

## Recognition and eye movements with partially hidden pictures of faces and cars in different orientations

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**Abstract.** Inverted faces are more difficult to identify than upright ones. This even applies when pictures of faces are partially hidden in geometrical designs so that it takes some seconds to recognise them. Similar, though not as pronounced, orientation preferences apply to familiar objects. We compared the recognition times and patterns of eye movements for two sets of familiar symmetrical objects. Pictures of faces and of cars were embedded in patterns of concentric circles in order to render them difficult to recognise. They were presented in four orientations, at 90° intervals from upright. Two experiments were conducted with the same set of stimuli; experiment 1 required participants to respond in terms of faces or cars, and in experiment 2 responses were made to the orientation of the embedded image independently of its class. Upright faces were recognised more accurately and faster than those in other orientations; fixation durations were longer for upright faces even before recognition. These results applied to both experiments. Orientation effects for cars were not pronounced and distinctions between 90°, 180°, and 270° embedded images were not consistent; this was the case in both experiments.

**Keywords:** face recognition, inverted faces, eye movements, hidden figures, cars

### 1 Introduction

Research on picture recognition has concentrated on one stimulus more than others—the human face (Calder and Young 2005; Farah et al 1998; Johnston and Edmonds 2009; Kanwisher 2000; Tsao and Livingstone 2008). Moreover, the characteristic pattern of eye movements when viewing pictures of faces, established by Yarbus (1967), has been replicated many times and has become an accepted canon in face research (see Tatler et al 2010). Despite this, the eye movement dimension has been somewhat neglected (but see Bindemann et al 2009; Williams and Henderson 2007). In almost all studies of face perception the pictures are readily recognisable as belonging to that class of objects (faces), and often the observer's task is to provide the identity of the face, or to discriminate between the equivalence of pairs of pictures. We report two experiments in which the objects represented were not immediately recognisable, as they were embedded in geometrical carrier designs. That is, the pictorial images were partially hidden in geometrical patterns and it took some seconds before they could be recognised. Moreover, two classes of objects were pictorially embedded in concentric circular designs—faces and cars. When viewed frontally, pictures of faces and cars share symmetry about a vertical axis and both have prominent paired parts, like eyes or headlights. Indeed, comparisons of both processing and scanning frontally viewed upright faces and cars display similarities (Windhager et al 2008, 2010). Introducing uncertainty about the class of objects embedded (faces or cars) in the geometrical carriers, rather than restricting all the pictorial stimuli to a single class, enables more detailed determination of factors that might be differentially associated with processing one of them (faces). Because the pictorial images take some seconds to be recognised, more subtle issues of eye movements can be addressed. This technique allows us to consider inspection behaviour before and after the observer recognises the category of object that they are viewing. At first, the viewer is unable to determine the class of object embedded in the

geometric pattern and it is several seconds before this awareness emerges. As such, these stimuli offer a unique opportunity to study inspection behaviour for face stimuli when perception is dissociated from awareness.

In general, pictures of objects are recognised more readily in an upright orientation. This applies particularly to pictures of faces (Köhler 1940; Rock 1973; Rossion 2008; Yin 1969) and it has been an aspect of artistic manipulation for centuries (Wade 2007; Wade and Nekes 2005; Wade et al 2003). When discussing the optical inversion experiments of Stratton (1897), Wolfgang Köhler described the effect clearly: “For this experiment I select a picture, or outline-drawing of an object, which shows a conspicuous change in appearance when it is upside down. This is the case, for instance, with photographs of known or unknown persons. They change so much that what we call facial expression disappears almost entirely in the abnormal orientation” (1940, pages 25–26). As Goffaux and Rossion (2007) remarked, “inverting a face stimulus has become one of the most widely used stimulus transformations to prevent the processing of facial configuration” (page 995). Face inversion has been used as an index of the cognitive processing style for face perception. It is widely accepted that face processing involves two distinct processing styles: configural or holistic processing of the global structure and arrangement of features in the face, and featural or piecemeal processing of the individual components (eg Collishaw and Hole 2000; Lui et al 2010; Schwaninger et al 2005; Watier et al 2010). When a picture of a face is inverted, the normal arrangement of features is disrupted (the eyes now appear below the mouth etc) so disrupting the configural information in the face stimulus. In contrast the individual features are not as disrupted by this inversion. As such, face inversion disrupts the configural information in a face, but spares featural information, thus specifically hindering the possibility to employ a configural processing style on the face stimulus. Evidence for this specificity of effect comes from comparing the ability of participants to discriminate face pairs in which very subtle manipulations of either featural or configural information are introduced (Freire et al 2000). For upright face pairs participants are highly sensitive to both types of subtle manipulation. For inverted faces participants remain very sensitive to featural differences between the pairs, but not to configural differences. The common finding that inversion has a less detrimental effect on recognition for nonface pictures has been used to argue that a dominance of configural processing of objects is specific to face stimuli, with a greater reliance on featural processing for nonface stimuli (eg Yin 1969).

The specificity of inversion for disrupting configural but not featural facial information has been used to explore the neural mechanisms that might underlie these two processing styles (Itier et al 2007; Yoval and Kanwisher 2005). This approach has been used to argue that the right fusiform gyrus is intimately involved in the configural processing of faces, although the face specificity of this region is controversial (see McKone et al 2007).

While much attention has been paid in the literature to upright and inverted faces, fewer studies have examined intermediate orientations. Schwaninger and Mast (2005) found that performance around the horizontal was inferior to that for both upright and inverted faces. Thus, in addition to upright (0°) and inverted (180°) pictorial images, those inclined at orientations of 90° and 270° were examined. Using pictures of faces and cars, Rossion and Curran (2010) found that inversion effects were greater for the former (measured in terms of accuracy), even amongst car experts. Examining pictorial images of faces and cars inclined at 90° and 270° to the normally upright orientation breaks down the symmetry around the vertical axis. That is, comparison of performance at these orientations with those at 0° and 180° will provide an indication of the importance of the axis of symmetry.

We have previously reported a study using pictures of embedded faces as stimuli (Tatler et al 2007): comparisons were made between the geometrical carrier pattern alone, and

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with the embedded face in both an upright and inverted orientation. Each stimulus was presented for 10 s, and the time taken to recognise whether a face was present or not was measured, as were observers' eye movements throughout the observation period. Twenty such combinations of pattern alone, pattern with upright face, and pattern with inverted face were presented. Participants took around 4 s to respond and found it much easier to report the absence of an embedded face than its presence. For the latter, participants took longer to report the presence of an inverted face than an upright one. Moreover, observers were faster at detecting the presence of an upright face than the absence of a face in the pattern. The characteristics of eye movements also differed between the three configurations: fixation times were longer and saccade amplitude was smaller when an upright face was present than for either of the other conditions. Interestingly, differences in inspection behaviour depended crucially on the perceptual experience of the observer: differences in inspection behaviour between upright and inverted faces arose only when the face was correctly detected by the observer; there was no difference in inspection behaviour for upright and inverted embedded faces when they were not detected by the observer. As such, while the physical presence of an embedded face influenced inspection behaviour irrespective of the viewer's percept, the orientation of the face had an effect only when the viewer was aware that a face was present.

In summary, our previous study suggested three main findings. First, the presence of an embedded stimulus can exert influences on inspection even when an observer was unaware of the embedded image. Second, the results pointed to the influence of inversion on viewing behaviour and its contingency upon the emergence of a conscious percept of the embedded face. Third, for these embedded faces, the orientation influenced inspection behaviour. However, our previous work did not allow us to look at face-specific perceptual effects on inspection behaviour because only faces were used as the embedded images. In addition, we used a variety of patterns into which we embedded faces and inspection behaviour was influenced by the nature of the carrier pattern.

The geometrical carrier patterns were different for each embedded face, half being rectilinear and the other half being curvilinear. Faces embedded in rectilinear patterns were easier to detect (they were detected more accurately and faster) than faces embedded in curvilinear patterns, in which the pattern contains a strongly defined centre. Not only did the two types of pattern change the ability of the observer to detect the hidden face, but they also gave rise to different eye movement strategies. Longer fixations, separated by smaller saccadic relocations, occurred when viewing curvilinear patterns. In order to remove differences based upon the geometry of the carrier patterns, the same (concentric circular) pattern was used for all embedded images in the present experiments.

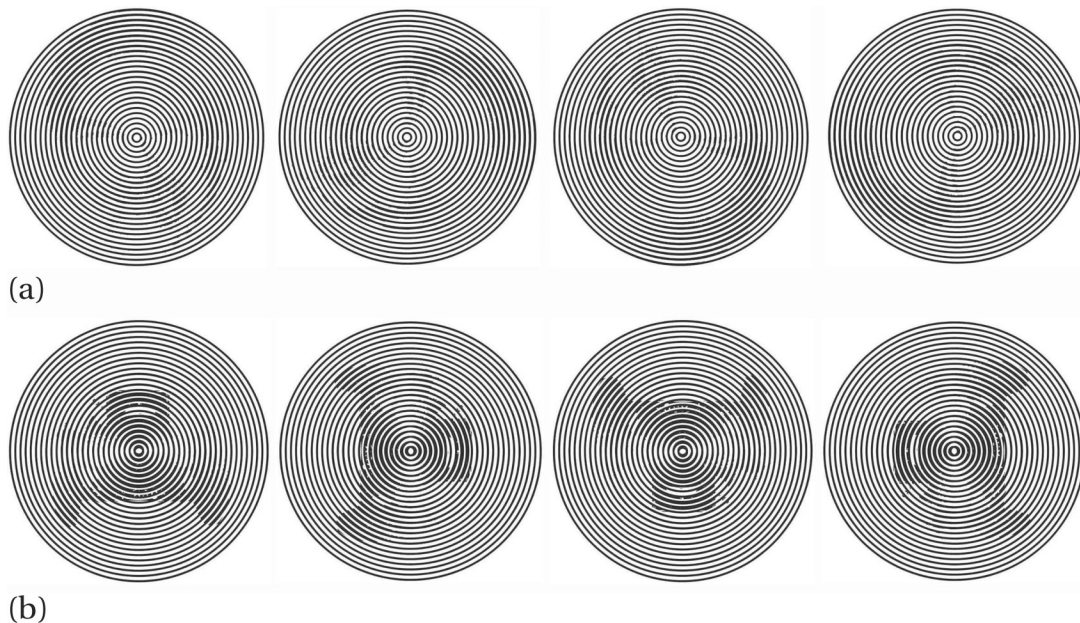
Two experiments aim to compare detection and inspection for face and nonface (car) objects all embedded in the same carrier pattern. Moreover we will compare detection and inspection for objects embedded at four orientations: with rotations of 0°, 90°, 180°, and 270° clockwise from upright (see [figure 1](#)). The experiments involve different tasks for the observers which differentially emphasise the relevance of the embedded object class (experiment 1) or the orientation of the embedded object (experiment 2). As such, we are able to see whether rotation and object-specific detection and inspection effects depend upon the viewer's task.

These experiments allow us to address four key questions. First, are inspection patterns different for symmetrical pictures drawn from different categories (faces/cars)? Second, do embedded faces and cars show any evidence for inversion effects, and do these differ between the two classes of object? Third, does the task of the viewer influence the recognition and inspection behaviour of the viewers, and does this depend upon the class of embedded

object? Fourth, are there effects of the class of the embedded object that are expressed before recognition by the observer?

## 2 Experiments

Two experiments are reported which examined recognition and oculomotor behaviour when viewing patterns containing embedded images. All the geometrical carrier patterns were the same—concentric circles. In addition, uncertainty initially existed between the nature of the objects represented—faces or cars—as well as their initial visibility, examples of which are shown in [figure 1](#). All the pictures of faces and cars were derived from photographs of frontal views and they were approximately centred symmetrically about the carrier pattern. The same stimuli were used for both experiments, but the task required of the observer differed. In experiment 1 the task was to respond differentially when a car or a face was detected, with no requirement to signal orientation. In experiment 2 the task was to report the orientation of the embedded image, with no requirement to signal the nature of the embedded figure.



**Figure 1.** Examples of the stimuli used in the two experiments: (a) a picture of a face embedded in concentric circles at orientations of 0°, 90°, 180°, and 270°; (b) pictures of a car in similar orientations. Note: the embedded images are easier to see at this small size than was the case with larger stimuli in the experiments.

### 2.1 Method

**2.1.1 Participants.** Each experiment involved sixteen different participants who were naive to the purposes of the study and took part on a voluntary unpaid basis. All had normal or corrected-to-normal vision.

**2.1.2 Stimuli.** Ten perceptual portraits were created by embedding pictures of faces (viewed from the front) in a pattern of concentric circles (the carrier pattern). This was done by varying the local structure of elements in the carrier pattern, and as such the pictorial image was not defined by visible outline contours. The same procedure was applied to ten pictures of cars which had been photographed from the front. The concentric circles were drawn, photographed on lith (high-contrast) film, and then scanned. Like the concentric carrier pattern, the pictures of faces and cars were reduced to black and white and all background detail was removed. Negatives of the high-contrast images were superimposed on negatives

of the concentric circles so that the objects were represented by arcs of circles alone. Both the concentric circles and arc components were rendered positive so that when the latter was exactly superimposed on the former the arcs were invisible. The arc components were then shifted slightly relative to the concentric circles so that the faces/cars were minimally visible. Essentially, the embedded objects are defined by minor variations in the thickness of the carrier lines corresponding to the features of the pictorial image. The photographs of faces and cars were taken by us, and, since they are not standard images, all the embedded designs used in the experiment are shown (in an upright orientation) in [figure 2](#). The face/car image was then contained in the low spatial frequency content of the design whereas the carrier pattern consisted of high spatial frequencies. For the present experiment they were scanned (at 200 dpi) and presented on the monitors as described below. (A general strategy for seeing the embedded faces in the figures printed in figures 1 and 2, if they are initially difficult to detect, is to view them from several metres rather than from reading distance.)

Each pictorial image could be presented in one of four orientations (see [figure 1](#)) and over the course of the experiment each participant viewed all four orientations of each embedded image, in random order. Each participant therefore viewed eighty experimental stimuli. The size of the display is crucial to the ease of detecting the embedded face/car: the smaller the overall pictorial image the more easily a face or car can be detected. Pilot data suggested that embedded images were detectable but only after several seconds for designs subtending approximately 15°. While the pictorial images subtended 15°, they were displayed on a computer screen with an area subtending 40° horizontally and 30° vertically and had a resolution of 1600 x 1200 pixels. The position of the pictorial image within the display area varied randomly on each trial.

**2.1.3 Eye movement recording.** Eye movements were recorded using an SR Research Ltd EyeLink II eye tracker, sampling pupil position at 500 Hz. The spatial accuracy of the tracker was calibrated using a nine-point target grid and assessed using a further nine-point grid. The eye tracker was recalibrated if the second nine-point grid revealed a spatial accuracy worse than  $\pm 0.5$  deg. Eye position data were collected for the eye that produced the better spatial accuracy as determined using the calibration. Saccades and fixations were defined using the saccade detection algorithm supplied by SR Research: saccades were identified by deflections in eye position in excess of 0.1 deg, with a minimum velocity of  $30 \text{ deg s}^{-1}$  and a minimum acceleration of  $8000 \text{ deg s}^{-2}$ , maintained for at least 4 ms. The eye tracker is head mounted and no chin rest was employed; participants were asked to keep the head relatively still.

### 3 Experiment 1

The task for the sixteen participants in experiment 1 was to distinguish between the class of pictorial images presented—whether they were pictures of faces or cars. No instruction concerning the orientation in which the embedded images were presented was given.

#### 3.1 Procedure

Following calibration of the eye tracker, participants were told that they would see a series of pictorial images that could appear at any location on the screen. Each trial was preceded by a fixation marker located randomly within a radius of 10 deg from the centre of the screen. The particular pictorial image was then presented for 10 s. Participants were instructed to indicate whether a face or a car was being displayed on the screen by pressing the appropriate button on a Microsoft gamepad controller: button A to indicate a car, or button B to indicate a face. Subjects were asked to respond as soon as they recognised whether it was a picture of a face or a car. Presentation time of the stimuli did not vary according to participant response time. The eighty images were displayed in a different random sequence for each participant.



**Figure 2.** The range of stimulus patterns used in experiments 1 and 2. Columns 1 and 2 contain embedded faces and columns 3 and 4 display cars as viewed from the front. The five faces in column 1 are of males whereas those in column 2 are of females. Each image was presented upright (as shown) or inclined by 90°, 180°, or 270° as shown in figure 1, which uses the first examples of faces and cars shown above.

### 3.2 Results

**3.2.1 Recognition.** The behavioural data for comparisons between faces and cars will be presented before the patterns of eye movements are considered. While the participants' task was simply to decide whether the embedded object was a face or a car, and did not involve any judgment of orientation, we will analyse performance and inspection data in terms of both the object class and its orientation. Overall, the embedded images were recognised correctly on around 87% of trials, with the best performance (for upright faces) being 93% and embedded pictures of faces being recognised more accurately than those of cars in all orientations (table 1). A two (object class: face, car) by four (orientation: 0°, 90°, 180°, 270°) repeated measures ANOVA confirmed that the proportion of embedded faces that were recognised was significantly higher than that for cars:  $F(1, 15) = 5.27, p = 0.037, \text{partial } \eta^2 =$

0.260. However, there was no main effect of orientation,  $F(3, 45) = 0.60$ ,  $p = 0.622$ , partial  $\eta^2 = 0.038$ , suggesting that the orientation of the embedded object did not influence the accuracy of deciding whether the embedded object was a car or face. There was no interaction between object class and orientation:  $F(3, 45) = 0.49$ ,  $p = 0.691$ , partial  $\eta^2 = 0.032$ .

**Table 1.** Proportion of correct responses for embedded images of faces and cars at each orientation.

Stimulus type	Orientation (°)	Mean	Standard deviation
Face	0	0.93	0.12
	90	0.88	0.16
	180	0.88	0.17
	270	0.90	0.15
Car	0	0.83	0.22
	90	0.86	0.19
	180	0.81	0.23
	270	0.83	0.11

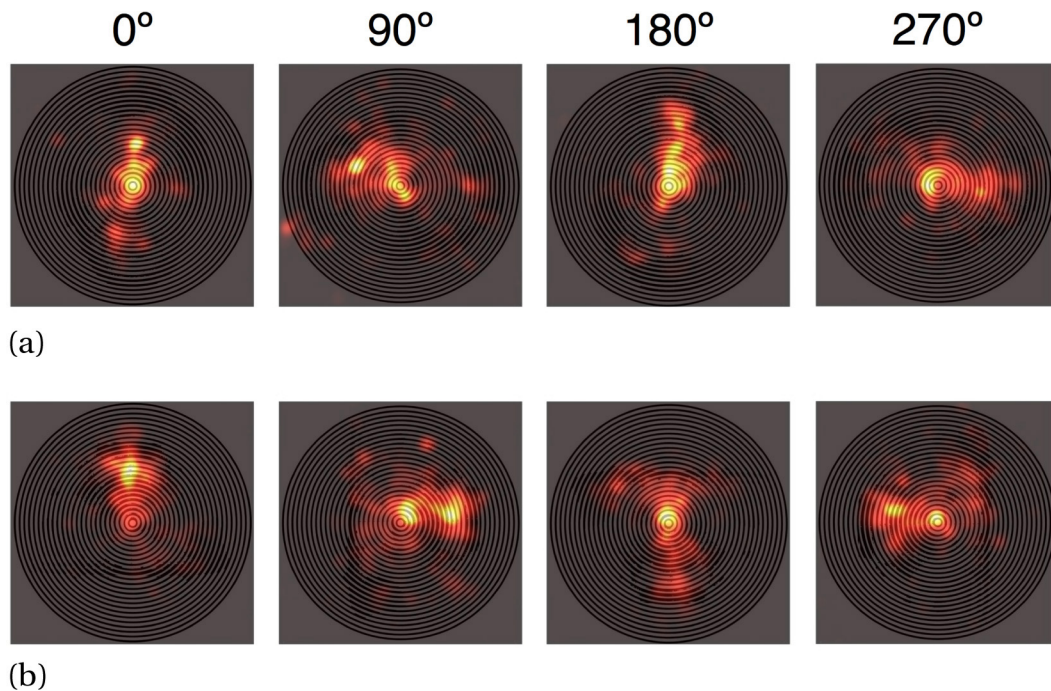
A similar pattern of results was found for the time taken to respond to the upright faces, but not to cars (table 2). Embedded faces were detected not only more accurately than cars but also considerably faster:  $F(1, 15) = 33.31$ ,  $p < 0.001$ , partial  $\eta^2 = 0.690$ . On average it required 3294 ms to respond to the face stimuli whereas the value for cars was 4142 ms. There was a main effect of orientation on response time:  $F(3, 45) = 5.55$ ,  $p = 0.003$ , partial  $\eta^2 = 0.270$ ; and a significant interaction between object class and orientation:  $F(3, 45) = 12.34$ ,  $p < 0.001$ , partial  $\eta^2 = 0.451$ . This interaction is evident in table 2: for faces, response time was shortest for upright faces and longest for inverted (180° rotation) faces; for cars, response time was longer for upright cars than for cars embedded at any other orientation. Post hoc Bonferroni-corrected t-tests confirmed that responses were faster for upright faces than for faces embedded at 90° ( $p = 0.024$ ), 180° ( $p = 0.001$ ), or 270° ( $p = 0.024$ ). Faces embedded upside down were responded to slower than faces embedded at 270° ( $p = 0.019$ ). No other contrasts were significant for embedded faces. For embedded cars, post hoc t-tests revealed no differences in response times between any of the embedded orientations.

**Table 2.** Response times (in ms) for embedded images of faces and cars at each orientation.

Stimulus type	Orientation (°)	Mean	Standard deviation
Face	0	2439	1386
	90	3515	1995
	180	4041	2087
	270	3182	1978
Car	0	4337	2113
	90	3975	2026
	180	4140	1942
	270	4116	2134

**3.2.2 Eye movements.** Figure 3 shows that at least qualitatively there were clear differences in how observers looked at the patterns in the eight different conditions of the first experiment. Distributions of gaze time are superimposed as ‘heat maps’ on the stimuli for which these data were collected. Data are plotted for one example face stimulus set (top row) and one example car stimulus set (bottom row) for each of the four orientations; data were combined across all sixteen observers. The distributions of gaze time were constructed from the fixation

events in the eye tracker data, adding a Gaussian with half-width-at-half-maximum of 1 deg and a magnitude equal to the duration of the fixation; that is the distributions plot gaze time, and not the number of fixations. We present these data as a demonstration that viewing behaviour did vary according to the object class and orientation. However, we do not present quantitative analysis of gaze locations due to the heterogeneity of the embedded faces: while these were similar, the precise placement of features within the patterns showed sufficient variability and so conclusions from these data would be hard to make.



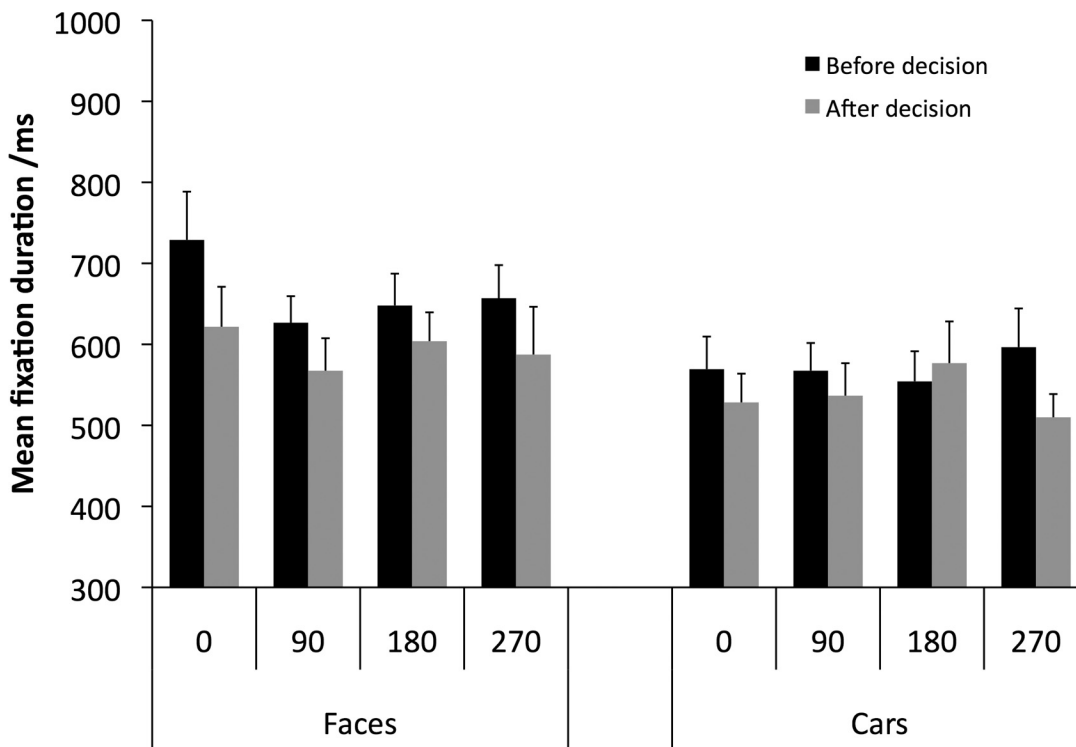
**Figure 3.** Gaze time accumulated over all sixteen observers in experiment 1 for (a) one example face stimulus set and (b) one example car stimulus set. Because these data are provided as a qualitative visualisation of inspection behaviour, the precise gaze times indicated by each colour are not shown here.

Following our previous work (Tatler et al 2007) we describe eye movements in terms of the fixation durations and saccade sizes. We also present data for the periods before and after responses to the embedded face or car (figure 4). A two (object class: face, car) by four (orientation: 0°, 90°, 180°, 270°) by two (decision state: before, after response) repeated measures ANOVA showed that fixation durations were longer on stimuli in which faces were embedded than on stimuli containing embedded cars:  $F(1, 15) = 31.99, p < 0.001$ , partial  $\eta^2 = 0.681$ . However, there were no main effects of orientation or decision state, and no significant interactions, suggesting that only the type of object embedded in the pattern influenced fixation durations during inspection. It should be noted that mean fixation durations on this task were quite a bit longer than the typical 300 ms found in picture viewing. This is in line with our previous work (Tatler et al 2007) for circular patterns and presumably reflects a combination of the difficulty of the task and the difficulty associated with the circular nature of the patterns.

Saccade sizes showed a slightly different pattern of results (figure 5). Saccades were smaller when viewing patterns with embedded faces than when viewing patterns with embedded cars:  $F(1, 15) = 8.22, p = 0.012$ , partial  $\eta^2 = 0.354$ . There was also a main effect of decision state,  $F(1, 15) = 4.37, p = 0.054$ , partial  $\eta^2 = 0.225$ , with smaller saccades after making a response than before. There was no main effect of the orientation of the embedded



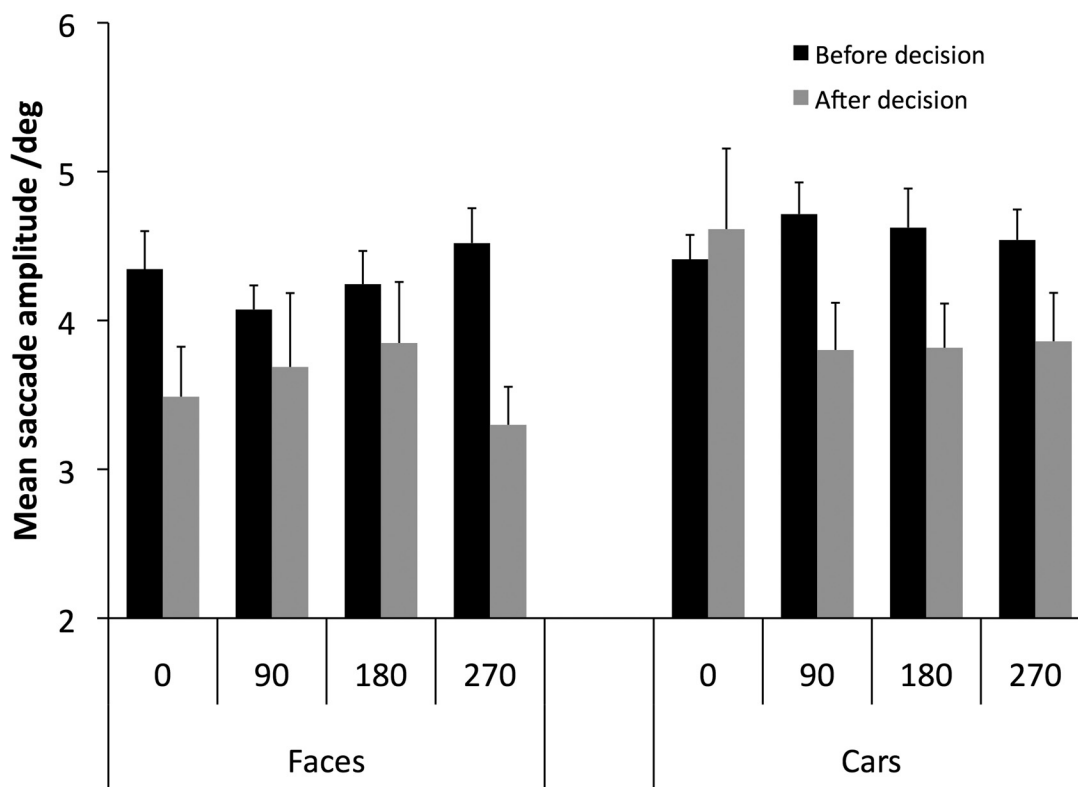
object. There was a significant three-way interaction:  $F(3, 45) = 3.99$ ,  $p = 0.013$ , partial  $\eta^2 = 0.210$ .



**Figure 4.** Mean fixation durations (ms) before and after responses were made, for faces and cars in each orientation. Error bars show +1 standard deviation from the mean.

### 3.3 Discussion

The data from experiment 1 suggest that, when viewing patterns with embedded faces and cars, the type and orientation of the embedded object influence inspection behaviour and detection performance. For the response time data we found a typical inversion effect: with pictures of faces, detection times when they were upright were faster than when the pictures were embedded at any other orientation. However, for cars, detection times were unaffected by the orientation at which they were embedded. When considering inspection behaviour, we found a three-way interaction between object class, orientation, and decision state for saccade amplitudes. This interaction suggests that the amplitude of saccades during viewing is sensitive to aspects of the stimulus (the object class and orientation) and to the perceptual experience of the observer (whether the observer has identified the embedded object). Sensitivity of eye movement behaviour to both the physical image and perceptual experience is consistent with findings from our previous study (Tatler et al 2007). However, we found that fixation durations were influenced significantly only by whether the embedded object was a face or a car. The absence of orientation effects and whether or not the observer had responded is in contrast to our previous findings for fixation duration. This may be due to the different nature of the task in the two studies: here, participants were simply asked to judge the class of object, ignoring the orientation at which it was embedded. However, in our previous study the task was to judge the orientation of the embedded object. Experiment 2 in the present study allows us to determine whether the differences between experiment 1 and our previous work can be attributed to this difference in task instructions for the observers.



**Figure 5.** Mean saccade sizes (deg) before and after responses were made, for faces and cars in each orientation. Error bars show +1 standard deviation from the mean.

## 4 Experiment 2

The task for the sixteen participants in experiment 2 was to report the orientation of the embedded pictorial image—whether they were inclined at 0°, 90°, 180°, or 270°—irrespective of whether the embedded object was a car or a face. Participants were instructed to indicate the orientation of the embedded image displayed on the screen; this task was performed by pressing the appropriate button on the Microsoft gamepad controller with the buttons orientated to reflect the four possible rotations (ie buttons were arranged in a diamond shape). To disambiguate the horizontally rotated (90° and 270°) objects, participants were asked to press the button corresponding to where the top of the embedded object (ie the top of the head or roof of the car) was located. Participants were asked to respond as soon as they recognised the orientation of the embedded image. Otherwise the stimuli and procedure were the same as for experiment 1.

### 4.1 Results

**4.1.1 Recognition.** When observers were reporting the orientation of an embedded image alone (table 3), their performance was poorer than when distinguishing between faces and cars (experiment 1, table 1). This may be expected since there were four possible responses in this as compared with two in the first experiment. Nonetheless, embedded faces were correctly detected on 67% of trials which exceeded those for cars (52%); this difference was confirmed by a two-way repeated measures ANOVA which revealed a main effect of object class:  $F(1, 15) = 11.38, p = 0.004, \text{partial } \eta^2 = 0.413$ . There was no main effect of orientation, but there was a significant interaction between object class and orientation:  $F(3, 45) = 3.68, p = 0.019, \text{partial } \eta^2 = 0.197$ . Post hoc Bonferroni-corrected t-tests were used to break down this interaction. Performance for correctly identifying the orientation of upright faces

was better than that for faces embedded at 90° ( $t = 0.009$ ). No other comparisons were significant.

**Table 3.** Proportion of correct responses for embedded images of faces and cars at each orientation.

Stimulus type	Orientation (°)	Mean	Standard deviation
Face	0	0.78	0.17
	90	0.56	0.29
	180	0.65	0.32
	270	0.69	0.29
Car	0	0.52	0.22
	90	0.55	0.22
	180	0.48	0.29
	270	0.53	0.26

A similar numerical pattern can be seen for response times (table 4). Even when the response was in terms of orientation, embedded pictures of faces were detected more rapidly than those for cars (2799 ms as compared with 3795 ms):  $F(1, 15) = 36.72$ ,  $p < 0.001$ , partial  $\eta^2 = 0.710$ . However, for response times there was no interaction between object class and orientation, nor was there a main effect of orientation.

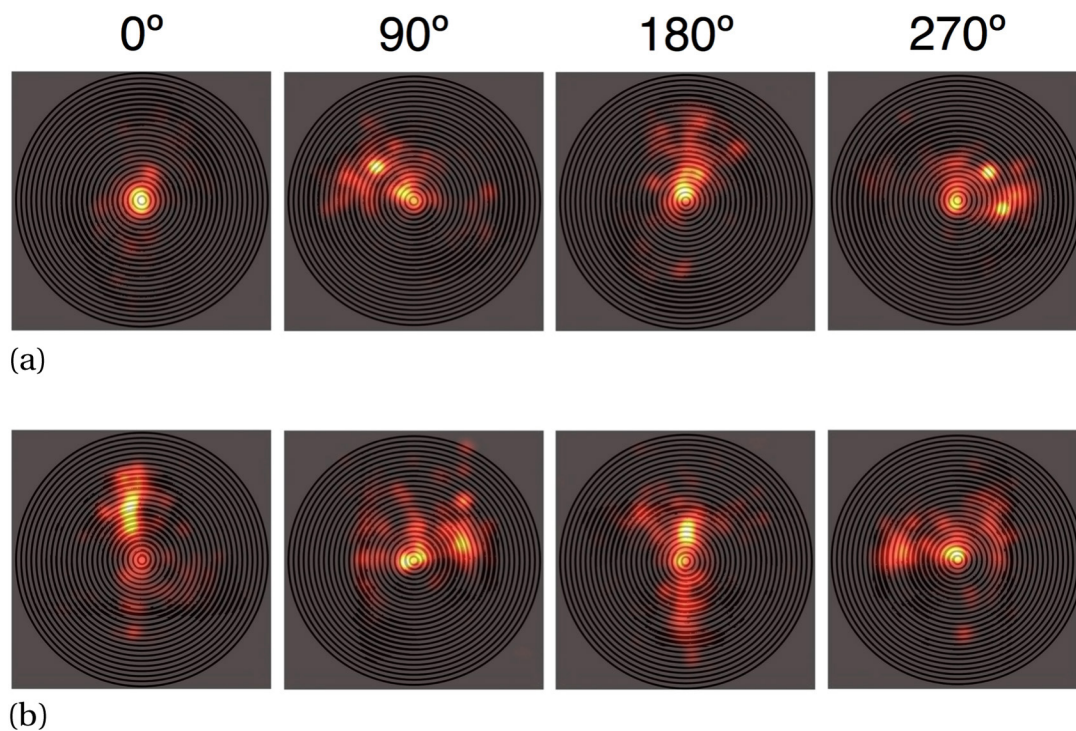
**Table 4.** Response times (in ms) for embedded images of faces and cars at each orientation.

Stimulus type	Orientation (°)	Mean	Standard deviation
Face	0	2483	738
	90	3132	1176
	180	2851	1009
	270	2736	873
Car	0	3789	1217
	90	3868	1158
	180	3709	1403
	270	3811	2134

4.1.2 *Eye movements.* Figure 6 plots cumulative gaze time distributions for the same face and car stimuli that were shown in figure 3 above. As before, clear qualitative differences are apparent according to the class and orientation of the embedded object.

As in experiment 1, the eye movements were recorded before and after a response was made in order to determine whether there were differences prior to recognition of the orientation of the embedded images. For fixation durations, there was a significant main effect of object class,  $F(1, 15) = 29.51$ ,  $p < 0.001$ , partial  $\eta^2 = 0.663$ , with longer fixations on faces than on cars (figure 7). No other main effects or interactions were significant, although the interaction between object class, orientation, and decision state approached significance:  $F(3, 45) = 2.57$ ,  $p = 0.066$ , partial  $\eta^2 = 0.146$ . Fixations in experiment 2 were longer than in experiment 1 (compare with figure 4). We assume that the longer fixation durations in this experiment reflect the added difficulty of this task (which was also evident in the lower accuracies of responses in table 4).

For saccade amplitudes the pattern of results was largely similar to that found in experiment 1 (figure 8). There was a main effect of object class,  $F(1, 15) = 9.53$ ,  $p = 0.008$ , partial  $\eta^2 = 0.389$ , with smaller saccades made to patterns with embedded faces than those with embedded cars. There was a main effect of decision state,  $F(1, 15) = 7.55$ ,  $p = 0.015$ ,



**Figure 6.** Gaze time accumulated over all sixteen observers in experiment 2 for (a) one example face stimulus set and (b) one example car stimulus set. Because these data are provided as a qualitative visualisation of inspection behaviour, the precise gaze times indicated by each colour are not shown here.

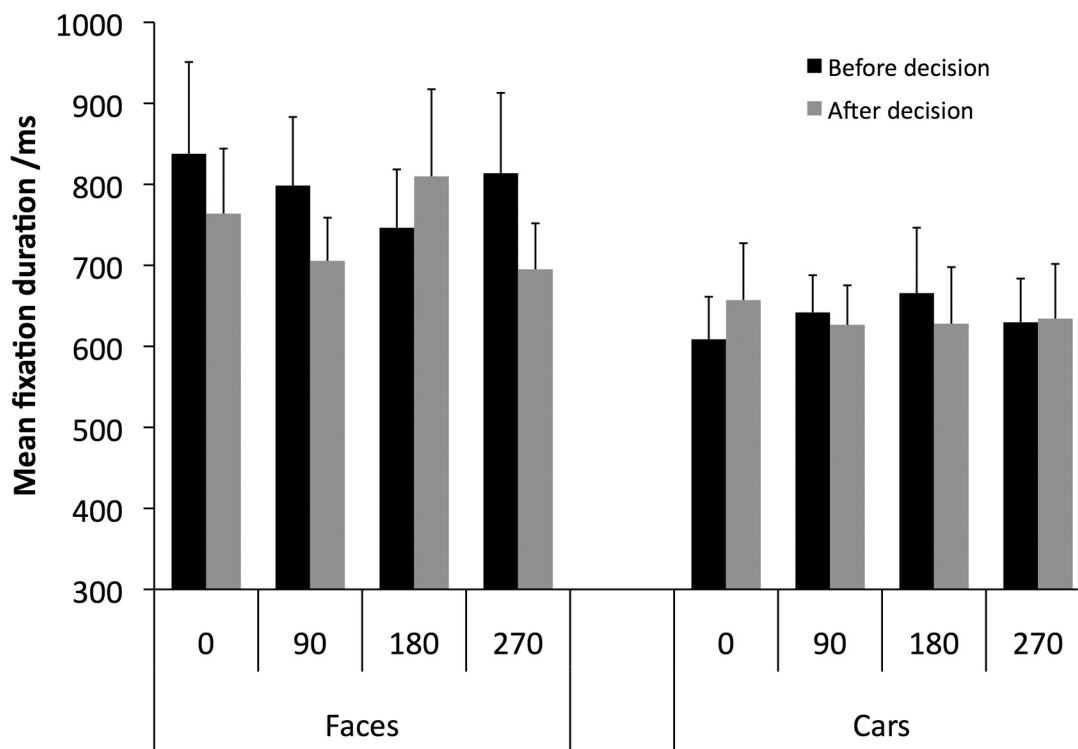
partial  $\eta^2 = 0.335$ , with smaller saccades after the decision than before. There was no main effect of orientation on saccade amplitude, but there was an interaction between the orientation of the embedded object and the decision state:  $F(3, 45) = 3.29$ ,  $p = 0.029$ , partial  $\eta^2 = 0.180$ . No other interactions were significant.

The interaction between object orientation and decision state was broken down using post hoc Bonferroni-corrected t-tests. Saccades were significantly shorter after the decision for upright ( $p = 0.001$ ) and inverted ( $p = 0.026$ ) objects, but not for objects embedded at 90° or 270°. In contrast to the data for fixation durations, there were no clear differences between the saccade amplitudes recorded in experiments 1 and 2. We assume that this suggests that saccade amplitudes are insensitive to the difficulty of the task and are more strongly governed by the nature of the stimuli, whereas fixation durations are sensitive to task difficulty.

#### 4.2 Discussion

Experiment 2 showed that, when judging the orientation of an object embedded in a geometric pattern, the class and orientation of the embedded object influenced both performance and inspection behaviour. In general, the effects were in line with those found in experiment 1, when participants judged the type of object embedded rather than its orientation. Accuracy data showed that people were better able to judge the orientation of faces than cars and that the best performance was for upright faces. However, in contrast to experiment 1, response time data for experiment 2 showed no inversion effect: faces were responded to quicker than cars, but the orientation of the face or car had no effect on response time.

In terms of inspection behaviour, fixation durations were shorter for embedded faces than cars, but were unaffected by the orientation of the object or whether the observer had made their decision about the orientation of the embedded object. This pattern of results for



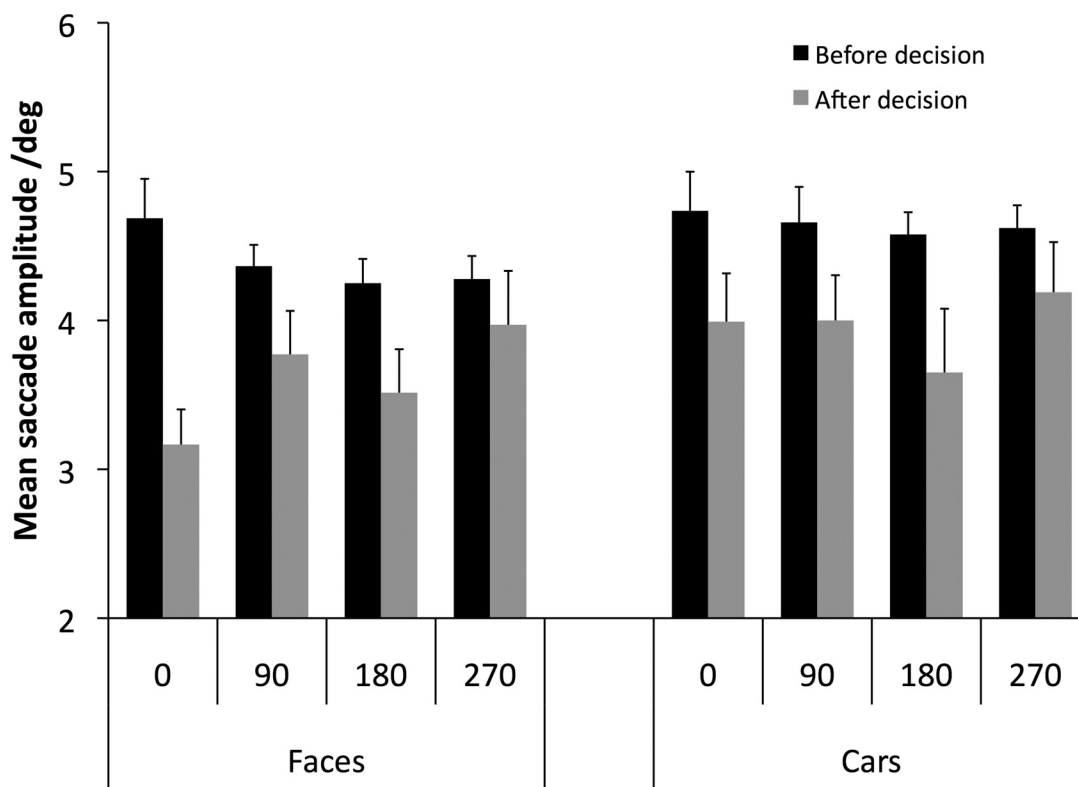
**Figure 7.** Mean fixation durations (ms) before and after responses were made, for faces and cars in each orientation. Error bars show +1 standard deviation from the mean.

fixation duration is the same as was found in experiment 1. For saccade amplitudes, as in experiment 1, evidence was found for an effect of inversion, but this was not specific to faces. Saccades were generally shorter for patterns with embedded faces, but the inversion effect was manifest only in a two-way interaction between orientation and decision state. This interaction arose because saccades became smaller after the observer's response for upright and inverted objects, but not for objects embedded horizontally. The lack of three-way interaction in this experiment suggests that this effect of inversion on saccade amplitudes was not sensitive to whether the embedded object was a face or a car.

The data from experiment 2, therefore, suggest general differences in the ability and time for observers to make judgments about the patterns and the inspection behaviour when viewing patterns with embedded faces or cars, even when the class of object is not relevant to the observer's task. When comparing it with our previous study (Tatler et al 2007), we find a similar pattern of results for saccade amplitude: for both upright and inverted objects, saccade amplitudes decrease following the observer's judgment of orientation. However, our present results extend these previous findings in two ways. First, we can show that this effect is not specific to faces, but generalises to upright and inverted cars. Second, we can show that this decrease in saccade amplitude following a judgment of orientation is specific to upright and inverted objects and is not found when the object is embedded at 90° or 270° from upright.

## 5 Discussion

It is clear from both experiments that there are differences in the facility with which partially hidden pictures of faces are recognised and scanned relative to partially hidden cars. Restricting initial consideration to faces/cars in the normal upright orientation, faces are recognised more accurately and quickly and fixation durations on the patterns containing



**Figure 8.** Mean saccade sizes (deg) before and after responses were made, for faces and cars in each orientation. Error bars show +1 standard deviation from the mean.

them are longer both before and after recognition. Saccade sizes, on the other hand, are similar. These results obtained whether the task required participants to report on the class of object embedded (face/car) or the orientation in which they were presented. The results contrast to those of Windhager et al (2010), who found few differences in eye movement patterns when viewing pictures of clearly visible frontal faces and cars.

Upright faces were recognised more quickly than those in other orientations in both experiments and they were generally fixated for longer. These distinctions did not apply to cars: they were recognised as reliably and rapidly in all orientations and they did not display different patterns of oculomotor behaviour. Thus, the inversion effect is strong for pictures of faces but not for cars, a result consistent with a wealth of previous literature on the consequences of inverting faces and other objects (eg Yin 1969). These findings also demonstrate that the same pattern of inversion effects that has been found for instantly recognisable face and nonface stimuli can be found for face and nonface stimuli that are initially hidden from the viewer's awareness. The existence of face-specific behavioural responses to the pictures used in the present study shows that it is a suitable set of stimuli for studying face-specific processes, while at the same time offering the advantage of being able to study face viewing prior to the emergence of a conscious percept of the image of the face.

Despite the attention that has been devoted to inverted faces (see Rossion 2008), less concern has been given to other orientations and so the effects for 90° and 270° rotations in our experiments are of interest. Differences between 90°, 180°, and 270° rotations of the embedded images did not produce such consistent effects. This suggests that symmetry around the vertical axis is not the factor defining the superiority of upright faces, and nor is the orientation of the component features. Our results contrast to those found by Schwanger and Mast (2005) who found inferior performance for horizontally oriented faces

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than for either upright or inverted faces. In our data there is little to distinguish horizontally rotated and inverted faces in terms of detection performance, reaction time, or inspection behaviour. However, we do find some evidence of an inspection effect specific to upright and inverted faces. In experiment 2 saccade amplitudes decreased after the face was recognised, but only for faces embedded in the upright or inverted orientations. There was no such decrease in saccade amplitude after recognition for horizontally rotated faces. This result may imply some differentiation between horizontal and vertical rotations of the embedded faces, but it is hard to draw any conclusions about this from the present data.

By comparing the two experiments of the present study we are able to consider the influence of the viewers' task not only on inspection behaviour, but also on face-specific processes such as the inversion effect. We found clear evidence for a face-specific inversion effect on response time in both experiments. As such, even when the task required no judgment about the type of embedded figure, there was a clear advantage present for making orientation judgments about upright faces. However, despite these response time similarities between the two experiments there were differences in the superiority of upright faces in the two experiments. When the task was to detect whether faces or cars were embedded, orientation did not differentiate between the proportion of correct responses; when the task involved discriminating orientation, then upright faces were detected more accurately. In terms of inspection behaviour, very similar patterns were found between the two experiments. In both tasks fixation durations were longer upon patterns containing faces than upon those containing cars, and it is notable that this was the case even when the task did not require recognition of the class of embedded object (experiment 2). For saccade sizes there was broad similarity between the two experiments, with smaller saccades when viewing patterns with embedded faces than when viewing patterns with embedded cars. The point of departure between the two experiments emerged in the context of interactions between object class and orientation. When the task was to discriminate between faces and cars irrespective of orientation, then both object class and orientation were involved in an interaction (specifically, a three-way interaction with decision state). Thus, in this experiment the orientation and class of the embedded figure both influenced the amplitudes of saccades during inspection. However, when the task was to recognise the orientation of the object irrespective of its class, there was no interaction that involved both object class and orientation. These findings demonstrate that in general inspection behaviour differed between faces and cars and the differences were the same irrespective of the task of the observer. However, more subtle aspects of inspection behaviour were sensitive to the task demands.

Our stimuli offer a rare opportunity to consider whether face-specific effects such as that produced by inversion are contingent on the conscious awareness of a face or can be observed in the absence of recognising that the stimulus is a face. Any interactions found in our analyses that involved the decision state of the observer would indicate that inspection depended upon what the viewer was aware of in the stimulus under inspection. Such interactions were found in both experiments for saccade amplitudes. In experiments 1 and 2 saccades were smaller following the observer's decision than prior to the decision. This suggests that the conscious experience of the observer can play a role in the inspection behaviour. In experiment 2 there was an interaction between the orientation of the embedded face and the decision state of the observer. This arose because of a specific decrease in saccade amplitude following a decision when viewing an upright or inverted object. No such decrease in saccade amplitude was found following a decision about a horizontally embedded object. One possible interpretation of the three-way interaction between object class, orientation, and decision state found for saccade sizes in experiment 1 might be

that the face-specific viewing effects that we have described above are dependent upon the awareness of the observer. However, there is insufficient power in our data to dissect this interaction fully. In both experiments the finding that the observer's decision state influenced saccade sizes is suggestive of an importance of awareness upon inspection and thus might suggest that face-specific viewing behaviour is contingent upon recognition of the embedded image. In contrast to the data for saccade sizes, in both experiments fixation duration was found to depend only upon the object class and there were no main effects or interactions involving the observer's decision state. As a result this implies that, while there were differences between how faces and cars were viewed, these differences were present both before and after recognition. These results therefore raise the possibility that face-specific viewing effects upon fixation duration exist even prior to the recognition of the face. It is also notable that in the first experiment there is a numerical trend toward an influence of orientation on fixation duration. Both before and after recognition, there is a trend toward longer fixations for patterns with upright faces embedded than for faces embedded at any other orientation. No such numerical trend is evident for embedded cars. As such, there is an indication that the orientation of the embedded face can exert some influence on viewing prior to recognition of the face.

One of the factors that has been implicated in configural as opposed to featural processing of faces is the spatial frequency spectrum of the pictures (Watier et al 2010). The partially hidden faces used in our experiments are of interest in this context because they are defined in terms of the low spatial frequencies in the stimuli. Performance, in terms of both recognition and oculomotor behaviour, distinguishes between pictures of faces and cars. However, unlike most other studies of pictorial face perception, the task of observers was not to identify particular faces nor to discriminate between them but to determine whether a particular low spatial frequency target belonged to the category of faces. Under these circumstances, low spatial frequency content is adequate to distinguish pictures of faces from cars and to influence the durations for which each category is fixated.

## 6 Conclusion

Experiments on picture recognition of faces typically involve identifying particular instances of the category rather than the category itself. In our experiments uncertainty existed regarding the category of objects because faces or cars were partially hidden in carrier patterns of concentric circles. Under these conditions the inversion effect was strong for pictures of hidden faces but not for cars; this is consistent with previous literature on the consequences of inverting faces and other objects. Upright pictures of faces were processed more rapidly and accurately than those in other orientations, and there were few differences between horizontal and inverted faces; variations in oculomotor behaviour were less clear cut. The effects were obtained in both experiments even though the tasks were different—responding to categories (face/car) or to orientations. We suggest that the use of partially hidden figures can pose questions for both recognition and inspection behaviour that would be otherwise difficult to address.

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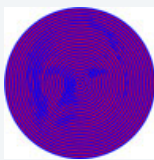


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