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Similar exemplar pooling processes underlie the learning of facial identity and handwriting style: Evidence from typical observers and individuals with Autism

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ABSTRACT

Considerable research has addressed whether the cognitive and neural representations recruited by faces are similar to those engaged by other types of visual stimuli. For example, research has examined the extent to which objects of expertise recruit holistic representation and engage the fusiform face area. Little is known, however, about the domain-specificity of the exemplar pooling processes thought to underlie the acquisition of familiarity with particular facial identities. In the present study we sought to compare observers' ability to learn facial identities and handwriting styles from exposure to multiple exemplars. Crucially, while handwritten words and faces differ considerably in their topographic form, both learning tasks share a common exemplar pooling component. In our first experiment, we find that typical observers' ability to learn facial identities and handwriting styles from exposure to multiple exemplars correlates closely. In our second experiment, we show that observers with Autism Spectrum Disorder (ASD) are impaired at both learning tasks. Our findings suggest that similar exemplar pooling processes are recruited when learning facial identities and handwriting styles. Models of exemplar pooling originally developed to explain face learning, may therefore offer valuable insights into exemplar pooling across a range of domains, extending beyond faces. Aberrant exemplar pooling, possibly resulting from structural differences in the inferior longitudinal fasciculus, may underlie difficulties recognising familiar faces often experienced by individuals with ASD, and leave observers overly reliant on local details present in particular exemplars.

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1. Introduction

Contrary to intuition, familiar and unfamiliar faces are thought to recruit different types of visual processing (Hancock et al., 2000; Jenkins and Burton, 2011; Megreya and Burton, 2006). As faces become more familiar, observers develop the so-called internal feature advantage; they are better able to match targets using the eyes, nose, and mouth (Ellis et al., 1979; Osborne and Stevenage, 2008; Young et al., 1985). In contrast, unfamiliar face matching is frequently based on external features, such as hairstyle and face shape. Relative to unfamiliar faces, familiar faces may also place lower demands on visual working memory (Jackson and Raymond, 2008) and are easier to detect under conditions of reduced attention (Jackson and Raymond, 2006). However, the most striking difference between familiar and unfamiliar face perception is arguably the ease with which we can recognise individuals across encounters. Matching strangers' faces across different photographic images can be surprisingly difficult (Bruce et al., 1999; Megreya and Burton, 2008; White et al., 2014). For example, when asked to sort photographs of individuals according to the identity of those depicted, observers frequently overestimate the number of individuals present (hereafter the *overestimation effect*; Jenkins et al., 2011; Murphy et al., 2015). In contrast, recognising familiar faces (e.g., celebrities, colleagues, friends, family) across multiple encounters appears effortless, despite substantial differences in pose, hairstyle and lighting.

Differences in the visual processing of familiar and unfamiliar faces have prompted considerable interest in face learning, the process by which unfamiliar faces become familiar. Previous evidence suggests that face learning is determined, at least in part, by the time observers spend viewing faces. Participants allowed to observe faces for 45 s each outperform those who view the same faces for 15 s on subsequent recognition tests (Memon et al., 2003). Similarly, simple repetition of single facial images can improve subsequent recognition of actors in dynamic video stimuli (Roark et al., 2006). Crucially, however, experiencing a given face in different poses, situations, and lighting conditions (*so*-called exemplar variation), also contributes to face learning,

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independently of viewing time. Observers exposed to many variable exemplars during training, outperform observers repeatedly presented with a limited number of exemplars on recognition tests, when viewing time is equated (Murphy et al., 2015). The pooling of multiple exemplars appears to be integral to the acquisition of facial familiarity and underlies robust recognition performance.

Exemplar-database and averaging accounts have been proposed to explain how exemplar pooling; i.e., the process of identifying and combining exemplars of a common source, facilitates the acquisition of facial familiarity. According to exemplar-database models, familiar faces are recognised through comparison with previous encounters with that face (Longmore et al., 2008). Having encountered a given face on many occasions, in different poses, lighting and viewing conditions, observers are able to densely sample the potential instance space. Thereafter, the likelihood of a close match between a novel encounter and a previously stored instance is high, yielding superior recognition performance. Familiarization has also been modelled as an averaging process (Benson and Perrett, 1993; Burton and Jenkins, 2011; Jenkins and Burton, 2011). According to this view, multiple encounters with a face allow the visual system to form a robust average of that facial identity. Transient differences in lighting, shadow, hairstyle, expression are discounted, leaving a stable representation of permanent, reliable features.

The present study sought to compare the exemplar pooling processes that underlie the acquisition of facial familiarity with those recruited by non-face stimuli. The specificity of the perceptual processing recruited by faces has been long debated. Some authors have argued that cognitive and neural representations are face-specific; that they are qualitatively different to those recruited by objects (McKone et al., 2007; McKone and Robbins, 2011). For example, upright faces may recruit stronger holistic representation – whereby features are integrated into a unified whole – than objects (Robbins and McKone, 2007), and may preferentially engage regions of the fusiform gyrus (Kanwisher, 2000). Other authors have argued that faces and other 'objects of expertise' – categories of objects i) with which the observer has extensive visual experience, and ii) which comprise exemplars that share a common prototypical feature arrangement – are processed in similar regions (Gauthier et al., 2000; Gauthier et al., 1999) and recruit similar types of representation (Diamond and Carey, 1986; Gauthier et al., 1998).

Despite the interest in the domain-specificity of face perception more broadly, there is currently a dearth of evidence addressing the nature of the exemplar pooling process recruited during face learning.[1] Authors have therefore avoided strong claims about domain-specificity (Burton and Jenkins, 2011). In the present study, we compared the acquisition of familiarity for facial identities and handwriting styles, from exposure to multiple exemplars. Despite considerable differences in topographic form, neuroimaging suggests that both faces (Kanwisher et al., 1997) and handwritten words (Barton et al., 2010a) engage bilateral portions of fusiform gyrus. Although reading is predominantly a left hemisphere process (e.g., Price, 2012), some prosopagnosic patients with right lateral fusiform damage also exhibit impaired perception of handwriting style (Barton et al., 2010b; Hills et al., 2015). Crucially, a similar variance structure is present within a set of facial photographs depicting the same individual, and a pool of hand-written examples of the same word produced by the same author. A given exemplar drawn from either of these sets contains a common source signal present across exemplars, and exemplar-specific variation; for example, associated with lighting conditions, viewpoint, hair-style (in the case of faces), or writing implement, pressure, speed of production, hand position (in the case of handwriting).

We describe two experiments that address the same question – whether similar exemplar pooling processes underlie the learning of facial identity and handwriting style – but do so using different complementary approaches. In our first experiment, we examine the covariation of individual differences in the typical population. In our second experiment, we use developmental neuropsychology to examine whether the learning of faces and handwriting styles dissociates in ASD.

2. Exemplar pooling in typical observers

The aim of our first experiment was to compare typical observers' ability to learn facial identities and hand-writing styles from exposure to multiple exemplars. The covariation of individual differences has previously been used to examine whether two tasks recruit common social perception processes (e.g., Wang et al., 2012; Yovel and Kanwisher, 2008; Yovel et al., 2014). Should the learning of facial identity and handwriting style recruit common exemplar pooling processes, we reasoned that typical observers' recognition of familiarised identities and styles should correlate, despite the gross differences in their form.

2.1. Methods

2.1.1. Participants

Forty-eight healthy adults (M_{age}=24.7 years; SD_{age}=6.8 years; 11 males) participated in the first experiment in return for a small honorarium. All participants had normal or corrected-to-normal vision, gave informed consent, and were fully debriefed upon task completion. Ethical clearance was granted by the local ethics committee, and the study was conducted in accordance with the ethical standards laid down in the 6th (2008) Declaration of Helsinki.

2.1.2. Training procedure

The facial stimuli employed during training were taken from the set constructed by Murphy et al. (2015). This set of 768 photographic images comprises 96 images of eight to-be-learned identities. The images sample a broad range of poses, expressions, hairstyles, lighting conditions, and camera parameters (Fig. 1a). In each image, the to-be-learned identity is the only face visible and appears central and prominent. In all other respects, the raw photographic images are unaltered. None of the facial images depict individuals wearing glasses or sunglasses. A parallel set of handwriting stimuli were purposely created for the present study. Individuals were asked to write the same word ("backgrounds"), repeatedly, in different colours and textures, using different pens and pencils, employing different pressures, at different speeds (Fig. 1b). We elected to use a single word to ensure that the stimuli had a prototypical arrangement. By selecting a word ("backgrounds") comprising 11 unique characters, we hoped to encourage exemplar variation. The handwritten words were digitised, positioned centrally within the image, and saved as. bmp files. The final set of 768 images comprised 96 exemplars of eight handwriting styles. All training images were cropped to square aspect ratios subtending 3° vertically when viewed in the array at a distance of 60 cm.

The training procedure comprised 24 trials. Each training trial presented 48 images, simultaneously in a 6×8 array. Twelve

[1] Previous research has addressed whether individuation expertise for newly acquired non-face object categories resembles face recognition expertise in typical observers (e.g., Gauthier et al., 1998) and in individuals with prosopagnosia (e.g., Duchaine et al., 2004; Rezlescu et al., 2014). However, these studies address learning through the repetition of a single exemplar, and not exemplar pooling (i.e., the learning of identity through exposure to exemplar variation).

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