claim. In particular, evidence for separate mechanisms would require a demonstration that Edward could learn to individuate 20 Greebles, but be unable to learn to individuate 20 faces using the same task. Moreover, the potential sensitivity of the acquisition of expertise to prosopagnosia may depend on the underlying cause of the prosopagnosia; that is, whether the specific mechanisms used in the *acquisition* of expertise are concomitantly impaired (for a similar argument, see Bukach, Gauthier, & Tarr, 2006). Thus, specific predictions for the acquisition of Greeble expertise, and likewise, performance on any test with nonface objects, should depend on the particular deficit that underlies the face recognition impairment. Consequently, the "space" of neuropsychological

[1] For a discussion of the issue as to whether Greebles "look like" faces, see Sheinberg, Tarr, Gauthier, and Bub (2010).

[2] Traditionally, only response time data to verification hits (correct trials in which the label and Greeble match) from the *20 known Greebles* are analyzed after the initial introduction to all 20 Greebles has been accomplished. Thus we do not test for criterion before session five, and verification data from the 10 "unknown" Greebles are excluded. In addition, to assure that response time estimates are reliable and expertise criterion is not met prematurely due to high variability, data are binned across two verification blocks (called "sessions" by Duchaine et al.), and a dependent *t*-test is carried out on the average response times by stimulus ($df = 19$). It is not clear whether Duchaine et al. excluded data from hits to "unknown" Greebles, nor what type of statistical test was used as they did not report *df*. More importantly, they did not bin data from multiple blocks, and thus criterion may have been reached due to high variability, rather than because the means were close. In fact, the last training session plotted in Edward's graph suggests that average response time to individual trials was at least 500 ms longer than average response time to family judgments.