



Contributions of individual face features to face discrimination



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ABSTRACT

Faces are highly complex stimuli that contain a host of information. Such complexity poses the following questions: (a) do observers exhibit preferences for specific information? (b) how does sensitivity to individual face parts compare? These questions were addressed by quantifying sensitivity to different face features. Discrimination thresholds were determined for synthetic faces under the following conditions: (i) 'full face': all face features visible; (ii) 'isolated feature': single feature presented in isolation; (iii) 'embedded feature': all features visible, but only one feature modified. Mean threshold elevations for isolated features, relative to full-faces, were 0.84x, 1.08, 2.12, 3.34, 4.07 and 4.47 for head-shape, hairline, nose, mouth, eyes and eyebrows respectively. Hence, when two full faces can be discriminated at threshold, the difference between the eyes is about four times less than what is required when discriminating between isolated eyes. In all cases, sensitivity was higher when features were presented in isolation than when they were embedded within a face context (threshold elevations of 0.94x, 1.74, 2.67, 2.90, 5.94 and 9.94). This reveals a specific pattern of sensitivity to face information. Observers are between two and four times more sensitive to external than internal features. The pattern for internal features (higher sensitivity for the nose, compared to mouth, eyes and eyebrows) is consistent with lower sensitivity for those parts affected by facial dynamics (e.g. facial expressions). That isolated features are easier to discriminate than embedded features supports a holistic face processing mechanism which impedes extraction of information about individual features from full faces.

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1. Introduction

Human faces share the same basic template (i.e. two eyes, above a nose, above a mouth). Therefore, in order to discriminate between them, humans have to be sensitive to subtle idiosyncratic differences in the positions and shapes of individual features. This process is made more complex by variations associated with facial dynamics used to express a wide range of emotions and communicate the direction of attention through variations in eye gaze. In order to use visual face information to accurately recognize individuals and to appropriately interpret dynamic facial information, the primate brain has evolved an interconnected network, including the occipital face area (OFA) (Gauthier et al., 2000), the superior temporal sulcus (Allison, Puce, & McCarthy, 2000) and the fusiform face area (FFA) (Kanwisher, McDermott, & Chun, 1997). The latter appears to be particularly important in the processing of face information which is used to discriminate between different identities

(Grill-Spector, Knouf, & Kanwisher, 2004; Kanwisher & Yovel, 2006).

1.1. Familiar vs unfamiliar face recognition

The way in which this network processes individual faces is dependent upon a number of factors. For example, it is well established that faces are processed differently depending on their level of familiarity (Johnston & Edmonds, 2009). Familiar faces can be recognized despite marked changes in lighting, contrast and viewpoint (Hancock, Bruce, & Burton, 2000; Hill, Schyns, & Akamatsu, 1997; Johnston, Hill, & Carman, 1992), allowing for a degree of identity constancy. Unfamiliar face discrimination, on the other hand, is susceptible to errors resulting from incidental image artefacts, such as illumination or context changes (Bruce et al., 1999). Even a mere change in facial expression can impair unfamiliar face recognition (Bruce, 1982). fMRI has been used to show that adaptation of the BOLD signal within the FFA, which results from repeated viewing of the same unfamiliar face, can be released when the same face is shown from different viewpoints (Ewbank & Andrews, 2008). Viewpoint transformations, however, were not sufficient to remove FFA adaptation for familiar faces, suggesting

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that the same population of neurons responds to a particular familiar face irrespective of the direction from which it is viewed. Moreover, fMRI studies have found evidence of different cortical activation patterns in face-sensitive brain areas for familiar and unfamiliar faces (Eger, Schweinberger, Dolan, & Henson, 2005; Rossion, Schiltz, Robaye, Pirenne, & Crommelinck, 2001). A dissociation between familiar and unfamiliar faces is also seen in neurological conditions: some patients with prosopagnosia demonstrate preserved unfamiliar face discrimination, despite a marked impairment of familiar face recognition (Benton & Van Allen, 1972). There are also reports of the opposite; patients may be impaired for unfamiliar face matching yet can recognize familiar faces normally (Malone, Morris, Kay, & Levin, 1982).

1.2. External and internal features

Faces contain a wealth of information. Previous research has investigated which information may be particularly important for the processing of face identity. A broad categorization has been made by dividing faces into external (e.g. head-shape) and internal (e.g. eyes) features. Physiologically, these sources of information are available at the level of FFA: fMRI response from the FFA is sensitive to manipulations of both external and internal face features (Andrews, Davies-Thompson, Kingstone, & Young, 2010; Axelrod & Yovel, 2010).

Behaviorally, the relative importance of external versus internal features appears, once more, to depend on familiarity. Familiar face recognition accuracy is significantly higher when observers base their judgement on internal, compared to external features (Campbell, 1999; Clutterbuck & Johnston, 2005; Ellis, Shepherd, & Davies, 1979; Haig, 1985; Longmore, Liu, & Young, 2015; Osborne & Stevenage, 2008; Young, Hay, McWeeny, Flude, & Ellis, 1985). This reliable internal feature advantage for familiar faces may be a product of increased attention to features used for conveying emotions and intentions (Ellis et al., 1979). In addition, the relatively fixed nature and position of internal features, as opposed to variable external features such as hairstyles and facial hair, may make internal features a more reliable recognition cue in the long-term (Young, 1984).

Evidence regarding the relative contributions of external and internal face information to unfamiliar face perception, on the other hand, is inconclusive. An early report found that recognition of unfamiliar faces was most accurate when forehead and hairline information was utilized (Davies, Ellis, & Shepherd, 1977). A number of subsequent studies have also identified an external feature advantage for unfamiliar face discrimination (Bruce et al., 1999; Fraser, Craig, & Parker, 1990; Haig, 1986; Nachson & Shechory, 2002; Veres-Injac & Persike, 2009). Participants perform within normal limits on clinical tests of unfamiliar face recognition when all internal feature information has been removed (Duchaine & Weidenfeld, 2003). Further, learning to recognize an unfamiliar face is associated with a significant increase in the time spent viewing the external features (Henderson, Williams, & Falk, 2005).

On the other hand, a number of reports have found no evidence of an external feature advantage for unfamiliar face perception (Clutterbuck & Johnston, 2002; Ellis et al., 1979; Hines, Jordan-Brown, & Juzwin, 1987; Longmore et al., 2015; Young et al., 1985). For example, Young and colleagues found no difference in the speed at which observers matched familiar and unfamiliar faces based on their external features. Similarly, it has been reported that unfamiliar face recognition accuracy was equivalent when observers were given either external or internal feature information (Ellis et al., 1979). The range of experimental approaches used (different memory demands, incidental photographic details) may partially account for these conflicting results (see 4.1 for details).

The first aim of the present study was to systematically investigate the relative weighting of a range of internal and external face features for unfamiliar face discrimination. We employed simplified synthetic faces in a discrimination paradigm with minimal memory requirements. The synthetic face metric allows performance to be measured in a way that facilitates direct comparison of sensitivity to different face components with each other and with that for full faces. The results will provide a formal quantification of the relative contributions of component features to unfamiliar face discrimination.

1.3. Holistic face processing

Holistic processing is generally understood to describe the integration of individual features into an interdependent representation (Maurer, Le Grand, & Mondloch, 2002; Rossion, 2008). The processing of faces is considered to be holistic, rather than piecemeal (Maurer et al., 2002; Richler & Gauthier, 2014). Richler, Cheung, and Gauthier (2011) have shown that face recognition accuracy is correlated with the degree to which individual observers engage holistic face processing and it has been proposed that impaired holistic processing may be a cardinal feature of acquired prosopagnosia (Ramon, Busigny, & Rossion, 2010). As a consequence of holistic processing, the extraction of information about individual features from full faces is impeded (Sinha, Balas, Ostrovsky & Russell, 2006). This is perhaps best illustrated by the composite face effect: combining the top half of the face of one individual with the bottom half of the face of another impairs recognition of the component identities (Young, Hellawell, & Hay, 1987).

Although recognition accuracy is significantly greater within full faces, observers can still recognize isolated features (Tanaka & Farah, 1993). In previous studies, masking paradigms have been used to elucidate the neural mechanisms which underlie face processing. Like other aspects of visual perception, face discrimination is impaired by a preceding mask (Loffler, Gordon, Wilkinson, Goren, & Wilson, 2005). Although the strongest masking effect is seen for full face masks, isolated or scrambled face parts also significantly impair performance (Farah, Wilson, Drain, & Tanaka, 1998; Loffler, Gordon, et al., 2005). These results suggest that, while holistic processing may be the dominant strategy, faces also recruit feature-based processing. This is consistent with evidence from a recent fMRI study which indicates that response patterns recorded from the OFA and FFA distinguish between isolated features (Henriksson, Mur, & Kriegeskorte, 2014). A second aim of the present study was to quantitatively investigate the impact of holistic processing on individual feature discrimination for unfamiliar faces.

We addressed this aim in the following way. Discrimination sensitivity for individual face features was first measured with the features presented in isolation. The experiment was then repeated with the same features embedded within a fixed face context (see Fig. 2). In both conditions, the change to the task-relevant feature was identical and therefore the available information was the same, irrespective of whether the feature of interest was presented alone or alongside unchanged features. A comparison of discrimination sensitivity for individual features under these two conditions was designed to investigate the extent and nature of holistic and configural processing. We made three distinct predictions about the effect of embedding features, relative to presentation is isolation. Firstly, if unfamiliar faces recruit only part-based processing, it would be expected that discrimination thresholds are largely unaffected by the addition of a face context; performance for the isolated and embedded conditions would be comparable (see 3.2 for a discussion of the effects of spatial uncertainty and attention). Secondly, face computation might be driven by

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