Attention misplaced: The role of diagnostic features in the face-inversion effect

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Acknowledgements

The authors would like to thank Helmut Leder, Bruno Rossion, Goethe van Belle, and two anonymous reviewers for interesting comments made on a previous version of this manuscript. This research was in part funded by grant PTA-030-2003-00524 from the ESRC awarded to Peter J Hills for his PhD research program.

Abstract

Inversion disproportionately impairs recognition of face stimuli compared to non-face stimuli arguably due to the holistic manner in which faces are processed. A qualification is put forward in which the first point fixated upon is different for upright and inverted faces and this carries some of the face-inversion effect. Three experiments explored this possibility by using fixation crosses to guide attention to the eye or mouth region of the to-be-presented faces in different orientations. 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 results suggest that the first facial feature attended to is important for accurate face recognition and this may carry some of the effects of inversion.

Humans are experts at recognising upright faces (e.g., Carey, 1992; Diamond & Carey, 1986; Rhodes, Hayward, & Winkler, 2006). Possibly due to this expertise, inverted faces are significantly harder to recognise than their upright counterparts (e.g., Hochberg & Galper, 1967; Leder & Carbon, 2005; Valentine & Bruce, 1986). Further, distortions to faces are harder to detect in inverted faces than upright faces (Bartlett & Searcy, 1993; Leder & Bruce, 1998) unless they are cued (Barton, Deepak & Malik, 2003). In fact, faces are disproportionately affected by inversion compared to other objects (e.g., houses or scenes, Yin, 1969). This face-inversion effect is one of the most robust findings in the face perception literature (for a review see e.g., Valentine, 1988).

To explain the face-inversion effect, researchers often turn to the notion that there are distinct types of processing (see e.g., Freire, Lee & Symons, 2000; Rossion & Gauthier, 2002). Expertise in face processing, it is proposed, is based upon second-order relational (Carey, 1992; Diamond & Carey, 1986) or holistic/configural processing (Hole, 1994; Tanaka & Farah, 1993). Researchers have proposed that inversion disrupts second-order relational or holistic/configural processing based on experiments assessing the interactivity of facial features (Sergent, 1984) and the parts and wholes test (Tanaka & Farah, 1993) and experiments using: composite faces (Young, Hellawell, & Hay, 1987), thatcherisation (e.g., Bartlett & Searcy, 1993), distinctiveness ratings (e.g., Searcy & Bartlett, 1996); and recognition paradigms (e.g., Rhodes, Brake, & Atkinson, 1993).

While the style of processing explanation is parsimonious, we wish to offer and test an extension to this for the observed face-inversion effect. This new account is underpinned by the relative diagnosticity of different facial features, otherwise known as the feature-saliency effect. The feature-saliency effect is where certain features are more important for face recognition than others (e.g., Davies, Ellis, & Shepherd, 1977).

It has been established that there is a hierarchy of features in terms of their diagnostic value to face recognition (Shepherd, Davies, & Ellis, 1981). Specifically, the hairline and the eyes appear to be important, at least for White participants: When describing faces, participants tend to describe the hairline and eyes more than any other feature (Ellis, Deregowski, & Shepherd, 1975). More experimental evidence comes from the fact that distortions to the eyes are easier to detect than distortions to other features (Endo, 1986; Haig, 1986a, b, Hosie, Ellis, & Haig, 1988) and 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; Pellicano & Rhodes, 2003; Wenger & Townsend, 2000). Further, when upper facial features or the eyes are concealed, face recognition (Gosselin & Schyns, 2001; Haig, 1986a), discrimination (Haig, 1985), and judgements (Dal Martello & Maloney, 2006) are more severely affected than if lower facial features are concealed. 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). Furthermore, there is an inversion effect (indicative of expert processing) for the internal facial features (including the eyes, Rakover & Teucher, 1997, see also Riesenhuber, Wolff, Gilad, & Sinha, 2004; Yovel & Kanwisher, 2004) but not for external facial features (Ellis, Shepherd, & Davies, 1979; Phillips, 1979). Additionally, prosopagnosic patients rely less on the eye region and more on the mouth when processing faces (Bukach, Bub, Gauthier, & Tarr, 2006; Caldara et al., 2005; Orban de Xivry, Ramon, Lefèvre, & Rossion, 2008)[1].

[1] There is, however, no evidence that suggests that guiding prosopagnosics to look at the eyes aids their face recognition abilities. This is likely to be due to due to eye region providing extensive information about the relationship between multiple features (eyes, eyebrows, and nose) that prosopagnosics find

According to Haig (1985; 1986a) and Davies et al. (1977) the eyes are critically important for face recognition and may be partially responsible for some of the face-specific effects (such as the inversion effect, see also Itier, Alain, Sedore, and McIntosh, 2007). Given this premise, the question about how feature-saliency may interact with inversion must be asked (c.f., Barton, Keenan, & Bass, 2001). Specifically, are the eyes really less salient or less observed in an inverted face? There is evidence that the eyes are less scanned in an inverted face and that the scanning sequence is more random for inverted faces (Barton, Radcliffe, Cherkasova, Edelman, & Intriligator, 2006, but see Williams & Henderson, 2007, for a different interpretation). Thus, if the first point fixated upon is forced to be between the eyes , then the inversion effect may be smaller. Similarly, if the eyes were made less salient and scanned less than a less diagnostic feature (e.g., the mouth) in an upright face then recognition accuracy may be lower. One method for increasing the likelihood of a first fixation landing on a desired location is with attentional cueing.

It has been established that cueing does alter the accuracy with which some facial distortions are detected. Barton and colleagues have conducted a series of studies in which participants had to determine which of three faces simultaneously presented was different from the other two (an odd-one-out paradigm, Barton et al., 2001) or in a change detection paradigm (Barton et al., 2003). These faces differed on relatively small spatial changes or colour changes to the eyes or mouth. They were either presented upright or inverted. Barton et al. found that spatial position alterations to the eyes and the mouth were detected accurately in upright faces but less so in inverted faces, although horizontal changes to the eyes were less affected by inversion than vertical changes to the eyes-plus-eyebrows and mouth (Sekunova & Barton, 2008, see also Goffaux & Rossion, 2007). Furthermore, when participants were cued

difficult to deal with (see Orban de Xivry, 2008)..

as to which features had been altered due to every trial in one experimental block containing alterations to one feature only, changes made to the mouth were noticed in upright and inverted faces; the inversion effect was removed. However, changes made to the eyes were still affected by inversion. Thus, when the mouth region was made more salient, the effect of inversion was reduced. Their conclusions were that the eyes are typically more salient than the mouth in upright faces. However, in inverted faces, the perception of less salient facial regions is disproportionately affected. That is, that the inversion effect affects spatial relationships though these effects differ according to feature saliency.

It is clear from the work of Barton and his colleagues that cueing or expectation can affect the face-inversion effect. Furthermore, the feature-saliency literature indicates that the eyes are a more diagnostic feature for face recognition than the mouth. Thus, the feature-saliency effect could be a factor in the face-inversion effect: Inverting a face leads to fixations being directed to a less diagnostic part of the face (the mouth, as described above). Thus, fixation to the most diagnostic region guides accuracy in face recognition and if this is disrupted by inversion, accuracy is lower. Thus, cueing the eyes may lead to better recognition of an inverted face relative to no cueing, whereas cueing the mouth in an upright will lead to lower recognition accuracy relative to no cueing as it is a less diagnostic feature. This will, in turn, affect the face-inversion effect such that cueing the eyes would reduce the decrements in face recognition performance due to inversion, whereas cueing the mouth would not.

In order to address whether feature cueing can affect face recognition accuracy, a novel paradigm has been devised that allows for testing the extent of the feature-saliency effect in face recognition. To guide attention to particular facial regions (either between the eyes or the mouth of a face), fixation crosses were used. This paradigm was applied to three studies in which upright or inverted faces were presented to participants in an old/new recognition paradigm. Experiment 1 assessed the impact of fixation crosses cueing the eyes or the mouth in inverted and upright faces. Experiment 2 extended the effect whereby the faces were positioned high or low with the fixation cross always appeared at the same location, thus addressing whether expectancy affected the feature-cueing effects. Experiment 3 assessed whether the effect that feature cueing had was greater at learning or at test.

Experiment 1

Experiment 1 tested our feature-saliency hypothesis using fixation crosses preceding upright and inverted faces cueing the eyes or the mouth. A 2 x 3 factorial design was employed with the factors: orientation of the face and feature cued. For each face, its orientation was matched at learning and test. Likewise, for each face, the feature cued was matched from learning to test. The fixation cross preceded the location of the to-be-cued region (either between the eyes or the mouth). In previous studies, authors tend to position fixation crosses in the "centre" of a face, in which the centre is between the eyes (e.g., Henderson, Williams, and Falk, 2005). This is consistent with our cueing of the eyes in upright faces. Given the increased diagnostic value of the eyes in face recognition, we would expect that cueing the eyes will lead to greater recognition accuracy. If our novel attentional hypothesis is reliable, then cueing the eyes in an inverted face will result in a smaller inversion effect than cueing less salient features. Thus, we predict an interaction between facial orientation and position of the fixation cross. Thus, we are making *a piori* hypotheses about the simple effects.

Method

Participants

An opportunity sample of 60 (48 female, aged 18 to 33, mean = 22.7 years) Undergraduates from the School of Psychology at Cardiff University and the Department of Psychology at Anglia Ruskin University took part in this study as partial fulfilment of a course requirement or were paid £3 for participating. All participants reported that they had normal vision.

Materials

One-hundred-and-twenty faces from a face database held at Stirling University[2] (Frowd, Hancock, & Carson, 2004) were used to assess the inversion effect. All stimuli were presented in greyscale. These were of typical looking White males (with no extraneous features, e.g., beards or glasses), aged between 18 and 35. The faces were presented on the same plain grey background and all clothing was masked. Hair was also masked. Due to this, the geometric centre of the face stimuli was the centre of the nose. An example of the face stimuli used is presented in Figure 1. All images were presented in 72 dpi resolution. Participants' responses were recorded on a standard computer keyboard, and the participants sat at a distance of 60 cm from the monitor. For half the participants, the images used for learning subtended the visual angle 5.35^0 along the horizontal and 7.12^0 along the vertical (75 mm x 100 mm) and the images used for test subtended the visual angle 8.88^0 along the horizontal and

[2] We would like to thank Charlie Frowd for providing these stimuli.

11.87^0 along the vertical (125 mm x 167 mm). For the other half of participants, the images subtended the visual angle 8.88^0 along the horizontal and 11.87^0 along the vertical for learning and the images at test subtended the visual angle 5.35^0 along the horizontal and 7.12^0 along the vertical for counterbalancing. This was used help control for picture recognition rather than face recognition[3]. Inverted versions of the faces were also generated. Fixation crosses were 1 mm thick and 20 mm high and wide. All stimuli were presented on a high-resolution colour monitor and were displayed using SuperlabPro™ 2 Research Software.

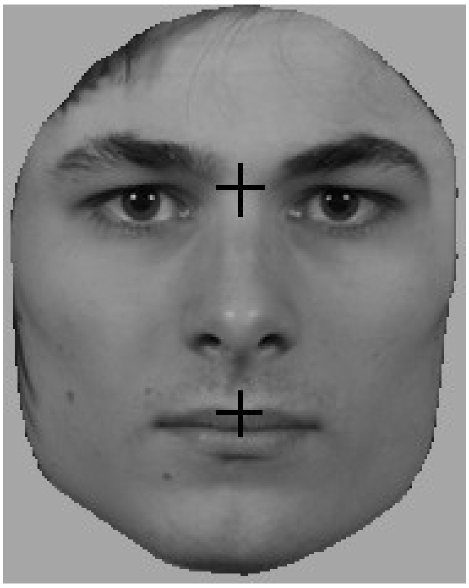

Figure 1. An example of a face from the database used in the present experiment with the spatial position of the fixation crosses superimposed (the image was of DAR and was not used in the study).

Procedure

A standard old/new recognition paradigm was employed. The experimental procedure involved three consecutive phases: learning; distractor; and test. In the learning phase, participants were presented with 60 (30 upright, 30 inverted) of the faces sequentially

[3]We acknowledge that changing size of the stimuli does not completely eradicate pictorial recognition, however it does serve as an additional control and rules out very low-level perceptual effects.

in a random order. Prior to each face a fixation cross appeared for 150 ms. This fixation cross cued the eyes or the mouth of the subsequent stimulus. In the control condition, the screen was blank for 150 ms. Following the fixation cross, the face was presented for 1500 ms, during which time participants rated each face for how attractive they thought the face was on a 1 to 9 Likert-type scale.

Immediately following the learning phase, participants were given an irrelevant questionnaire as a distracter, which typically lasted four minutes. Once participants had completed this questionnaire, the test phase began. For this, participants were presented with all 120 (60 target and 60 distractor) faces sequentially in a random order and were instructed to state whether they had seen each face before by pressing the appropriate keys. Half of the target and distractor faces were presented upright and half inverted. Orientation of faces was matched from learning to test. The same cueing conditions were used in the test as the learning phase: a third of the faces had the eyes cued, a third had the mouth cued, and a third had no cueing. Position of the fixation cross was matched from learning to test. The duration of the fixation cross (or blank screen) was 150 ms. Participants were instructed to be as fast and as accurate as possible. Each trial was response terminated (mean response time = 1004 ms).

Design

A 2 x 3 within-subjects design was employed, whereby the two independent variables were: the orientation of the face (upright or inverted); and the feature cued (the eyes, mouth, or no cueing). Orientation of the face was matched across learning and test for each face. The feature cued was matched across learning and test for each face. The face stimuli were counterbalanced, such that each appeared as a target and a distractor on equal number of times and each appeared upright and inverted an equal number of times. This created four counterbalance groups that had equal numbers of participants within them. The location of the fixation cross was randomised according to the rule that it cued the eyes, mouth and was not present an equal number of times for both upright and inverted faces. Recognition accuracy was measured using the signal detection theory measure of stimulus discriminability, *d'*.

Results & Discussion

The old/new responses were converted into the measure of recognition accuracy *d'* using the Macmillan and Creelman (2005) method. In this analysis, where no misses and false alarms were recorded for a particular condition for one participant, the counts were replaced with 0.5 (Macmillan & Creelman, 2005; Snodgrass & Corwin, 1988). The means for upright and inverted faces that were preceded by a fixation cross which cued the eyes or the mouth and the control (no cueing) condition are presented in Figure 2. Mean hit and false alarm rate are presented in Table 1. The data summarised in Figure 2 were subjected to a 2 x 3 factorial ANOVA with the factors: orientation of the face (upright and inverted) and the features being cued (eyes, mouth, or no cueing). There was a significant main effect of orientation, $F(1, 59) = 53.26$, $MSE = 0.73$, $p < .001$, $\eta_p^2 = .47$, whereby upright faces were more accurately recognised than inverted faces (mean difference = 0.66). There was also a main effect of cueing, $F(2, 118) = 21.61$, $MSE = 0.48$, $p < .001$, $\eta_p^2 = .27$. Bonferoni corrected pairwise comparisons were used to explore this main effect. Recognition accuracy was higher when the eyes were cued than when the mouth was cued (mean difference = 0.57, $p < .001$) and when there was no cueing (mean difference = 0.17, $p = .05$).

Recognition accuracy was lower when the mouth was cued than when there was no cueing (mean difference = 0.40, $p < .001$). These main effects were qualified by a significant interaction, $F(2, 118) = 4.14$, $MSE = 0.50$, $p = .02$, $\eta_p^2 = .07$.

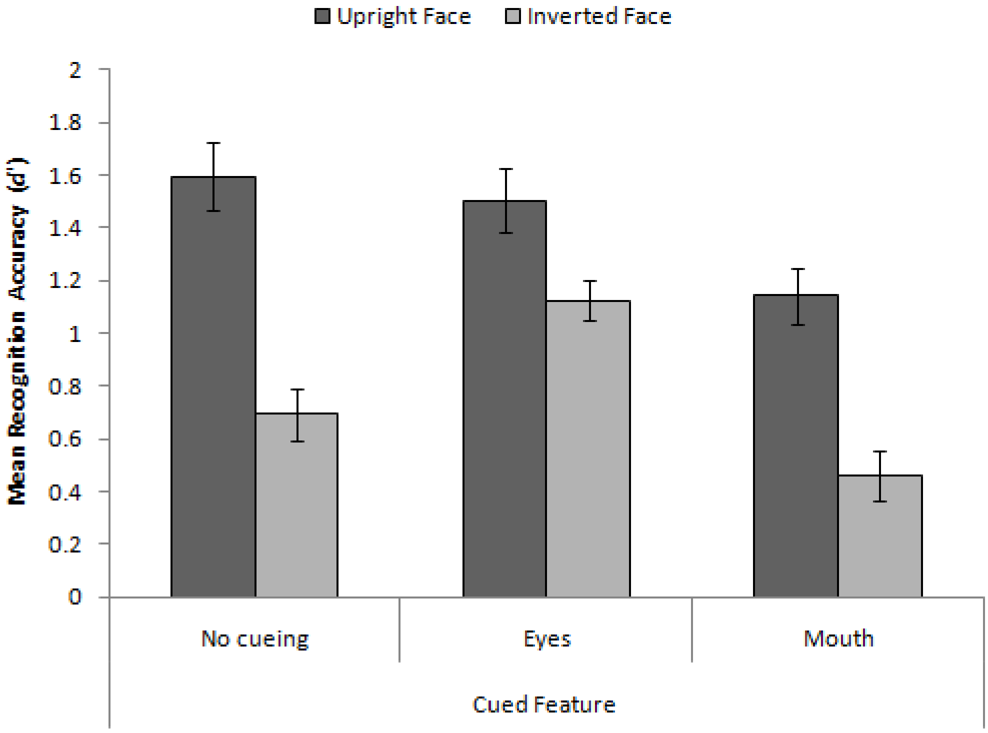

Figure 2. Mean recognition accuracy (*d'*) for upright and inverted faces with either the eyes, mouth, or no feature cued for Experiment 1. Error bars represent standard error.

The interaction was tested with paired-samples t-tests on the inversion effect, calculated by subtracting the *d'* for the inverted condition from the *d'* for the upright condition. Two approaches were employed, comparing the inversion effect against zero and comparing them against each other. This revealed that the inversion effect was significant in the no cueing condition, $t(59) = 5.12$, $p < .001$, effect size $r = .42$, the eyes condition, $t(59) = 3.65$, $p = .001$, effect size $r = .32$, and the mouth condition, $t(59) = 5.47$, $p < .001$, effect size $r = .45$. Furthermore, the magnitude of the inversion effect was significantly smaller when the eyes were cued (mean = 0.38, SE = 0.10) than when the mouth was cued (mean = 0.70, *SE* = 0.13), $t(59) = 1.75$, $p = .085$, effect size $r = .17$, and when there was no cueing (mean = 0.90, SE = 0.18), $t(59) = 2.60$, $p = .012$ effect size $r = .22$. There was no significant difference in magnitude of the inversion effect when the mouth was cued compared to when there was no cueing, $t(59) = 1.24$, $p = .22$, effect size $r = .09$. In addition, upright faces that had the mouth cued were recognised less accurately than upright faces that had the eyes cued (mean difference = 0.41, $t(59) = 2.74$, $p = .008$, or were not cued (mean difference = 0.51), $t(59) = 3.27$, $p = .002$. There was no difference between recognition accuracy for upright faces with the eyes cued and with no cueing (mean difference = 0.09), $t(59) = 0.69$, $p = .49$. Inverted faces that had the eyes cued were recognised more accurately than inverted faces that had the mouth cued (mean difference = 0.73), $t(59) = 5.95$, $p < .001$, or no cueing (mean difference = 0.43), $t(59) = 3.30$, $p = .002$. Recognition accuracy of inverted faces with the mouth cued was also lower than when there no cueing $t(59) = 7.23$, $p < .001$.

Table 1.

Mean (and SE) hit and false alarm (FA) rate for Experiments 1 and 2 split by orientation of the face and the position of the fixation cross.

		Cueing Type		
		No cueing	Eyes cued	Mouth cued
Upright face	Hit rate	.73 (.03)	.73 (.03)	.61 (.03)
	FA rate	.23 (.02)	.23 (.02)	.25 (.02)
Inverted face	Hit rate	.56 (.03)	.67 (.02)	.56 (.03)
	FA rate	.34 (.02)	.28 (.02)	.35 (.02)

Experiment 2Experiment 1	**Upright face**	Hit rate	.77 (.02)	.69 (.03)
		FA rate	.20 (.01)	.25 (.02)
	Inverted face	Hit rate	.72 (.02)	.61 (.03)
		FA rate	.26 (.02)	.43 (.03)

The results presented here suggest that if fixations are directed to the eyes then recognition accuracy is higher than if fixations are directed to the mouth in both upright and inverted faces. This is consistent with the increased diagnosticity of the eyes. However, the results indicate that the magnitude of the inversion effect is smaller if the eyes are cued than if the mouth was cued or when there was no cueing. This simple effect was predicted by our attentional hypothesis. The consequence of this research is that where one first looks greatly affects ones recognition accuracy in face recognition. When unguided, one may look at the upper part of a face image leading to an initial fixation on the eyes for upright or mouth for inverted faces. Such a preference for looking to the upper part of the face may partially explain the standard face-inversion effect as observed when uncued. Cuing the eyes reduces the inversion detriment. Cueing the mouth in an upright face produces a recognition detriment. Therefore, the face-inversion effect may partly be a consequence of initial fixation (this will be discussed further in the General Discussion).

Experiment 2

Experiment 1 indicated that there may be an attentional mechanism to the inversion effect. However, the faces were always presented in the middle of the screen and the fixation crosses were presented in the top or bottom portion of the screen. This could have provided the participants with a cue as to where the top of the face should be, which may explain the results. It may have increased the expectancy that the top of the face should appear where the cue was and expectancy can modulate the effects of being unable to process holistically (Rossion, 2009).

Experiment 2 was conducted whereby the fixation cross always remained in the centre of the screen preceding all faces. The faces however, were positioned high or low relative to the screen and presented either upright or inverted. The position of the fixation cross still cued the eyes or mouth in the face. In this situation, the fixation cross will not provide a cue as to where the top of the face will be. For each face positioning and orientation were matched from learning to test. A 2 x 2 factorial design was employed with the factors: orientation of the face and feature cued. The control condition was not run in Experiment 2 since we have demonstrated a standard inversion effect using these stimuli in Experiment 1. This also increases the experimental power. The hypotheses are the same as in Experiment 1.

Method

Participants

An opportunity sample of 40 (27 female, age range 18 to 43 years, mean = 25.6 years) participants from the Participation Panel at Cardiff University or Anglia Ruskin University took part in this study and were paid £4 for participation. All had self-reported normal or corrected vision.

Materials

The same experimental set-up and face database was used for this Experiment as in Experiment 1, except that 64 faces were used. They were presented in the same size and were of the same type as those in Experiment 1. These were either presented raised sufficiently for the fixation cross to cue the mouth, or lowered such that the fixation cross cued the eyes for upright faces (and vice versa for inverted faces).

Design & Procedure

Experiment 2 employed a 2 x 2 within-subjects design whereby the independent variables were orientation of the face (upright or inverted) and feature cued (eyes or mouth). Given that cueing the eyes produced a similar pattern of results to no cueing for upright faces in Experiment 1, the no cueing condition was not conducted in Experiment 2. Recognition accuracy was measured using the SDT measure *d'*. The faces were counterbalanced such that each appeared as a target the same number of times as a distractor, and counterbalanced for presentation orientation and position on screen. Similar to Experiment 1, Experiment 2 employed a standard old/new recognition paradigm except that in the learning phase, 32 faces were learnt, and in the test phase, 64 (32 target and 32 distractor) faces were presented. All other procedural aspects were the same as those in Experiment 1.

Results & Discussion

The mean recognition accuracy (*d'*) data are summarised in Figure 3. Mean hit and false alarm rate is presented in Table 1. The pattern of results indicates that both upright and inverted faces are recognised better with the eyes cued than with the mouth cued. The data summarised in Figure 3 were subjected to a 2 x 2 factorial ANOVA with the factors: orientation of the face (upright or inverted) and feature cued (eyes or mouth). The main effect of face orientation was significant, $F(1, 39) = 61.13$, $MSE = 0.21$, $p < .001$, $\eta_p^2 = .61$, whereby upright faces were recognised more accurately than inverted faces (mean difference = .56). The main effect of feature cued was significant, $F(1, 39) = 77.68$, $MSE = 0.18$, $p < .001$, $\eta_p^2 = .67$, where recognition accuracy was greater when the eyes were cued than when the mouth was cued (mean difference = 0.59). The interaction between orientation of the face and position of the face was significant, $F(1, 39) = 6.66$, $MSE = 0.24$, $p = .014$, $\eta_p^2 = .15$. This was revealed through a significant inversion effect (as calculated in Experiment 1) when the eyes were cued, $t(39) = 4.40$, $p < .001$, effect size $r = .44$, and when the mouth was cued, $t(39) = 6.13$, $p < .001$, effect size $r = .57$. Additionally, the inversion effect was larger when the mouth was cued (mean = 0.76, $SE = 0.12$) than when the eyes were cued (mean = 0.49, $SE = 0.09$), $t(39) = 2.58$, $p = .014$, effect size $r = .29$. Furthermore, recognition accuracy was higher when the eyes were cued than when the mouth was cued for upright faces (mean difference = 0.39), $t(39) = 4.27$, $p < .001$, and for inverted faces (mean difference = 0.79), $t(39) = 7.09$, $p < .001$.

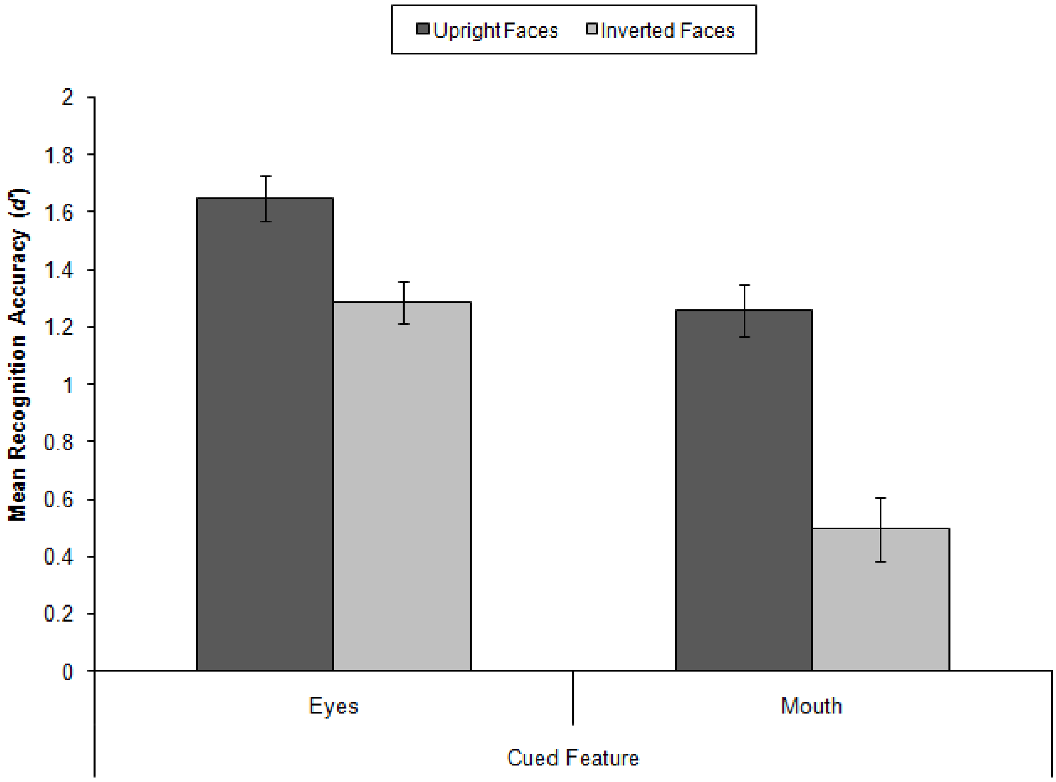

Figure 3. Mean recognition accuracy (*d'*) for upright and inverted faces split by feature cued (eyes or mouth) for Experiment 2. Error bars represent standard error.

The findings from Experiment 2 were consistent with those of Experiment 1. Fixation crosses cueing the eyes of an inverted face reduces the detrimental effect of inversion. Additionally, overall cueing the mouth led to lower recognition accuracy than cueing the eyes. This replication of the effect observed in Experiment 1 suggests that the position of the fixation cross and expectancy within the screen was not responsible for the original findings. It must be noted that the effect size in the reduction of the inversion effect due to the position of the fixation crosses was larger in Experiment 2 than in Experiment 1. This could be due to differences in stimuli number in the two experiments. Experiment 2 had fewer stimuli and thus reduced task demands. This may have provided participants with more attentional resources, thus allowing them to use the fixation crosses more efficiently.

Experiment 3

Although Experiments 1 and 2 provide evidence that fixation on diagnostic features plays a role in the face-inversion effect, there are many questions that remain unanswered. Given that the feature cued was matched at learning and at test in Experiments 1 and 2, it could be argued that the results are a product of feature-rather than face-recognition. Thus, Experiment 3 was conducted in which the features cued were not matched from learning to test. This also assesses the relative importance of feature cueing at learning and at test.

In Experiment 3, all the faces were learnt upright, with either their eyes or mouth cued. The subsequent recognition test included upright and inverted faces. These faces had the eyes or mouth cued at learning. For half the faces, the feature cued at learning was matched to test and for half the faces this was not matched. Thus, a fully factorial design was employed. For clarity, the conditions were (learning cue – test cue respectively); eyes-eyes; eyes-mouth; mouth-eyes, mouth-mouth. Given our findings thus far, we expect a main effect of feature, but whether this effect is at learning or test is unclear. The magnitude of the inversion effect will be reduced by cueing the eyes.

Method

Participants & Materials

An opportunity sample of 50 (36 female, age range was 18 to 47 years, mean = 24.3 years) participants from the Participation Panel at Cardiff University took part in this study and were paid £4 for participation. All had self-reported normal or corrected vision. The same experimental set-up and face database was used for this Experiment as in Experiment 1, except that 160 male faces were used.

Design & Procedure

Experiment 3 employed a 2 x 2 x 2 within-subjects design with the factors: orientation of the face at test (upright or inverted); feature cued at learning (eyes or mouth); and feature cued at test (eyes or mouth). Recognition accuracy was measured using the SDT measure *d'*. The faces were counterbalanced such that each appeared as a target the same number of times as it did a distractor, and counterbalanced for presentation orientation. Feature cueing was randomised in a similar manner to that conducted in Experiment 1. Similar to Experiment 1, Experiment 3 employed a standard old/new recognition paradigm except that in the learning phase, 80 faces were learnt, and in the test phase, 160 (80 target and 80 distractor) faces were presented. In the learning phase, faces were always presented upright.

Results & Discussion

The mean recognition accuracy (*d'*) are summarised in Figure 4[4]. Mean hit rate and false alarm rate is presented in Table 2. The data summarised in Figure 4 were subjected to a 2 x 2 x 2 within-subjects ANOVA with the factors: orientation at test (upright or inverted); feature cued at learning (eyes or mouth); and feature cued at test (eyes or mouth). This revealed a significant main effect of orientation, $F(1, 49)$ =

[4] For the 'new' faces in the recognition test, there was no fixation cross at learning. Thus, to compute *d'* an omnibus FA rate was used (Shriver, Young, Hugenberg, Bernstein, & Lanter, 2008). This was based on the orientation and cueing conditions – thus, four FA rates were used: upright eyes cued; upright mouth cued; inverted eyes cued; and inverted mouth cued. The results follow the same pattern if the same overall FA was used, but would be less appropriate as it would overestimate the FA for upright faces and underestimate it for inverted faces.

255.18, $MSE = 0.22$, $p < .001$, $\eta_p^2 = .84$, whereby upright faces were recognised more accurately than inverted faces (mean difference = 0.75). The main effect of feature cued at learning was also significant, $F(1, 49) = 39.61$, $MSE = 0.21$, $p < .001$, $\eta_p^2 = .45$, in which recognition accuracy was greater when the eyes were cued at learning than when the mouth was cued at learning (mean difference = 0.29). There was also a main effect of feature cued at test, $F(1, 49) = 20.57$, $MSE = 0.28$, $p < .001$, $\eta_p^2 = .30$, in which recognition accuracy was greater when the eyes were cued at test than when the mouth was cued at test (mean difference = 0.24).

The orientation by feature cued at learning interaction was significant, $F(1, 49) = 7.99$, $MSE = 0.35$, $p = .007$, $\eta_p^2 = .14$, as was the orientation by feature cued at test interaction, $F(1, 49) = 3.89$, $MSE = 0.10$, $p = .05$, $\eta_p^2 = .07$. These interactions revealed themselves through significant inversion effects in all conditions: eyes cued at learning, $t(49) = 9.50$, $p < .001$, effect size $r = .69$; mouth cued at learning, $t(49) = 10.48$, $p < .001$, effect size $r = .72$; eyes cued at test, $t(49) = 13.55$, $p < .001$, effect size $r = .80$; mouth cued at test, $t(49) = 13.05$, $p < .001$, effect size $r = .79$. Additionally the inversion effect was larger when the mouth was cued (at learning, mean = 0.92, $SE = 0.09$; at test, mean = 0.81, $SE = 0.06$) than when the eye was cued (at learning, mean = 0.58, $SE = 0.06$; at test, mean = 0.68, $SE = 0.05$). No other interaction was significant, largest $F(1, 49) = 0.98$, smallest $p > .32$.

These results indicate that the effect of cueing the eyes occurs whether this cueing occurs at learning or at test. However, the effect sizes seem to indicate that the cueing effects are greater at learning than at test. This is consistent with the premise that first fixations are and early encoding is important for accurate face recognition.

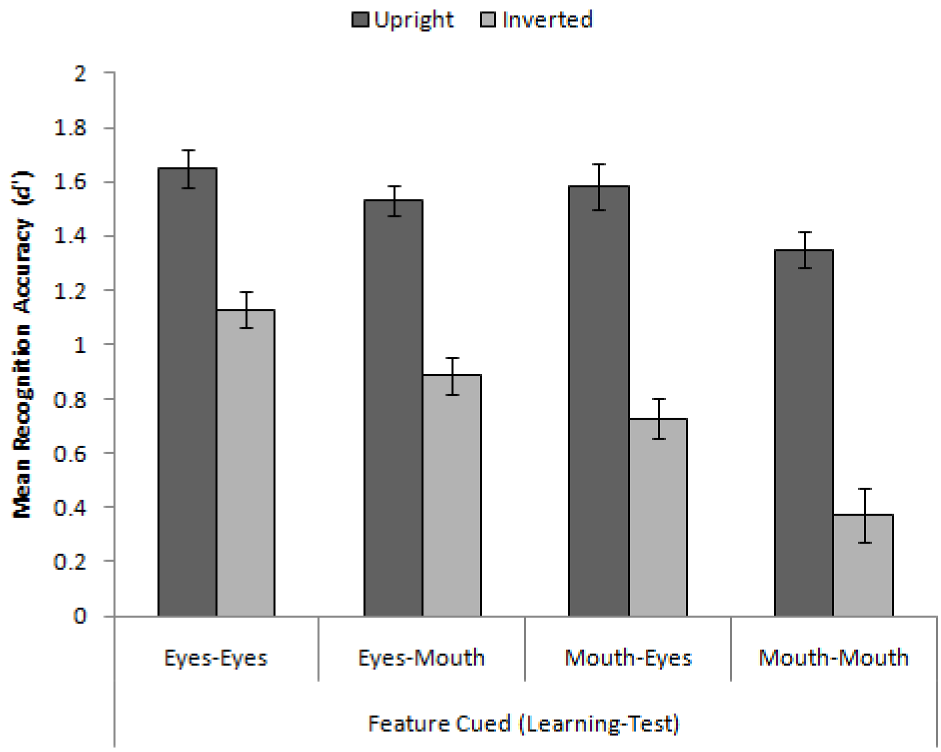

Figure 4. Mean recognition accuracy (*d'*) for upright and inverted faces split by cued feature for Experiment 3. Error bars represent standard error.

Table 2.

Mean (and SE) hit and false alarm (FA) rate for Experiment 3 split by orientation of the face and the position of the fixation cross.

		Cueing Type (Learning-Test)			
		Eyes-Eyes	Eyes-Mouth	Mouth-Eyes	Mouth-Mouth
Upright face	Hit rate	.76 (.02)	.75 (.02)	.74 (.03)	.69 (.02)
	FA rate	.19	.21	.19	.21
Inverted face	Hit rate	.71 (.02)	.66 (.02)	.58 (.03)	.48 (.04)
	FA rate	.30	.33	.30	.33

General Discussion

Three experiments were reported here that demonstrated that cueing the eyes in a face-recognition task reduces the detrimental effects of inversion. Experiment 1 established the basic paradigm and found that cueing the eyes prevent much of the deleterious effects of inversion, whereas cueing the mouth did not. Additionally, cueing the eyes led to greater recognition accuracy than cueing the mouth. Experiment 2 found that these cueing effects were shown not to depend on expectations. In Experiment 3, we found that these cueing effects were maintained when the orientation of faces was not matched from learning to test. Additionally, the cueing effects seemed to be greater during learning than during test (compare the η_p^2 values). These experiments demonstrate the diagnostic utility of the eyes in face perception and that the location of the first fixation has an effect on recognition accuracy and might even underpin the face-inversion effect.

In the introduction, we presented a novel attentional hypothesis extending the fact that the eyes have increased diagnosticity in face recognition. In all experiments, recognition accuracy was greater when the eyes were cued than when the mouth was cued. This adds to the literature explaining how important the eyes are for face perception. In addition, cueing the eyes reduced the magnitude of the inversion effect relative to no cueing or cueing the mouth. This hypothesis suggests that the first feature fixated upon guides how accurately faces will be recognised, and if this is diagnostic, then accuracy will be greater than if it is not diagnostic. Thus, in an inverted face the first feature fixated upon is typically less diagnostic than in an upright face.

The present results also add to the literature concerning how there is a hierarchy of features (Haig, 1985, McKelvie, 1976), in which the eyes are the most salient feature. The work of Barton and colleagues (2001, 2003, Sekunova & Barton,

2008) demonstrates how inversion interacts with this factor. Specifically, inversion disrupts discrimination of vertical changes to the eyes and mouth unless the mouth changes are cued (Sekunova & Barton, 2008)[5].

Taking Barton and colleagues' findings and ours together, inversion, feature-saliency, and attentional cueing appear to interact. Cueing diagnostic features reduces the face-inversion effect for recognition (our findings), but does not affect detecting changes to these features in inverted faces (Sekunova & Barton, 2008). Cueing less diagnostic features does not affect the face-inversion effect for recognition, but does aid in detecting when changes are made to these features. This interaction is often under explored in face recognition studies and may represent the critical aspect of the face processing system. Indeed, this interaction and the hierarchy of feature salience (Barton et al., 2003), suggests that some features are more critical to face recognition than others. Some authors may argue that this contradicts the holistic processing account as it implies that all features are processed equally. However, this is not necessary for the holistic processing account since certain regions or features may carry more information for coding holistically (Schwarzer, Huber, & Dümmler, 2005) and that information about all features can be extracted from a central fixation, at least for upright faces (Rossion, 2009, Van Belle, De Graef, Verfaillie, Rossion, & Lefèvre, 2010). Our data suggests holistic information is harder to extract from fixations to an individual feature such as the mouth. These data are, also, consistent with data from Sekuler, Gaspar, Gold, and Bennett (2004), who found that the features used in a discrimination task are the same for upright and inverted faces, but that the extraction of information is more efficient from upright faces.

[5] This, at first, seems inconsistent with our present findings. However, there was a limited memory component in Sekunova and Barton's study compared to ours. Their participants could simply compare mouths across three stimuli. In the present study, participants could not employ this strategy. The two different paradigms are thus likely to produce different results.

Our data lead to the conclusion that the accurate encoding of a face relies on attention being allocated to the most diagnostic features. If fixation is first paid to less diagnostic features then encoding will be poorer. By default, White participants' will first fixate between the eyes at the bridge of the nose (e.g., Hsiao & Cottrell, 2008, Orban de Xivry et al., 2008). This is consistent with our data suggesting that in upright faces no cueing produced similar accuracy to cueing between the eyes. If a face is inverted, the participant has to search, in the first instance, for the most diagnostic features. This suggests that we normally do not fixate enough upon the eyes in inverted faces. This may cause a delay in the accurate processing of the face, which may be related to the delay in the face-specific ERP N170 when processing an inverted face (Bentin et al., 1996; Eimer, 2000; Itier & Taylor, 2002, 2004; Jeffreys, 1993)[6]. However, Jacques and Rossion (2009) have indicated that the ERP P1 is more susceptible to interactions between fixation position and orientation rather than N170. Indeed, there is eye-tracking data supporting the claim that the eyes are fixated upon less in inverted faces than in upright faces (Barton et al., 2006) and the mouth receives more fixations in inverted faces than in upright faces (Williams & Henderson, 2007, but see Van Belle et al., 2010) This, in turn, causes the face to be less well encoded and more difficult to recognise. Indeed, the "special" and expert nature of face recognition (e.g., Enns & Shore, 1997; Farah, Tanaka, & Drain, 1995) may be, in part, due to a specialist attentional system to the most diagnostic facial features.

Although we have introduced an attentional explanation of the face inversion effect, recent evidence suggests that these data could be incorporated within a slightly

[6] This assumes that there are parallels between the behavioural face inversion effect (i.e., less accurate encoding of inverted faces leading to lower recognition accuracy) and the ERP effects (i.e., delay or larger amplitude in the N170 for inverted faces). This may not be precise and there is debate as to what the N170 truly represents.

modified holistic processing account for two reasons. Firstly, the eye region may actually provide more configural information[7] than other features (Caldara et al., 2005; c.f., Blais, Jack, Scheepers, Fiset, & Caldara, 2008). Secondly, central fixations (between the eyes, or bridge of the nose, Hsiao & Cottrell, 2008; Orban de Xivry, 2008) may lead to an extraction of information about the whole face. Indeed, participants' visual field is more restricted when viewing inverted faces (Rossion, 2009), preventing participants from extracting information about the whole face. Evidence comes from data showing that when the perceptual window is limited (using gaze-contingent windows masking parafoveal views) to one feature at a time, recognition of upright faces is impaired whereas recognition accuracy of inverted faces is substantially less impaired (Van Belle et al., 2010). Furthermore, participants encouraged to engage in analytical processing tend to fixate on each feature individually, whereas participants engaging in holistic processing tend to fixated in a central position between the eyes (Schwarzer et al., 2005).

Our data adds to this theory by showing that extraction of holistic information from upright faces is impaired if the mouth is the focal feature. It also indicates that in inverted faces, fixating on a diagnostic region is more useful than a less diagnostic region or feature. Thus, we propose that there may be an interaction between holistic processing and feature saliency (c.f., Barton et al., 2003) provided the interpretation of holistic processing is based on restriction of perceptual field (Rossion, 2009). That is, that the ideal fixation point for accurate encoding is weighted according to the diagnostic value of the nearby features. The region that provides the most amount of holistic information is between the eyes (e.g., Schwarzer et al., 2005) because the eyes are of more diagnostic value (e.g., Haig, 1986a, b).

[7] By implication, the assumption is configural processing is at least related to holistic processing.

Previously, we highlighted the participants' race. This is an important limitation of our study in terms of generalisation to non-White stimuli and participants. The features that are most diagnostic in the recognition of White faces are different from the features that are most diagnostic in the recognition of Black or East Asian faces (Ellis, 1975; c.f., O'Toole, Deffenbacher, Abdi, & Bartlett, 1991). The eyes are not so often described by Black participants (Shepherd et al., 1975) or scanned by East Asian participants in free-viewing conditions[8] (Blais et al., 2008; Caldara, Zhou, & Miellet, 2010; Kelly, Miellet, & Caldara, 2010; but see Goldinger, He, & Papesh, 2009). This suggests that they have lower diagnostic value in the recognition of Black and East Asian faces than White faces. Alternatively, holistic processing can be extracted from regions other than between the eyes in East Asian observers, or fixation location may be unrelated to information extracted (Kuhn & Tatler, 2005). This is based on the fact that recognition accuracy rates do not differ cross-culturally (Kelly et al., 2010). . The cross-cultural differences in fixation pattern (Blais et al., 2008) indicate that cueing the eyes of a Black face would not necessarily lead to high recognition accuracy and would not affect the magnitude of the face-inversion effect.

As described, we are not presenting this attention to diagnostic features framework to account for all deficits due to inversion. We are suggesting that there is an attentional element interacting with holistic processing to the face-inversion effect in recognition paradigms, not that it is the cause of all deficits due to inversion (such as configural or relational changes affecting identification accuracy more than featural changes, e.g., Leder & Bruce, 2000). There maybe multiple mechanisms involved in inversion effects, with different paradigms recruited different mechanisms (similar to

[8] Caldara et al. (2010) used a gaze-contingent foveal window to locate which features are scanned. In the least restricted conditions, the eyes were less fixated upon by East Asian observers. In more restricted viewing conditions, the eyes were fixated upon by East Asian observers,

evidence suggesting that different spatial frequencies are recruited for different tasks, Schyns, Bonnar, & Gosselin, 2002; Schyns & Oliva, 1999).

Before we can conclude that there is an attentional element in the face-inversion effect additional studies need to be conducted to further the three experiments reported here. Firstly, the relationship between fixating upon diagnostic features, perceptual field (Rossion, 2008), and holistic processing could be better elucidated. How fixation crosses and feature cueing affect other face perception processes (for example, the N170) could be explored. If the N170 is associated with processing of the eye region (e.g., Bentin et al., 1996; Itier et al., 2007; Latinus & Taylor, 2006, but see Eimer, 1998), then cueing the eyes in an inverted face may remove any delay in the N170 caused by inversion. Eye-tracking data could also explore whether cueing of the eyes actually attracts the eyes and whether this affects the perceptual field (e.g., Rossion, 2009; Van Belle et al., 2010).

The novelty of the approach applied in this study has many implications for further studying feature saliency in face recognition. Additionally, this study has major implications for the research that employs fixation crosses in face recognition. We suggest that the fixation crosses may actually be having an unintended influence on face perception tasks. Having a fixation cross in the centre of the screen often indirectly cues the eyes or the bridge of the nose (e.g., Henderson et al., 2005). This may artificially increase the recognition accuracy of upright faces. Researchers should thus be careful how they choose to place any fixation cross or use fixation boxes around where the stimuli will be presented. Blais et al.'s (2008) solution to prevent anticipatory strategies in eye-movements could address our concerns: That is to present stimuli in pseudo-random locations on screen. To conclude, we have presented evidence to suggest that the face-inversion effect may in some part be modulated by fixations made to the eye region, in which cueing to the eyes of an inverted face reduces the recognition deficit caused by inversion.

References

Althoff, R. R. & Cohen, N. J. (1999). Eye-movement-based memory effect: a reprocessing effect in face perception. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25,* 997 – 1010.

Bartlett, J. C. & Searcy, J. (1993). Inversion and configuration of faces. *Cognitive Psychology, 19,* 473 – 497.

Bartlett, J. C., Search, J. H., & Abdi, H. (2003). What are the routes to face recognition? In M. A. Peterson & G. Rhodes (Eds), *Perception of Faces, Objects, and Scenes: Analytic and Holistic Processes.* Oxford: Oxford University Press.

Barton, J. J. S., Deepak, S., & Malik, N. (2003). Attending to faces: change detection, familiarization, and inversion effects. *Perception, 32,* 15 – 28.

Barton, J. J. S., Keenan, J. P., & Bass, T. (2001). Discrimination of spatial relations and features in faces: Effects of inversion and viewing duration. *British Journal of Psychology, 92,* 527 – 549.

Barton, J. J. S., Radcliffe, N., Cherkasova, M. V., Edelman, J., & Intriligator, J. M. (2006). Information processing during face recognition: The effects of familiarity, inversion, and morphing on scanning fixations. *Perception, 35*, 1089 - 1105.

Bentin, S., Allison, T., Puce, A., Perez, E., & McCarthy, G. (1996). Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience, 8,* 551 – 565.

Blais, C., Jack, R. E., Scheepers, C., Fiset, D., & Caldara, R. (2008). Culture shapes how we look at faces. *PLoS One, 3,* e3022.

Bukach, C. M., Bub, D. N., Gauthier, I., & Tarr, M. J. (2006). Perceptual expertise effects are not all or none: spatially limited perceptual expertise for faces in a case of prosopagnosia. *Journal of Cognitive Neuroscience, 18,* 48 – 63.

Caldara, R., Schyns, P., Mayer, E., Smith, M. L., Gosselin, F., & Rossion, B. (2005). Does prosopagnosia take the eyes out of face representations? Evidence for a defect in representing diagnostic facial information following brain damage. *Journal of Cognitive Neuroscience, 17,* 1652 – 1666.

Caldara, R., Zhou, X., & Miellet, S. (2010). Putting culture under the '*Spotlight*' reveals universal information use for face recognition. *PlosOne, 5,* e9708. Doi:10.1371/journal.pone.0009708.

Carey, S. (1992). Becoming a face expert. *Philosophical Transactions of the Royal Society of London B, 335,* 95 – 103.

Dal Martello, M. F. & Maloney, L. T. (2006). Where are kin recognition signals in the human face? *Journal of Vision, 6,* 1356 – 1366.

Davies, G., Ellis, H. D., & Shepherd, J. (1977). Cue saliency in faces as assessed by the 'Photofit' technique. *Perception, 6,* 263 – 269.

Daw, P. S. & Parkin, A. J. (1981). Observations on the efficiency of two different processing strategies for remembering faces. *Canadian Journal of Psychology, 35,* 351 – 355.

Deffenbacher, K. A., Leu, J. R., & Brown, E. L. (1981). Memory face faces: Testing method, encoding strategy, and confidence. *American Journal of Psychology, 94,* 13 – 26.

Diamond, R. & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology: General, 115,* 107 – 117.

Eimer, M. (2000). Effects of face-inversion on the structural encoding and recognition of faces – evidence from event-related brain potentials. *Cognitive Brain Research, 10,* 145 – 158.

Ellis, H. D. (1975). Recognizing faces. *British Journal of Psychology, 66,* 409 – 426.

Ellis, H. D., Deregowski, J. B., & Shepherd, J. W. (1975). Descriptions of White and Black faces by White and Black subjects. *International Journal of Psychology, 10,* 119 – 123.

Ellis, H. D., Shepherd, J. W., & Davies, G. M. (1979). Identification of familiar and unfamiliar faces from internal and external features: some implications for theories of face recognition. *Perception, 8,* 431 – 439.

Endo, M. (1983). Cue saliency in briefly presented faces: a comparison with cue saliency in upside-down faces. *Tohoku Psychologica Folia, 42,* 85 – 91.

Enns, J. T. & Shore, D. I. (1997). Separate influences of orientation and lighting in the inverted-faces effect. *Perception & Psychophysics, 59,* 23 – 31.

Farah, M. J., Tanaka, J. W., & Drain, M. (1995). What causes the face inversion effect? *Journal of Experimental Psychology: Human Perception and Performance, 21,* 628 – 634.

Freire, A., Lee, K., & Symons, L. (2000). The face-inversion effect as a deficit in the encoding of configural information: direct evidence. *Perception, 29,* 159 – 170.

Frowd, C. D., Hancock, P. J. D., & Carson, D. (2004). EvoFIT: a holistic, evolutionary facial imaging technique for creating composites. *ACM Transactions on Applied Psychology, 1,* 1 – 21.

Goffaux, V. & Rossion, B. (2007). Face inversion disproportionately impairs the perception of vertical but not horizontal relations between features. *Journal of*

Experimental Psychology: Human Perception and Performance, 33, 995 – 1002.

Goldinger, S. D., He, Y., Papesh, M. H. (2009). Deficits in cross-race face learning: Insights from eye movements and pupillometry. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 35,* 1105 – 1122. DOI: 10.1037/a0016548

Gosselin, F. & Schyns, P. G. (2001). Bubbles: a technique to reveal the use of information in recognition tasks. *Vision Research, 41,* 2261 – 2271.

Haig, N. D. (1984). The effect of feature displacement on face recognition. *Perception, 13,* 505 – 512.

Haig, N. D. (1985). How faces differ – a new comparative technique. *Perception, 14,* 601 – 615.

Haig, N. D. (1986a). Exploring recognition with interchanged facial features. *Perception, 15,* 235 – 247.

Haig, N. D. (1986b). High-resolution facial feature saliency mapping. *Perception, 15,* 373 – 386.

Heisz, J. J. & Shore, D. I. (2008). More efficient scanning for familiar faces. *Journal of Vision, 8,* 1 – 10.

Henderson, J. M., Williams, C. C., & Falk, R. J. (2005). Eye movements are functional during face learning. *Memory & Cognition, 33,* 98 – 106.

Hills, P. J. & Lewis, M. B. (2006). Reducing the own-race bias in face recognition by shifting attention. *Quarterly Journal of Experimental Psychology, 59,* 996 – 1002.

Hochberg, J. & Galper, R. E. (1967). Recognition of faces: I. an exploratory study. *Psychonomic Science, 9,* 619 – 620.

Hole, G. (1994). Configurational factors in the perception of unfamiliar faces. *Perception, 23,* 65 – 74.

Hosie, J. A., Ellis, H. D., & Haig, N. D. (1988). The effect of feature displacement on the perception of well-known faces. *Perception, 17,* 461 – 474.

Hsiao, J. H. & Cottrell, G. (2008). Two fixations suffice in face recognition. *Psychological Science, 19,* 998 – 1006.

Itier, R. J., Alain, C., Sedore, K., & McIntosh, A. R. (2007). Early face processing specificity: It's in the eyes! *Journal of Cognitive Neuroscience, 19,* 1815 – 1826.

Itier, R. J. & Taylor, M. J. (2002). Inversion and contrast polarity reversal affect both encoding and recognition processes of unfamiliar faces: a repetition study using ERPs. *Neuroimage, 15,* 353 – 372.

Itier, R.J. & Taylor, M. J. (2004). Effects of repetition learning on upright, inverted and contrast-reversed face processing using ERPs. *Neuroimage, 21,* 1518 – 1532.

Jacques, C. & Rossion, B. (2009). Spatio-temporal dissociation between low- and high-level effects of stimulus inversion on early face-sensitive electrophysiological responses. *Journal of Vision, 9,* 533. doi: 10.1167/9.8.533

Jeffreys, D. A. (1993). The influence of stimulus orientation on the vertex positive scalp potential evoked by faces. *Experimental Brain Research, 96,* 163 – 172.

Joseph, R. M. & Tanaka, J. (2002). Holistic and part-based face recognition in children with autism. *Journal of Child Psychology and Psychiatry, 43,* 1 – 14.

Kelly, D. J., Miellet, S., & Caldara, R. (2010). Culture shapes eye movements for visually homogenous objects. *Frontiers in Psychology, 1,* 1- 7. doi: 10.3389/fpsyg.2010/0006.

Kuhn, G. & Tatler, B. W. (2005). Magic and fixation: now you don't see it, now you do. *Perception, 34,* 1155 – 1161.

Latinus, M. & Taylor, M. J. (2006). Face processing stages: impacts of difficulty and the separation of effects. *Brain Research, 1123,* 179 – 187.

Leder, H. & Bruce, V. (1998). Local and relational aspects of face distinctiveness. *Quarterly Journal of Experimental Psychology, 51A,* 449 – 473.

Leder, H. & Bruce, V. (2000). When inverted faces are recognised: the role of configural information in face recognition. *Quarterly Journal of Experimental Psychology, 53A,* 513 – 536.

Leder, H. & Carbon, C. (2005). When context hinders! Learn-test compatibility in face recognition. *Quarterly Journal of Experimental Psychology, 58A,* 235 – 250.

Maurer, D., Le Grand, R., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences, 6,* 255 – 260.

McKelvie, S. (1976). The role of eyes and mouth in the memory of a face. *American Journal of Psychology, 89,* 311 – 323.

McKone, E. & Yovel, G. (2009). Why does picture-place inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. *Psychonomic Bulletin, & Review, 16,* 778 – 797.

Orban de Xivry, J.-J., Ramon, M., Lefèvre, P., & Rossion, B. (2008). Reduced fixation on the upper area of personally familiar faces following acquired prosopagnosia. *Journal of Neuropsychology, 2,* 245 – 268.

O'Toole, A., Defenbacher, K., Adbi, H., & Bartlett, J. (1991). Simulating the "other-race effect" as a problem in perceptual learning. *Connection Science, 3,* 163 – 178.

Pellicano, E. & Rhodes, G. (2002). The influence of divided attention on holistic face perception. *Cognition, 82,* 225 – 257.

Phillips, R. J. (1979). Some explanatory experiments on memory for photographs of faces. *Acta Psychologica, 43,* 39 – 56.

Rhodes, G., Brake, K., & Atkinson, A. (1993). What's lost in inverted faces? *Cognition, 47,* 25 – 57.

Rhodes, G., Hayward, W. G., & Winkler, C. (2006). Expert face coding: configural and component coding of own-race and other-race faces. *Psychonomic Bulletin & Review, 13,* 499 – 505.

Rakover, S. S. & Teucher, B. (1997). Facial inversion effects: parts and whole relationship. *Perception & Psychophysics, 59,* 752 – 761.

Risesenhuber, M., Jarudi, I., Gilad, S., & Sinha, P. (2004). Face processing in humans is compatible with a simple shape-based model of vision. *Proceedings in Biological Sciences, 271,* S448 – S450.

Rossion, B. (2008). Picture-plane inversion leads to qualitative changes of face perception. *Acta Psychologica, 128,* 274 – 289.

Rossion, B. (2009). Distinguishing the cause and consequence of face inversion: the perceptual field hypothesis. *Acta Psychologica, 132,* 300 – 312.

Rossion, B., Delvenne, J. F., Debatisse, D., Goffaux, V., Bruyer, R., Crommelinck, M., et al. (1999). Spatio-temporal localization of the face inversion effect: an event-related potentials study. *Biological Psychology, 50,* 173 – 189.

Rossion, B., Gauthier, I., Tarr, M. J., Despland, P., Bruyer, R., Linotte, S., et al. (2000). The N170 occipito-temporal component is delayed and enhanced to inverted faces but not to inverted objects: an electrophysiological account of face-specific processes in the human brain. *Neuroreport, 11,* 69 – 74.

Rossion, B. & Gauthier, I. (2002). How does the brain process upright and inverted faces? *Behavioral and Cognitive Neuroscience Reviews, 1,* 63 – 75.

Sæther, L., Van Belle, W., Laeng, B., Brennen, T., & Øvervoll, M. (2009). Anchoring gaze when categorizing faces' sex: evidence from eye-tracking data. *Vision Research, 49,* 2870 – 2880.

Schwarzer, G., Huber, S., & Dümmler, T. (2005). Gaze behavior in analytical and holistic face processing. *Memory and Cognition, 33,* 344 – 354.

Schyns, P. G., Bonnar, L., & Gosselin, F. (2002). Show me the features! Understanding recognition from the use of visual information. *Psychological Science, 13,* 402 – 409.

Schyns, P. G. & Oliva, A. (1999). Dr. Angry and Mr. Smile: When categorization flexibility modifies the perception of faces in rapid visual presentations. *Cognition, 69,* 243 – 265.

Searcy, J. H. & Bartlett, J. C. (1996). Inversion and processing of component and spatial-relational information in faces. *Journal of Experimental Psychology: Human Perception and Performance, 22,* 904 – 915.

Sekuler, A. B., Gasper, C. M., Gold, J. M., & Bennett, P. J. (2004). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology, 14,* 391 – 396. DOI: 10.1016/j.cub.2004.02.028.

Sekunova, A. & Barton, J. J. S. (2008). Long-range and short-range relations in the perception of the vertical position of the eyes in inverted. *Journal of*

Experimental Psychology: Human Perception and Performance, 34, 1129 – 1135.

Sergent, J. (1984). An investigation into component and configural processes underlying facial perception. *British Journal of Psychology, 75,* 221 – 242.

Shepherd, J., Davies, G., & Ellis, H. D. (1981). Studies of cue saliency. In G. Davies, H. D. Ellis, & J. Shepherd (Eds.), *Perceiving and Remembering Faces* (pp. 105 – 131). New York: Academic Press.

Shriver, E. R., Young, S. G., Hugenberg, K., Bernstein, M. J., & Lanter, J. R., (2008). Class, race, and the face: social context modulates the cross-race effect in face recognition. *Personality and Social Psychology Bulletin, 34,* 260 – 274.

Snodgrass, J. G. & Corwin, J. (1988). Pragmatics of measuring recognition: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 35 – 50.

Tanaka, J. W. & Farah, M. J. (1993). Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology, 46A,* 225 – 245.

Thompson, P. (1980). Margaret Thatcher – a new illusion. *Perception, 9,* 483 – 484.

Valentine, T. (1988). Upside-down faces: a review of the effect of inversion upon face recognition. *British Journal of Psychology, 79,* 471 – 491.

Valentine, T. & Bruce, V. (1986). The effects of race, inversion and encoding activity of face recognition. *Acta Psychologica, 61,* 259 – 273.

van Belle, G., De Graef, P., Verfaillie, K., Rossion, B., & Lefèvre, P. (2010). Face inversion impairs holistic perception: Evidence from gaze-contingent stimulation. *Journal of Vision, 10,* 1 – 13.

van der Linde, I. & Watson, T. (2010). A combinatorial study of pose effects in unfamiliar face recognition. *Vision Research, 50,* 522 – 533.

Walker-Smith, G. J., Gale, A. G., & Findlay, J. M. (1977). Eye movement strategies involved in face perception. *Perception, 6,* 313 – 326.

Wenger, M. J. & Townsend, J. T. (2000). Spatial frequencies in short-term memory for faces: a test of three frequency-dependent hypotheses. *Memory & Cognition, 28,* 125 – 142.

Williams, C. C., & Henderson, J. M. (2007). The face inversion effect is not a consequence of aberrant eye movements. *Memory & Cognition, 35*, 8, 1977-1985.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology, 81,* 141 – 145.

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configural information in face perception. *Perception, 16,* 747 – 759.

Yovel, G. & Kanwisher, N. (2004). Face perception: domain specific, not process specific. *Neuron, 44,* 889 – 898.