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Faces forming traces: Neurophysiological correlates of learning naturally distinctive and caricatured faces

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ABSTRACT

Distinctive faces are easier to learn and recognise than typical faces. We investigated effects of natural vs. artificial distinctiveness on performance and neural correlates of face learning. Spatial caricatures of initially non-distinctive faces were created such that their rated distinctiveness matched a set of naturally distinctive faces. During learning, we presented naturally distinctive, caricatured, and non-distinctive faces for later recognition among novel faces, using different images of the same identities at learning and test. For learned faces, an advantage in performance was observed for naturally distinctive and caricatured over non-distinctive faces, with larger benefits for naturally distinctive faces. Distinctive and caricatured faces elicited more negative occipitotemporal ERPs (P200, N250) and larger centroparietal positivity (LPC) during learning. At test, earliest distinctiveness effects were again seen in the P200. In line with recent research, N250 and LPC were larger for learned than for novel faces overall. Importantly, whereas left hemispheric N250 was increased for learned naturally distinctive faces, right hemispheric N250 responded particularly to caricatured novel faces. We conclude that natural distinctiveness induces benefits to face recognition beyond those induced by exaggeration of a face's idiosyncratic shape, and that the left hemisphere in particular may mediate recognition across different images.

Introduction

There is growing evidence that unfamiliar faces are processed qualitatively different than familiar ones. Familiar faces can be recognised with little effort even under difficult viewing conditions (Burton et al., 1999; Hancock et al., 2000). In contrast, unfamiliar face recognition is hampered by even minor differences between two pictures of the same face, and similar impairments apply to simultaneous face matching (Braje et al., 1998; Bruce et al., 1999; Hancock et al., 2000; Megreya and Burton, 2006). These observations have led to the assumption that familiar and unfamiliar faces may be processed in qualitatively different ways, with flexible, "abstract" processing of familiar faces, and more image-dependent processing of unfamiliar faces (for a recent review see Johnston and Edmonds, 2009). It has even been claimed that "unfamiliar faces are not faces" (Megreya and Burton, 2006), on the basis of the observation that unfamiliar faces, just like inverted faces, are processed in a more feature based manner similar to non-face objects. However, as face familiarity is achieved through learning initially unfamiliar faces, the question arises what characterises this transition. There seems to be a strong tendency among researchers to assume that facial shape (i.e., shape of individual features as well as their spatial configuration) is crucial for face recognition (e.g., Ellis et al., 1979; Maurer et al., 2002). However, the recognition of familiar faces is surprisingly preserved even for "shape-free" (Burton et al., 2001; Burton et al., 2005; Calder et al., 2001) and spatially distorted faces (Hole et al., 2002). One possibility is that spatial information is important for the encoding of unfamiliar faces, but that non-spatial information (e.g., texture) is relatively more important for familiar face recognition. In line with this idea, a recent study showed effects of moderate spatial caricaturing for unfamiliar, but not for familiar face processing (Kaufmann and Schweinberger, 2008).

We used event-related potentials (ERPs) to investigate how facial distinctiveness benefits face learning. Distinctiveness is often measured by asking the question of how easily a presented face can be detected in a crowd, e.g., on a busy train platform (Valentine and Bruce, 1986). But what exactly constitutes distinctiveness? According to the Multidimensional Face-Space Model (MDFS; Valentine, 1991), the dimensions of face-space represent all characteristics on which faces differ from one another. As the values on each dimension are supposed to be normally distributed, a majority of typical faces is supposed to cluster around the centre of face-space (but see Burton and Vokey, 1998). In contrast, distinctive faces differ from others in their position on one or more dimensions. They lie further in the periphery of face-space and therefore stand out. Facial distinctiveness facilitates

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efficient encoding and recognition (Dewhurst et al., 2005; Going and Read, 1974; Hancock et al., 1996; Vokey and Read, 1992).

Importantly, distinctiveness can be artificially enhanced by means of caricaturing (Lee et al., 2000; Rhodes et al., 1997; Stevenage, 1995). A common method is spatial caricaturing which exaggerates spatial differences between an individual and an averaged face. As this overstates the shape of both single features and their spatial configuration, the result is enhanced perceived distinctiveness. Mostly based on studies using line drawings, it has been claimed that caricatures of famous faces are recognised better, and are perceived as better likenesses, than veridical faces (the "superportrait hypothesis"; cf. Mauro and Kubovy, 1992; Rhodes, 1996). However, more recent studies using photorealistic caricatures (Allen et al., 2009; Hancock and Little, 2011; Kaufmann and Schweinberger, 2008, 2012) suggest that caricaturing does not enhance familiar face *recognition*, but that it does enhance face *learning*. Kaufmann and Schweinberger (2012) demonstrated that unfamiliar caricatures were better learned and recognised, with concomitant modifications of event-related potentials (ERPs; e.g., N170, P200, and N250, see below) associated with face processing.

Different ERP components can be utilised to study specific processing stages as described in cognitive models of face processing (Bruce and Young, 1986; Burton et al., 1990; Haxby et al., 2000; Schweinberger and Burton, 2003; for a review cf. Schweinberger, 2011). At ~100 ms after the presentation of a visual stimulus, the occipital P100 is sensitive to low-level stimulus properties such as luminance, spatial frequency, and brightness (Spehlmann, 1965), as well as to spatial attention (Mangun, 1995). An early face-sensitive component, the occipitotemporal N170 (Bentin et al., 1996), may be associated with categorical face "detection" or "structural encoding" (Bruce and Young, 1986). The N170 is delayed and enhanced by face inversion (Rossion et al., 1999; Schweinberger et al., 2004) and is reduced by feature scrambling (Latinus and Taylor, 2006). As the N170 shows little sensitivity to familiarity (Bentin and Deouell, 2000; Eimer, 2000) or exemplar repetition (Amihai et al., 2011; Schweinberger et al., 2002), it seems to be associated with processes preceding recognition. A relatively neglected component, the occipitotemporal P2 or P200, may reflect the processing of second-order relations between facial features (Latinus and Taylor, 2006). Importantly for the present study, the P200 has been related to perceived typicality of an unfamiliar face (Halit et al., 2000; Latinus and Taylor, 2005; Lucas et al., 2011; Stahl et al., 2008). A subsequent component, the occipitotemporal N250(r), is highly sensitive to repetitions of familiar faces, and has been related to the recognition of familiar or learned faces (e.g., Bindemann et al., 2008; Gosling and Eimer, 2011; Kaufmann et al., 2009; Schweinberger et al., 2002; Tanaka et al., 2006). Finally, a centroparietal late positive component (LPC) is often larger for previously encountered compared to novel stimuli (Friedman and Johnson, 2000; Rugg et al., 1996). This difference, the ERP "old/new effect", is generally observed in recognition memory experiments, across stimulus domains and modalities. In the context of face recognition, this component may be related to the activation of "Person Identity Nodes" (PINs; Burton et al., 1990), and thus may reflect explicit episodic and/or semantic memory (Bentin and Deouell, 2000; Schweinberger and Burton, 2003).

Although right hemisphere (RH) superiority is typically assumed for face recognition (Farah, 1990), recent evidence also suggests a left hemisphere (LH) contribution to image-independent processing in particular (Cooper et al., 2007; Kaufmann et al., 2009; see also Marsolek et al., 1992, for similar results using non-face stimuli).

To date, surprisingly few studies investigated ERP correlates of the processing of facial distinctiveness. One revealed an increased "Difference due to memory" (Dm) component at the encoding of naturally distinctive faces (Sommer et al., 1995). In addition, more recent studies observed effects of spatial caricaturing in terms of increased ERP negativity in the N170 and N250 responses (Kaufmann and Schweinberger, 2008), as well as in the occipitotemporal P200. Kaufmann and Schweinberger (2012) used spatially caricatured (two levels, 35% and 70%) and veridical faces in a learning paradigm, and showed near-linear increases with caricaturing level both in performance and in the amplitude of posterior ERP negativity in the P200 and N250 time ranges. However, since only veridical and caricatured faces were used, the possibility remains that the effects were caused solely by spatial distortions rather than by increased distinctiveness (for potentially related findings, cf. Burkhardt et al., 2010). Another limitation was the use of identical images at learning and test, which prevents any firm conclusions as to whether effects of caricaturing would generalise across images of learned faces.

The present study is to our knowledge the first to compare learning of spatial caricatures, *naturally distinctive*, and non-distinctive faces, in order to investigate ERP correlates of the acquisition of face representations. Importantly, we presented slightly different images of one identity at learning and test in order to study face – rather than image – recognition. Accordingly, and considering previous findings (e.g., Cooper et al., 2007; Kaufmann et al., 2009), we expected to find evidence for left hemisphere involvement in face recognition across images. Importantly, to compare the effects of artificial spatial exaggeration with those of natural distinctiveness, we ensured that caricatured and naturally distinctive faces were comparable in rated distinctiveness. We reasoned that similarities or differences between caricatures and naturally distinctive faces would help to further clarify the relative contribution of spatial information (as compared to non-spatial information such as texture) to distinctiveness and face learning.

We expected better learning for both naturally distinctive and caricatured faces compared to non-distinctive ones. ERPs were assessed at learning and test, with a specific focus on the N170, P200, N250, and LPC components (as discussed above), to clarify the precise mechanisms mediating any improved learning for these two types of faces. Specifically, if natural distinctiveness facilitates face learning via the same mechanisms as spatial caricaturing (possibly via more unique features and/or second-order spatial configurations), we would expect natural distinctiveness to elicit comparable ERP effects (e.g., reduced P200 and enhanced N250 responses) to those already established for spatial caricaturing. Alternatively, to the extent that the advantage of natural distinctiveness is only partially due to spatial information, amplitude effects of natural distinctiveness might be expected, over and above those seen by spatial caricaturing. Finally, a third possibility is that spatial caricaturing and natural distinctiveness elicit qualitatively (i.e., in timing, topography, or hemispheric involvement) different ERP effects.

Material and methods

Participants

Thirty-five participants (age in years: $m=22.9$, $SD=2.4$; 21 females; 32 right-handed) contributed data. All had normal or corrected-to-normal vision, and received course credit or were paid for participation. An additional bonus was contingent on correct performance on >70% (+€1) or >75% (+€2) of test phase trials. Data from four additional participants were excluded due to insufficient artefact-free EEG trials. Participants gave informed consent; the study was in accordance with the Declaration of Helsinki, and was approved by the Faculty Ethics Committee.

Stimuli

Stimuli were 240 unfamiliar faces from the Glasgow Unfamiliar Face Database (GUFD; Burton et al., 2010) and the Facial Recognition Technology (FERET) database (Phillips et al., 1998, 2000) in two full frontal colour images each, and without beards or glasses. Faces were all depicted in either neutral or moderately positive expression. Images were edited using Adobe Photoshop™ (CS2, Version 9.0.2) to