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First fixations in face processing: The more diagnostic they are the smaller the face-inversion effect

Peter J. Hills [a,*], Rachel E. Cooper [b], J. Michael Pake [a]

[a] Department of Psychology, Anglia Ruskin University, East Road, Cambridge CB1 1PT, UK
[b] Department of Psychology, University of Essex, Wivenhoe Park, Colchester, Essex CO4 3SQ, UK

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ABSTRACT

Hills, Ross, and Lewis (2011) introduced the concept that the face-inversion effect may, in part, be carried by the first feature attended to, since the first feature fixated upon is different for upright and inverted faces. An eye-tracking study that directly assesses this hypothesis by using fixation crosses to guide attention to the eye or mouth region of the to-be-presented upright and inverted faces was devised. Recognition was better when the fixation cross appeared at the eye region than at the mouth region. The face-inversion effect was smaller when the eyes were cued than when the mouth was cued or when there was no cueing. The eye-tracking measures confirmed that the fixation crosses attracted the first fixation but did not affect other measures of eye-movements. Furthermore, the location of the first fixation predicted recognition accuracy: when the first fixation was to the eyes, recognition accuracy was higher than when the first fixation was to the mouth, irrespective of facial orientation. The results suggest that the first facial feature attended to is more predictive of recognition accuracy than the face orientation in which they are presented.
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1. Introduction

In general, humans are experts at recognising faces (e.g., Carey, 1992; Diamond & Carey, 1986). One of the most reliable effects in face processing is that of the face-inversion effect (e.g., Valentine, 1988) in which inverted faces are harder to recognise than upright faces (Hochberg & Galper, 1967; Valentine & Bruce, 1986). Indeed, inversion disproportionately affects the later recognition of faces compared to other classes of objects (such as houses, Yin, 1969). This face-inversion effect is typically used as a measure of the expert nature of face processing (Edmonds & Lewis, 2007; Freire, Lee, & Symons, 2000), as it is disrupted by inversion (Farah, Tanaka, & Drain, 1995; Rhodes, Brake, & Atkinson, 1993).

Expertise in face processing, as has been proposed (e.g., Rossion & Gauthier, 2002), is based upon second-order relational (Leder & Bruce, 2000) or holistic processing (Hole, 1994; Tanaka & Farah, 1993). Rossion (2008) has offered a related explanation, suggesting that inversion reduces the size of the perceptual field (i.e., region of the visual world that can be attended to) preventing the whole face from being sampled quickly and it is this that prevents holistic processing. Other researchers explain the recognition deficit caused by inversion as being due to increased error during the encoding of inverted faces relative to upright faces (Valentine, 1988). This could be due to an alteration to the hierarchy of features (e.g., Haig, 1984) whereby certain features are more diagnostic in the encoding and processing of faces than others (similar to the feature-saliency effect, e.g., Shepherd, Davies, & Ellis, 1981). In upright faces, the hierarchy of features is typically found to be the eyes > nose > mouth > external features. While the explanations based on the type of processing have driven much of the research in this field, recent studies have indicated that diagnostic features have an important role in face processing (see e.g., Hills et al., 2011). Further, inversion may restrict the perceptual field causing less diagnostic features to be processed.

There is a great deal of experimental evidence that shows the primary importance of the eyes in face processing, at least for ethnically White participants. Participants tend to describe faces using the hairline and eyes more than any other feature (Ellis, Deregowski, & Shepherd, 1975). Distortions made to the eyes are easier to detect than distortions to other features (Endo, 1983; Haig, 1986a, 1986b; Hosie, Ellis, & Haig, 1988). Error rates are larger when testing recognition of noses or mouths in the parts/wholes test (Tanaka & Farah, 1993) than when testing the eyes (Joseph & Tanaka, 2002; Wenger & Townsend, 2000). Further, when the upper facial features or the eyes are concealed, face

* Corresponding author. Tel.: +44 8451962293.
E-mail address: peter.hills@anglia.ac.uk (P.J. Hills).

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recognition (Gosselin & Schyns, 2001; Haig, 1986a) and discrimination (Haig, 1985) are more severely reduced than if the lower facial features are concealed. The face-sensitive event related potential (ERP), N170 (Bentin, Allison, Puce, Perez, & McCarthy, 1996), is larger if a face has eyes than if it does not (Itier, Alain, Sedore, & McIntosh, 2007). There is an inversion effect for the internal facial features (including the eyes, Rakover & Teucher, 1997; Risesenhuber, Jarudi, Gilad, & Sinha, 2004; Yovel & Kanwisher, 2004) but not for external facial features (e.g., ears and hair, Ellis, Shepherd, & Davies, 1979; Phillips, 1979). A number of clinical populations, including patients with autism (Langdell, 1978), schizophrenia (Williams, Loughland, Gordon, & Davidson, 1999), and prosopagnosia (Bukach, Bub, Gauthier, & Tarr, 2006; Caldara et al., 2005; de Xivry, Ramon, Lefèvre, & Rossion, 2008), who have deficits in face processing, tend to rely less on the eye region and focus on the mouth when processing faces. Lastly, the eye region of a face is the most scanned part as revealed by eye-trackers (e.g., Althoff & Cohen, 1999; Heisz & Shore, 2008; Walker-Smith, Gale, & Findlay, 1977). Based on these studies, Itier et al. (2007) made the bold claim that the eyes may be partially responsible for some of the face-specific effects observed in certain paradigms and populations, including the face-inversion effect.

Based on this evidence, Hills et al. (2011) devised a study in which they directly tested whether attention to the eyes or other facial features affects face recognition. They used fixation crosses to cue either the eyes or mouth of a face during a standard old/new recognition test. Their results demonstrated that cueing the eyes led to greater recognition accuracy for faces than cueing the mouth. Importantly, this effect did not depend on the orientation of the face. In other words, cueing the eyes led to greater recognition accuracy in both upright and inverted faces than cueing the mouth. Crucially, cueing the eyes reduced the magnitude of the face-inversion effect whereas cueing the mouth did not affect the magnitude of the effect. This effect was observed using a relative measure of the face-inversion effect, since cueing the mouth caused lower recognition accuracy overall than cueing the eyes. This provides evidence that eye-processing may carry some of the face-inversion effect. Thus, these authors proposed an *attentional hypothesis* of the face-inversion effect based upon the idea of feature-saliency (the most diagnostic feature for face recognition is the eyes). According to this explanation, inverting a face leads to attention being directed to a less diagnostic part of the face.

There is some evidence from eye-tracking research that is consistent with this hypothesis. When the first fixation to a stimulus is not to the preferred landing position (e.g., Henderson, 1993) for that stimulus, there is a disruption to its encoding resulting in a longer first fixation. This disruption, it is theorised, is caused by the eye-movement system comparing the first fixation position to the preferred landing position (e.g., Coren & Hoenig, 1972; Parkhurst, Law, & Niebur, 2002). If these positions are not congruent, a re-orientation to the preferred landing position process occurs (Sæther, Van Belle, Laeng, Brennen, & Øvervoll, 2009). Once the preferred landing position is located, the native scanpath can be initiated. This process delays the initiation of the scanpath. Similarly, Vinette, Gosselin, and Schyns (2004) have indicated that automatic anchoring of gaze is critical and this may be a pre-requisite to initiation of the natural scanpath.

A direct test of this attentional hypothesis would be to actually measure the attentional process in action. Eye-tracking can be used to measure where attention is being directed (Gilchrist & Proske, 2006; Leonards & Scott-Samuel, 2005; Morand, Grosbras, Caldara, & Harvey, 2010; Norton & Stark, 1971; Phillips & David, 1994). This is logical given the functional nature of eye-movements to move parts of an image to the high-resolution fovea (Williams & Henderson, 2007) allowing for critical information to be focused on (Desimone & Duncan, 1995; Egeth & Yantis, 1997), though there is not a one-to-one relationship between fixation point and information encoding. The existing data show that there is a distinct scanpath (Norton & Stark, 1971) when viewing faces, with many prolonged fixations to the eyes and fewer shorter fixations to the mouth and other features (Althoff & Cohen, 1999; Bindemann, Scheepers, & Burton, 2009; Luria & Strauss, 1978; Stacey, Walker, & Underwood, 2005; Walker-Smith et al., 1977; Yarbus, 1969). Indeed, when viewing faces, the preferred landing position (Rayner, 1979) is between the eyes (Tyler & Chen, 2006, see also Hsiao & Cottrell, 2008), though this is likely to depend on the size and position of the presented face (cf., Hills, Sullivan, & Pake, 2012). Observations have suggested that 60–70% of fixation time is spent viewing the eyes during typical face processing experiments (e.g., Henderson, Falk, Minut, Dyer, & Mahadevan, 2001). This is the case for upright faces: but what is the evidence in inverted faces?

If inversion disrupts the perceptual field, preventing the whole face from being sampled by a single central fixation (Rossion, 2008, 2009) then you would expect that there would be more fixations made to inverted faces. Indeed, Barton, Radcliffe, Cherkasova, Edelman, and Intriligator (2006) have shown that there are typically more fixations made to inverted faces (see also Hills et al., 2012). When viewing inverted faces, the scanpath is less predictable as analysed with measures of entropy. Additionally, the first fixation to an inverted face is typically to the mouth (Barton et al., 2006). Inversion, thus, disrupts the first fixation and the following scanpath. However, there is a caveat, Williams and Henderson (2007) concluded that there is not an atypical scanpath when viewing inverted faces (even though they showed that the mouth did receive significantly more fixations in inverted faces than upright faces). Hills et al. (2012) have attempted to explain the differences between Williams and Henderson's (2007) findings and Barton et al.'s (2006) findings and we shall not repeat them here.

Thus, does the eye-tracking data show evidence for the attentional hypothesis of the face-inversion effect? The three studies that have used eye-tracking and inverted faces have reported conflicting findings. Both Barton et al. and Hills et al. showed that inversion disrupts the first fixation and the subsequent fixation pattern whereas Williams and Henderson reported no difference. Aberrant eye-movements when viewing inverted faces may be due to an atypical first fixation location and this may lead to a delayed or atypical scanpath.

This study thus aims to see whether there are eye-tracking differences when viewing upright and inverted faces and what these differences are. In particular, we are interested in whether the first fixation is different for the two classes of stimuli, whether there are subsequent scanpath differences, and also whether either or both of these impact on recognition accuracy. If we accept the evidence that the eyes are the most appropriate first fixation point, then it could be expected that when the first fixation is to the eyes, recognition accuracy of inverted faces will be more accurate than when the first fixation is not to the eyes. Thus, we shall conduct an analysis based on the natural location of the first fixation and the resulting recognition accuracy. If the eyes are found to be the optimal first fixation location for accurate recognition then this will contribute to our understanding of the face-inversion effect, providing a caveat to, or replacing, the configural processing explanation of it.

A second aim of this study is to replicate the fixation cross findings of Hills et al. (2011), such that we can be more confident of these effects. Within this, we need to be sure that the fixation crosses are having the effect that Hills et al. predicted in attracting the first fixation. If this is the case, then we would expect to find that the location of the first fixation is dependent on the position of the fixation cross and this affects subsequent recognition accuracy. Similarly, if we disrupt the initial fixation, by drawing it to the mouth, we can explore whether this then impacts on the ensuing scanpath. We can investigate whether this disruption causes the subsequent scanpath to be less predictable or whether it remains as predictable, but with a delay.

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