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Attention to faces: A change-blindness study

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Abstract. What strategies does human vision use to attend to faces and their features? How are such strategies altered by 2-D inversion or photographic negation? We report two experiments in which these questions were studied with the flicker task of the change-blindness literature. In experiment 1 we studied detection of configural changes to the eyes or mouth, and found that upright faces receive more efficient attention than inverted faces, and that faces shown with normal contrast receive more efficient attention than faces shown in photographic negative. Moreover, eyes receive greater attention than the mouth. In experiment 2 we studied detection of local changes to the eyes or mouth, and found the same results. It is well known that inversion and negation impair the perception and recognition of faces. The experiments presented here extend previous findings by showing that inversion and negation also impair attention to faces.

1 Introduction

1.1 *Attention to faces*

Faces are a rich source of crucial information. From a face we can often discern the identity of a person, their age, mood, health, gender, and direction of gaze. For good reason we attend preferentially to faces, starting early in infancy (Fantz 1961; Goren et al 1975; Johnson et al 1991; Kleiner and Banks 1987; Meltzoff and Moore 1977; Morton and Johnson 1991; Sackett 1966).

Even if a face is not attended, it can evoke an obligatory response from the human visual system. Studies of negative priming suggest that human vision builds descriptions of unattended faces, and that these descriptions are actively inhibited if they compete with target faces for control of responses (Khurana et al 2000). The obligatory processing of faces is evident in event-related potential (ERP) studies by a face-specific N170 at lateral posterior temporal electrodes (Bentin et al 1996; Bentin and Deouell 2000; Böetzel et al 1995; Cauquil et al 2000; Eimer 1998, 2000; Eimer and McCarthy 1999; George et al 1996; Jemel et al 1999); the N170 is evoked by facial stimuli even if they are not attended, but is enhanced by attention to centrally presented faces (Eimer 2000). In PET and fMRI studies, passively viewed faces evoke a response from the fusiform gyrus (Kanwisher et al 1996, 1997; McCarthy et al 1997; Puce et al 1995, 1996), which is enhanced by attention (Haxby et al 1994; Kanwisher et al 1997; Wojciulik et al 1998).

Although these studies suggest that attention is not required for human vision to build a description of a face, psychophysical studies using the method of 'bubbles' (Gosselin and Schyns 2001) indicate that human vision can use attentional strategies when viewing a face and that these strategies depend on the type of information that is being extracted from the face. In the bubbles method, subjects are shown a set of faces, one face at a time, and they categorize each face either by gender or emotion or some other property. Each face in the sequence is entirely occluded by a gray field, except for portions seen through Gaussian-shaped regions (the bubbles) which are placed at random from trial to trial. The Gaussians are varied in size, to look for different attentional strategies at different spatial-frequency scales. By analyzing which faces, with which random placements of Gaussian bubbles, were categorized correctly and incorrectly, Gosselin and Schyns were able to determine regions of the face that receive attention. They found that attention varies as a function of the categorization task and the spatial frequency. In judgments of emotion, for instance, observers pay attention primarily to the mouth at the high spatial frequencies, but not at the lower spatial frequencies. The bubbles technique links attention and looking because it allows the eye to look only at restricted portions of the image, ie the bubbles, as part of the procedure for assessing attention.

Studies of eye movements to faces also suggest that the pattern of attention to a face depends on the information being extracted. Lansing and McConkie (1999) found that observers make more eye movements to the upper half of the face when they judge speech intonation (statement versus question) than when they judge speech segments. Borod et al (1988) found that observers made more fixations to the left visual field (right side of the face) when judging emotions. More fixations to the left visual field have also been found in a free-viewing task (Mertens et al 1993). Althoff and Cohen (1999) found that eye movements to unfamiliar faces are also biased to the left visual field (right side of the face), and are more systematic than eye movements to famous faces. Moreover, observers fixated the eyes more often than the mouth, and this difference in fixations was greater for famous than for unfamiliar faces.

1.2 *Change detection and change blindness*

The bubbles and eye-movement studies tell us directly where on the face an observer looks. They can also tell us indirectly where an observer is attending, because eye movements are strongly influenced by attention, with attention often directing the eye to the attended location (Deubel and Schneider 1996).

However, where one looks is not an infallible guide to what one attends. This is a key insight of the literature on covert attention (Klein et al 1992; Posner 1980; Posner et al 1980), that has been confirmed by recent studies of change blindness and inattentional blindness. In one study by O'Regan et al (2000), observers viewed images depicting a variety of natural indoor and outdoor scenes, and were told to press a button each time they saw something change in the image. In fact, each time the observer blinked a change was made to some item in the scene, although observers were not told this. Observers failed to detect 40% of the changes that were made to the location where they fixated just before and after a blink, an effect that O'Regan et al call 'looking without seeing'. Similarly, experiments by Ballard et al (1995) and Hayhoe et al (1998) in which observers had to copy blocks displayed on a computer screen, showed that even when observers look directly at the blocks they often do not notice changes made to the blocks. Analogous results have been obtained by Zelinsky (1997) with scenes containing small collections of objects.

Findings like these indicate that attention in some cases is not linked to the location where one looks but to the aspects of the scene that are being grouped or otherwise processed (Mack and Rock 1998; O'Regan et al 2000; see also Driver and Baylis 1989; Duncan 1984). They also comport well with a 'deiectic' account of eye movements, in which the eye-gaze direction can simply serve as a pointer, much as a pointing finger serves when counting (Hayhoe et al 1998).

Given that where one looks is a useful but fallible guide to what one attends, it is prudent in the study of attention to faces to complement experiments based on memory, bubbles, or eye movements with experiments that can more directly reveal which aspects of the face are actively being processed. This is the motivation for the experiments presented here, which use the flicker task from the change-blindness literature [Rensink et al 1995, 1997; see also Pashler (1988) and Phillips (1974), who used a one-cycle version of the flicker task]. In this task, observers briefly see one image, then a blank screen, then the same image again with some change. The change might be the deletion or addition of an object, or it might be a change in the color, position, or orientation of an object, or some other such change. The cycling of the two images with an interposed blank screen continues until observers detect what has changed, or time runs out. This task proves surprisingly difficult, because the blank screen disrupts low-level motion signals that might direct attention to the change (Rensink et al 1997; Simons and Levin 1997). As a result, observers must attend and build, one by one, descriptions of objects in one image, and store these in visual short term memory (vSTM) for retention during the blank interval [Rensink 2000a, 2000b, 2000c; but see Zelinsky (2001) for an alternative account based on parallel attention]. Then observers must compare these items in vSTM with descriptions of objects in the other image that are also built, one by one, under the guidance of attention. During this flicker task, attention can be pulled by exogenous factors, such as colorful or high-contrast regions of an image. It can also be directed by endogenous factors, such as an individual's interests or task-based goals (O'Regan et al 2000; Shore and Klein 2000).

The flicker task has been used primarily to study attention to indoor and outdoor scenes, although Rensink (2000b) has also used it to study detection of change in arrays of rectangles, and Williams and Simons (2000) have used it to study detection of changes to a single multipart object. It has not before been used to study detection of changes within a single face, where the face plays the role of the entire scene. Therefore, in the experiments presented here, a face is the whole 'scene'; and we use the flicker task to study the detection of changes to parts of the face, in particular to the eyes and the mouth. From these studies we can infer the strategies of observers for attending to parts of a face.

1.3 *The perception of inverted faces*

There is reason to suspect that the strategies of observers for attending to facial features may be disrupted if the faces are inverted. It has long been known that inverting a portrait makes it more difficult to recognize. In *The Analysis of Sensations* Mach observes:

> "The portrait of a familiar personage, when turned upside down, is strange and puzzling to a person who does not recognize it intellectually. If we place ourselves behind the head of a person lying upon a couch, and unreflectingly give ourselves up to the impression which the face makes upon us, we shall find that our impression is altogether strange, especially when the person speaks." Mach (1886/1959, page 114)

And in *Art and Visual Perception* Arnheim remarks:

> "In surrealist motion pictures human faces are sometimes shown upside down. The effect is frightening; even though we know better, visual evidence insists that we are seeing a new kind of face, a monstrous variation, which carries the mouth on top of the eyes, closes its eyelids upward, and wears its hair on the bottom. The new face is sanctioned by a symmetry of its own: it looks self-contained and right side up." Arnheim (1954, page 68)

Several studies of explicit face processing have found that inverted faces are difficult to identify (Farah et al 1995; Kohler 1940; Scapinello and Yarmey 1970; Valentine and Bruce 1986; Yarmey 1971; Yin 1969; Young et al 1987), and that this difficulty is greater than for other inverted objects that are normally seen upright, such as houses or landscapes (Diamond and Carey 1986; Tanaka and Farah 1993), a result known as the face-inversion effect (FIE). This effect is more pronounced if the faces to be identified differ only in the spatial relationships between features, such as the eyes, nose, and mouth, than if they differ in properties of the features themselves, such as the brightness or color of the eyes, nose, and mouth (Diamond and Carey 1986; Freire et al 2000;

Leder and Bruce 2000; Rhodes 1988; Rhodes et al 1993; Rock 1974, 1975; Tanaka and Farah 1993; Thompson 1980; Young et al 1987). The FIE has also been found in perceptual matching tasks, where observers compare two inverted faces presented side-by-side (Searcy and Bartlett 1996; Valentine 1988), suggesting that inverting a face disrupts the perceptual encoding of that face.

In light of this evidence, it is natural to ask whether the FIE is due in part to disruption, when a face is inverted, of the normal strategies for attending to facial features. Our experiments study this question.

1.4 *The perception of faces seen in photographic negative*

There is also reason to suspect that the strategies of observers attending to facial features may be disrupted if the faces are shown in photographic negative.

Several studies of explicit face processing have found that it is difficult to identify faces displayed in photographic negative (Bruce and Langton 1994; Galper 1970; Galper and Hochberg 1971; Gauthier and Tarr 1997; Johnston et al 1992; Kemp et al 1996; Liu and Chaudhuri 1997; Liu et al 1999, 2000; Phillips 1972), and that this difficulty is greater than for most other objects (Subramanian and Biederman 1997).

Since natural light sources are typically seen as overhead (eg Ramachandran 1988), the negated-face effect may be due to a reversal of the apparent direction of lighting, with positive faces appearing to be top-lit and negated faces appearing to be bottom-lit (Hill and Bruce 1996; Johnston et al 1992; Liu et al 1999). Changing lighting between learning and test can disrupt recognition of faces (Braje et al 1998; Enns and Shore 1997; Hill and Bruce 1996; Troje and Bülthoff 1998), suggesting that direction of apparent lighting is encoded in face representations.

The negation effect has been found in face-matching tasks (Lewis and Johnston 1997) and in brain-imaging studies, with brain regions specialized for faces responding less strongly to negated faces (George et al 1999). Both results suggest that negating the face disrupts its perceptual encoding.

Negation alters low spatial frequencies, which in turn alters two cues used in face processing: shading (Hayes et al 1986) and spatial relationships (Lewis and Johnston 1997; Sergent 1984). In face-recognition tasks, shape-from-shading is more useful than other depth cues, such as shape-from-stereo (Liu et al 2000) and faces can be identified from shading alone (Bruce et al 1991; Bruce and Langton 1994; Hill and Bruce 1996; Liu et al 1999, 2000; Tarr et al 1998; Troje and Bülthoff 1996) but not as easily from edge information alone (Bruce et al 1991; Davies et al 1978; Leder 1996). Negation disrupts the analysis of shape-from-shading and therefore the perception of shape and of spatial relationships of the face.

In light of this evidence, it is natural to ask whether negation or changes in lighting disrupt the normal strategies for attending to facial features. Our experiments also study this question.

2 Experiment 1: Configural changes

As mentioned earlier, previous research indicates distinct roles for local features and configural properties in face processing (Diamond and Carey 1986; Leder and Bruce 1998, 2000; Rhodes et al 1993; Searcy and Bartlett 1996). By 'configural properties' we mean the spatial relationships between parts of the face such as the eyes, nose, and mouth.

A key finding of previous research is that 2-D inversion impairs recognition of faces that differ only in configural properties, but does not impair recognition of faces that differ only in local features. Here we ask whether this difference is due, at least in part, to attention: perhaps inversion impairs attention to configural properties of a face.

To test this hypothesis, in experiment 1a we studied attention to upright and inverted faces that differed only in configural properties.

Previous research has also found that photographic negation impairs face recognition (Galper 1970). Since photographic negation alters the perception of low spatial frequencies, it may impede extraction of configural information from the face (Lewis and Johnston 1997; Sergent 1984). To test this hypothesis, in experiment 1b we studied attention to photographic-positive and photographic-negative faces that differed only in configural properties.

To measure attention, we used a flicker display with a change-detection task. The assumption underlying this task is that attention to a feature increases the probability that changes in that feature will be detected. Attention to a feature does not, of course, guarantee detection of its changes. The key changes were to the mouth or to the eyes, which were translated up or down by ten pixels, thereby altering the configuration of the face while leaving the local features of the eyes and mouth unchanged.

2.1 *Method*

2.1.1 *Subjects.* Nineteen undergraduates from the University of California, Irvine, participated in experiment 1a, and twenty three in experiment 1b. All had normal or corrected-to-normal acuity, and all were naïve to the purposes of the experiment.

2.1.2 *Materials.* Eighty color images of faces were obtained from the Aberdeen face database (accessible through http://pics.psych.stir.ac.uk/). The faces were photographed in frontal view and lit from the front, minimizing shadows. We cropped and resized each image to 400×550 pixels, with a resolution of 72 pixels per inch. The images were presented in color on a Macintosh G3 laptop with a 14.1 inch active-matrix color screen, with a resolution of 1024×768 pixels. Each image was viewed by subjects at a distance of 22 inches, and subtended approximately 11.4 deg $\times$ 16.0 deg. Twenty nine of the faces were female; sixty one were male. Sixty three were young adults; twenty seven were middle-aged or older. All faces had the hair, ears, and neck within view, and all faces were assigned at random to the experimental conditions.

Three types of changes were made to the face images: eyes, mouth, and 'other'. For the 'other' changes, either the nose was inverted, a mole was added, or an ear was slightly detached from the head, as illustrated in figure 1. For the eyes change, both the right and left eyes (including the eye brows) were moved up or down as a unit by 10 pixels, as illustrated in figure 2 for upright and inverted faces, and in figure 3 for positive and negated faces. For the mouth change, the entire mouth was moved up or down by 10 pixels, as illustrated in figure 4 for upright and inverted faces, and

Figure 1. Typical 'other' changes used as stimuli in experiments 1 and 2. The nose was inverted, or a mole was added, or an ear was detached. The mole could be large or small, and could be located on the chin, cheeks, or forehead.

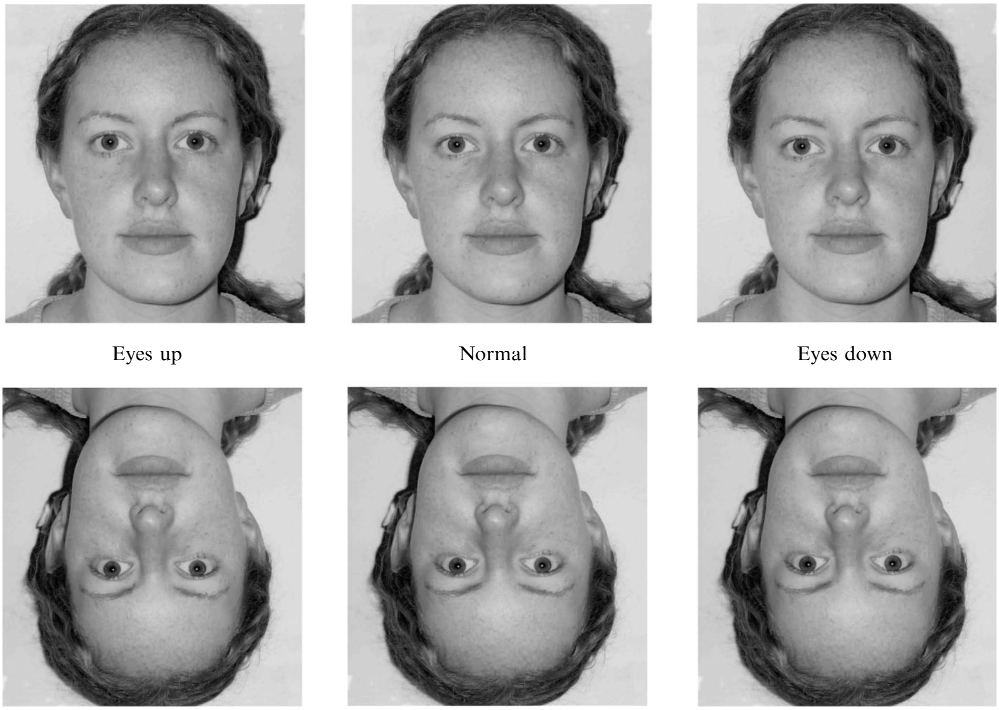

Figure 2. Changes to the eyes in experiment 1a. The top row shows the eyes raised ten pixels on the left, unchanged in the middle, and lowered ten pixels on the right. The bottom row shows the corresponding faces inverted.

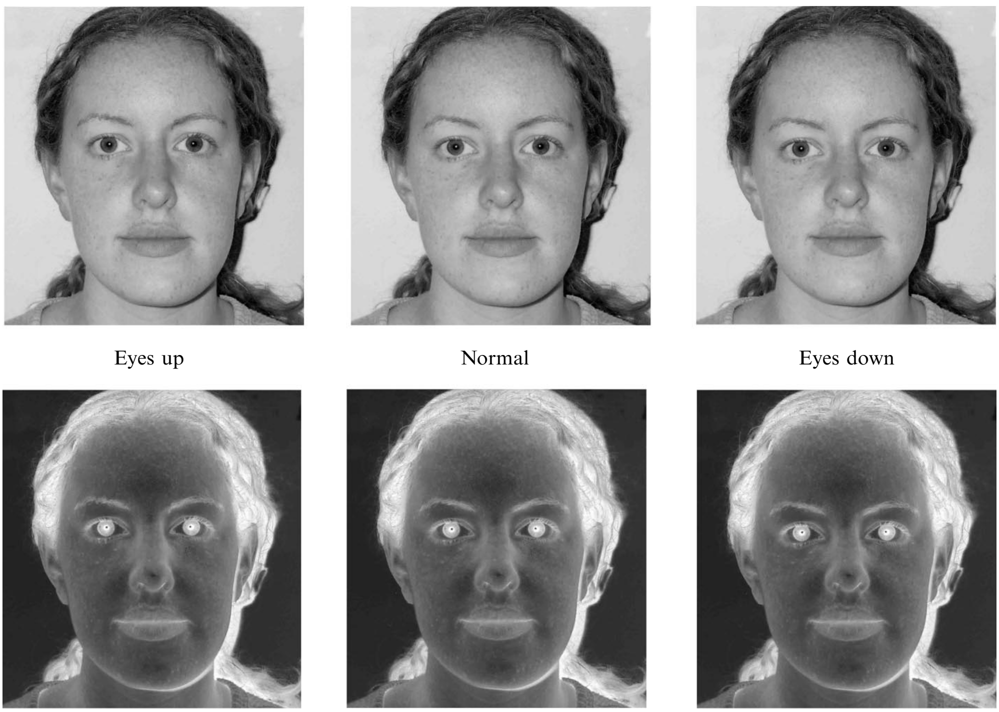

Figure 3. Changes to the eyes in experiment 1b. The top row shows the eyes raised ten pixels on the left, unchanged in the middle, and lowered ten pixels on the right. The bottom row shows the corresponding faces negated.

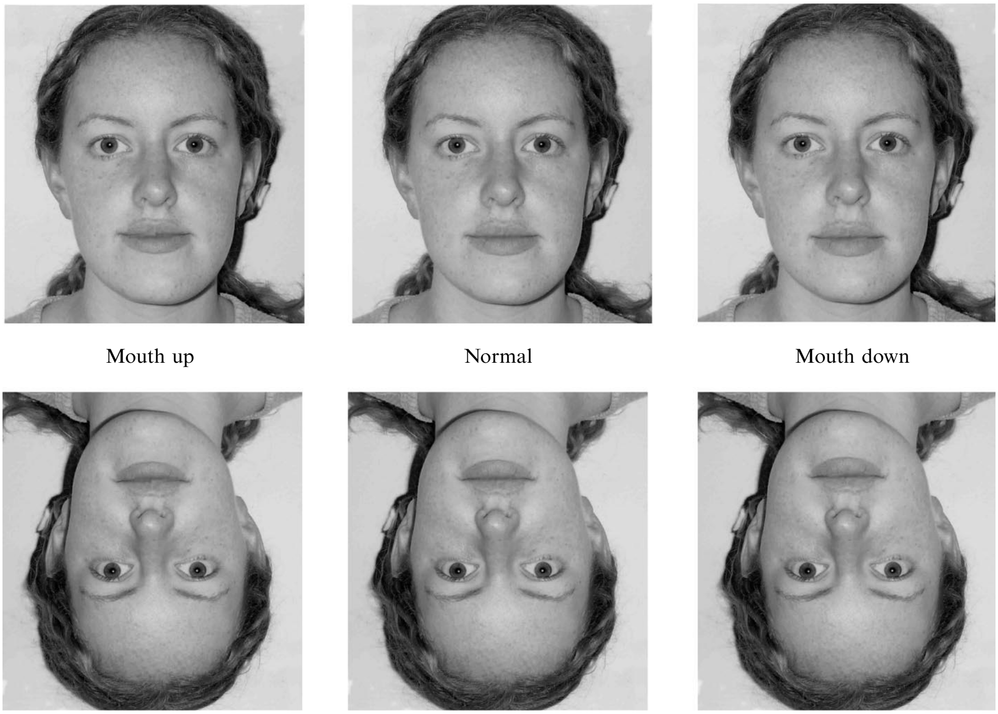

Figure 4. Changes to the mouth in experiment 1a. The top row shows the mouth raised ten pixels on the left, unchanged in the middle, and lowered ten pixels on the right. The bottom row shows the corresponding faces inverted.

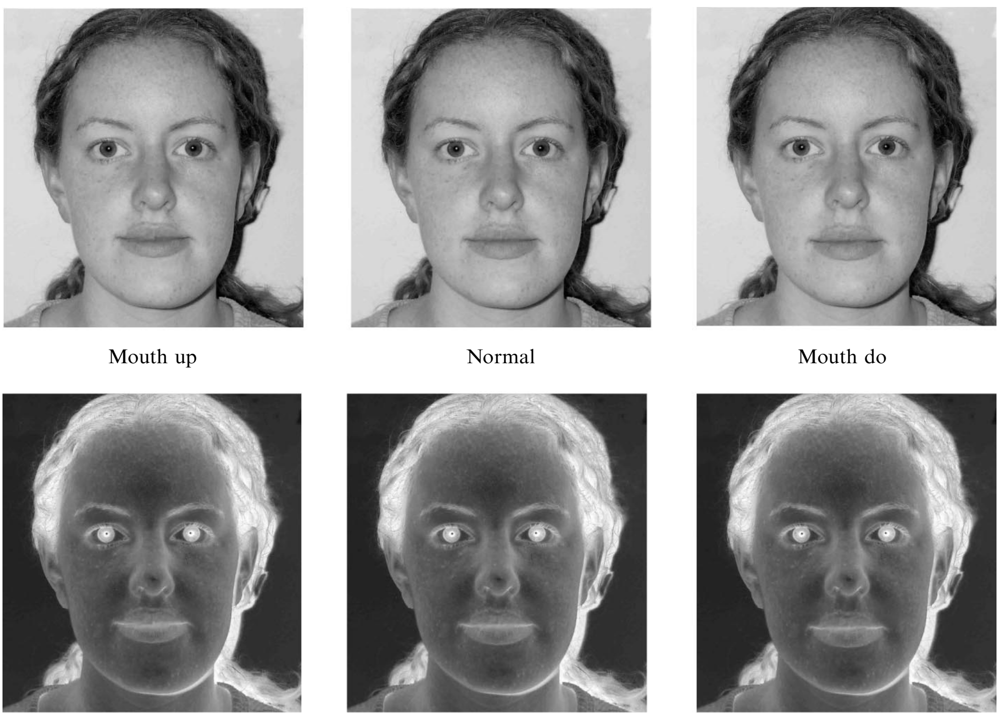

Figure 5. Changes to the mouth in experiment 1b. The top row shows the mouth raised ten pixels on the left, unchanged in the middle, and lowered ten pixels on the right. The bottom row shows the corresponding faces negated.

in figure 5 for positive and negated faces. We included the 'other' changes so that subjects could not simply attend to the eyes and mouth to perform the detection task. The 'other' changes required subjects to distribute their attention over the entire face. We made some of the 'other' changes obvious, for instance by not editing out edge artifacts around the changes, so that subjects would clearly see on some trials that changes to parts other than the eyes or mouth were involved, thus forcing them to attend to more than just the eyes and mouth. Some of the 'other' changes were less obvious, so that subjects would need to attend carefully to all parts of the face, not just the eyes and mouth. Since the only reason for the 'other' changes was to ensure that subjects attended to the whole face, not just eyes and mouth, they were not included in the analyses.

To create the inverted face images for experiment 1a, we simply rotated the face images by 180°.

To create photographic negatives for experiment 1b, the R, G, and B values were reversed by subtracting each value from 255. Since the monitor was not gamma corrected, the brightness and hues did not change linearly with the pixel values, and this may have compressed the dynamic range of the negated images.

Three properties of the negated stimuli are noteworthy: (i) multitone face photographs were used; (ii) the testing conditions were congruent, in that negated faces were flickered with negated faces; (iii) the faces were front-lit. The first two properties reduce the negation effect (Liu and Chaudhuri 1997). The third property reduces the chance that negated faces appear to be bottom-lit (Johnston et al 1992).

In experiments 1a and 1b, and in experiments 2a and 2b, all changes were made in Adobe Photoshop, and all boundaries of changes to the eyes and mouths were smoothed to remove artifacts.

2.1.3 *Design.* We used a 4×2 repeated-measures design for experiments 1a and 1b. The first factor, part change, had four levels: none, other, mouth, and eyes. For experiment 1a, the second factor, orientation, had two levels: upright and inverted. Which faces were shown upright and which were inverted was counterbalanced across subjects. For experiment 1b, the first factor was the same as for experiment 1a, and the second factor, contrast, had two levels: positive and negative. Which faces were shown positive and which were shown negative was counterbalanced across subjects.

On each trial two faces were shown repeatedly, one after the other, until the subject responded. In half of the trials, the 'same' trials, the two face images were identical; in the other trials, the 'different trials', one of the two images was altered. Since anomalous faces appeared in half of the 'same' trials, subjects could not adopt a strategy of simply looking for facial anomalies rather than looking for changes. In the 'different' trials, whether the altered image was presented first or second was counterbalanced.

There were five 'same' trials and 5 'different' trials at each level of each factor, for a total of $4 \times 2 \times 10 = 80$ trials. The experimental trials were preceded by 18 practice trials. Feedback was given during the practice trials, but not during the experimental trials.

2.1.4 *Procedure.* Subjects were tested individually. Each subject sat in normal room illumination, without head restraint, approximately 22 inches from a computer screen, which displayed the following instructions:

> "On each trial you will see two images of a face, shown one after the other repeatedly. If the two images are the same, hold down the 's' key until you see the words 'NEW TRIAL'. If the two images are not the same, hold down the 'k' key until you see the words 'NEW TRIAL'. Please respond as quickly and accurately as possible. If you press the 'k' key, please tell the experimenter what was different between the two faces. The first few trials are for practice. Do you have any questions?"

Each face image appeared for 1 s, and the blank screen for 100 ms. The alternation of face images continued until either the subject responded or the display completed five cycles. In the latter case the subject's response was recorded as 'same'. Each cycle lasted 2.2 s: 1 s for the first face, 100 ms for the blank screen, 1 s for the second face, and 100 ms for the second blank screen. Each subject was offered a 2 min rest half way through the experiment.

The displays were presented for 1 s each so that subjects had sufficient time to view each image, thus reducing the likelihood that any results would be due merely to perceptual problems. Trials were stopped after 5 cycles because pilot studies showed that a few subjects would adopt an extremely conservative strategy and take an order of magnitude more time to respond than most subjects, thus adding excessive variance to the reaction-time data. With only 5 cycles presented, subjects learned during the practice trials that they could not adopt this extremely conservative strategy. Other change-blindness studies have also limited the maximum number of cycles that subjects can view (eg O'Regan et al 2000). By treating trials in which subjects fail to respond as 'same' responses, we are defining 'same' to mean, 'could not find any difference in the alotted time'. This definition of 'same' is an interesting variable for the study of attention.

2.2 *Results*

2.2.1 *Accuracy.* In this and all the remaining experiments, for the part-change factor, only the eyes and mouth levels were of theoretical interest and included in the analysis. Since the only reason for the 'other' changes was to ensure that subjects attended to the whole face, not just the eyes and mouth, we did not include them in the analysis. The number of correct choices, out of 10, was computed for each subject for each level of the experiment.

Data were discarded from subjects who scored less than 6 out of 10 correct on the eyes or mouth for upright faces. The expected score for chance performance was 5. Our criterion was designed to discard data from subjects who did not perform minimally above chance on the ecologically most natural displays. Of 151 subjects tested in all the experiments reported here, data from only seven were discarded by this criterion.

Experiment 1a: Data were discarded from one subject who scored less than 6 correct on the eyes or mouth for upright faces. A 2 (part change) $\times$ 2 (orientation) repeated-measures ANOVA of number of correct choices found a significant effect of orientation ($F_{1,68} = 13.29$, $p = 0.0005$), but not of part change ($F_{1,68} = 2.513$, $p = 0.1176$), and no significant interaction ($F_{1,68} = 0.2262$, $p = 0.6359$). Figure 6 shows that accuracy was greater for upright than for inverted faces.

Experiment 1b: Data were discarded from five subjects who scored less than 6 correct on the eyes or mouth for upright faces. A 2 (part change) $\times$ 2 (contrast) repeated-measures ANOVA of number of correct choices found no significant effect of part change ($F_{1,68} = 0.0605$, $p = 0.8065$), a significant effect of contrast ($F_{1,68} = 6.46$, $p = 0.0133$), and no significant interaction ($F_{1,68} = 0.1681$, $p = 0.6831$). Figure 7 shows that accuracy was greater for positive than for negative faces.

2.2.2 *Detection time.* Again, for the part-change factor, only the eyes and mouth levels were of theoretical interest and included in the analysis. Mean detection times were computed for each subject for each level of the experiment, based only on those trials in which a change was correctly detected.

Experiment 1a: Data were discarded from one subject who scored less than 6 correct on the eyes or mouth changes for upright faces. A 2 (part change) $\times$ 2 (orientation) repeated-measures ANOVA of detection times found a significant effect of orientation ($F_{1,60} = 8.423$, $p = 0.0052$), but not of part change ($F_{1,60} = 0.352$, $p = 0.5552$), and no significant interaction ($F_{1,60} = 1.905$, $p = 0.1727$). Figure 8 shows that detection times were faster for upright than for inverted faces.

Experiment 1b: Data were discarded from five subjects who scored less than 6 correct on the eyes or mouth changes for upright faces. A 2 (part change) × 2 (contrast) repeated-measures ANOVA of detection times found no significant effect of part change ($F_{1,64} = 1.145$, $p = 0.2886$) or of contrast ($F_{1,64} = 1.565$, $p = 0.2155$), and no significant interaction ($F_{1,64} = 0.1517$, $p = 0.6982$). Figure 9 shows that detection times were not significantly faster for positive than for negative faces.

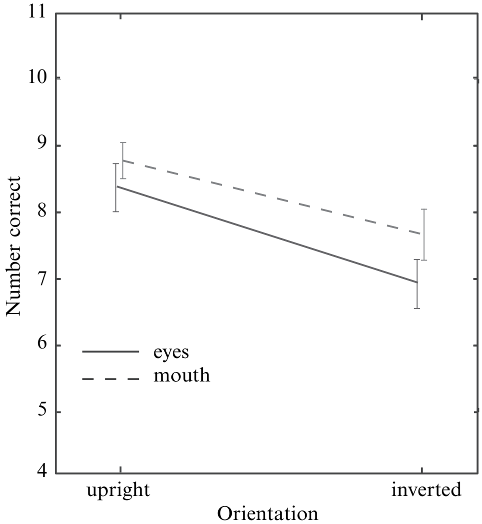

Figure 6. Detection accuracies in experiment 1a. Translations of the eyes or mouth by ten pixels are detected more accurately if faces are upright than if they are inverted. Error bars indicate standard error in this and all other figures.

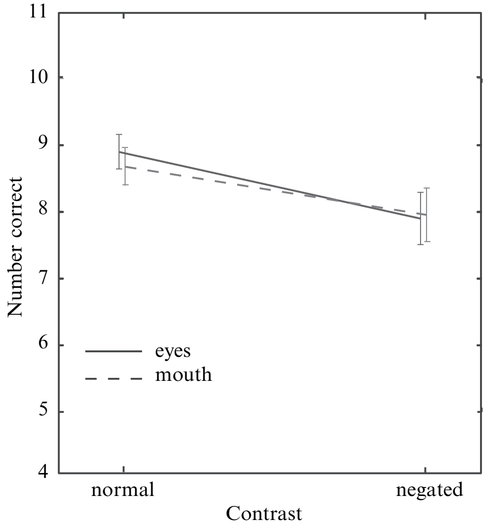

Figure 7. Detection accuracies in experiment 1b. Translations of the eyes or mouth by ten pixels are detected more accurately if faces have normal contrast than if they are negated.

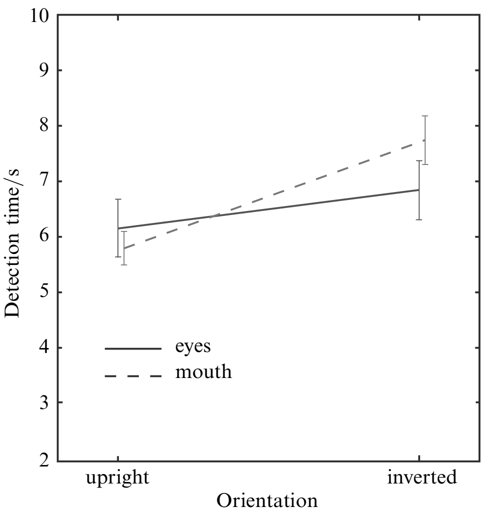

Figure 8. Detection times in experiment 1a. Translations of the eyes or mouth by ten pixels are detected more quickly if faces are upright than if they are inverted.

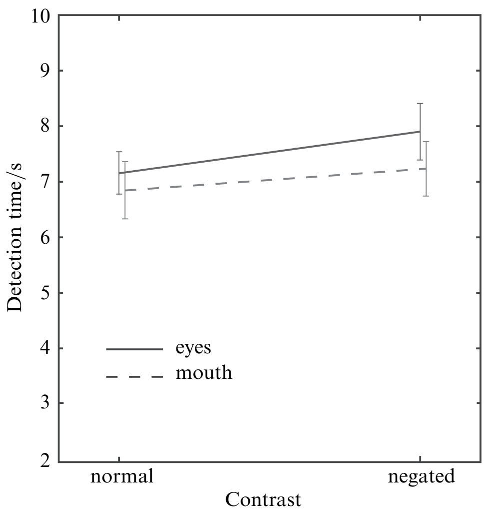

Figure 9. Detection times in experiment 1b. Translations of the eyes or mouth by ten pixels are detected with the same speed when faces have normal contrast as when they are negated.

2.3 *Discussion*

2.3.1 *Experiment 1a.* This experiment provides evidence that, in a change-detection task with configural changes, upright faces receive more efficient attention than inverted faces. Although many previous studies show that inversion impairs recognition of configural properties, this is the first direct evidence from a flicker task that inversion impairs attention to configural properties.

The data show that configural changes to the face are detected more quickly and accurately if the face is upright. This suggests that endogenous factors influence how subjects attend to configural features of the face. The endogenous control of attention is guided by the meaningful interpretation of a visual scene, and inversion of a scene impairs its meaningful interpretation (Rock 1974, 1975; Shore and Klein 2000). Inversion of the faces in our task could impair their meaningful interpretation, thereby disrupting the endogenous control of attention, and causing the slower and less-accurate detection of changes. The disruption could take at least two forms. First, an endogenous attentional-control strategy might be triggered by inverted faces, perhaps as a result of detecting an eye. This strategy might be appropriate for upright faces but inappropriate for, and therefore deleterious to, processing of inverted faces. Second, perhaps no endogenous control strategy is triggered by inverted faces, forcing the visual system to rely on exogenous factors to guide exploration of the face.

Our results are at odds with those of Shore and Klein (2000), who failed to find an effect of inversion on detection times in a flicker task. They concluded that detection of changes in a flicker task is guided not by endogenous factors, but by exogenous factors such as salience of image features. Several differences between our task and theirs could explain why we found evidence of endogenous control where they did not. First, our stimuli were pictures of faces, whereas theirs were pictures of naturalistic scenes. It may be that faces trigger endogenous control strategies that more generic scenes do not. Or the endogenous control strategies for faces may be more obligatory than those for more generic scenes. Second, our pictures of faces were presented for 1000 ms, whereas their pictures of scenes were presented for 555 ms. They suggest that the frequent global transients induced by the flicker method, which are not under control of the subject, could disrupt endogenous strategies. Our design gave subjects more time to view pictures between transients, perhaps interfering less with their endogenous strategies. Finally, faces are less complex than naturalistic scenes, and this fact alone could facilitate the extraction of meaning and the triggering of endogenous control for faces.

Our results indicate, contrary to the claims of Shore and Klein, that the flicker task is not limited to the study of exogenous factors on attention, but can be an effective method for studying the endogenous control of attention. In particular, in this first experiment, data from the flicker task indicate that subjects' endogenous control of attention to faces is impaired by inversion.

2.3.2 *Experiment 1b.* This experiment provides evidence that, in a change-detection task with configural changes, positive-contrast faces receive more efficient attention than negative-contrast faces.

The data show that configural changes to the face are detected more accurately if the facial contrast is positive rather than negative. This comports well with evidence that negation impairs face processing in a perceptual task, and that negation impairs extraction of configural information (Hayes 1988; Kemp et al 1990; Liu and Chaudhuri 1997). Kemp et al (1990) found no effect of negation if face features were presented alone, but clear effects of negation if they were presented within the context of a face, suggesting that negation impairs judgment of relationships between features that are placed within a face context. Perhaps the bounding contour of the face facilitates a convex interpretation (Gregory 1973), initiating construction of a 3-D face model via shape-from-shading cues. Since shape-from-shading is impaired by negation (Liu et al 1999), the disruption of this information may impair attention to and perception of configural elements in the face.

A between-subjects ANOVA on the detection times from experiments 1a and 1b shows a significant orientation × contrast interaction ($F_{1,31} = 4.662$, $p = 0.039$): the unnegated faces in experiment 1b are the same stimuli as the uninverted faces in experiment 1a, yet changes to the unnegated faces require one second longer to detect than do changes to the uninverted faces. This difference suggests that, although both inversion and negation are known to impair face processing, the impairments induced by negation might persist long enough to affect performance on positive images, so that negative and positive cases are both impaired. Impairments induced by inversion might have a shorter duration, so that performance on upright images is not affected.

2.3.3 *Perceptual controls.* One might argue that, since many studies have shown worse perception of configural information for inverted and negated faces, it is not surprising that experiment 1 finds that change detection is also worse. This finding is consistent with the claim that familiar objects and configurations are simply perceived more efficiently. Inverting or negating faces might degrade the facial images, making their features more difficult to encode. One need not appeal to impairments of attention to explain our results.

To control for this possibility, and to see the relative contributions of perception and attention to our results, we ran a control experiment. The control was the same as experiments 1a and 1b except that, on each trial, just prior to viewing the flickering face images, subjects saw on the computer screen for three seconds a cue—a printed word referring to the part of the face to which they should attend (mouth, eyes, nose, forehead, ears, chin, cheeks). We reasoned that if perceptual difficulties, and not attentional impairments, were responsible for our inversion and negation effects, then subjects' performance with inverted and negated faces should not be improved by such cueing. However, if attentional impairments are largely responsible for our effects, then subjects' performance should improve with cueing. A similar argument is made by Rensink et al (1997).

In experiment 1a, which studied configural changes in upright and inverted faces, the perceptual control experiments revealed a nonsignificant trend for subjects to be more accurate with cued rather than uncued faces ($F_{1,34} = 2.332$, $p = 0.136$). This trend may have missed significance due to a ceiling effect: accuracy for the uncued condition was sufficiently high that, even with the addition of cues, there was little room for improvement. In the cued control, mean accuracies for eyes were 9.00 upright and 8.06 inverted; for mouths they were 9.22 and 7.94.

For detection times in experiment 1a, the control experiments show a main effect of cueing ($F_{1,31} = 4.703$, $p = 0.038$), with subjects faster for cued than uncued faces. This reveals that the change-detection impairments reported in experiment 1a are not due to perceptual difficulties alone, but that they are, in part, a result of attentional impairment. Although previous research has shown that perception of configural information is impaired when the face is inverted, this study distinguishes the effects of perception and attention, and shows that attention is also impaired. In the cued control, mean detection times for eyes were 5.49 s upright and 6.34 s inverted; for mouths they were 4.43 s and 5.36 s.

For detection times there is a cue-by-part interaction ($F_{1,31} = 7.646$, $p = 0.009$) with cued conditions speeding responses of subjects more for changes to the mouth than changes to the eyes. Cueing reduces mean response times for eyes from 6.5 s to 5.9 s, and for the mouth from 6.8 s to 4.9 s. This interaction indicates that when subjects are cued, changes to the mouth are perceptually easier to see than changes to the eyes.

It also indicates that endogenous attention for the face prefers the eyes over the mouth: since the eyes already get more attention in the uncued condition, cueing does little to speed reaction times to the eye changes. The mouth changes are perceptually easier to see than the eye changes [an effect also found by Haig (1984)] and, since the mouth gets less attention than the eyes in the uncued condition, cueing greatly speeds reaction times to the mouth changes.

For accuracy levels in experiment 1b, configural changes made to positive and negative contrast images, the perceptual control experiments reveal a main effect of cueing ($F_{1,34} = 5.558$, $p = 0.024$), with subjects having better accuracy for cued than uncued images. This indicates that negation impairs attention. If negation impaired only perceptual processing, there would be little improvement with the addition of a cue. Our results demonstrate that impairments to both attention and perception contribute to the poorer performance with contrast-negated faces. In the cued control, mean accuracies for eyes were 8.83 upright and 8.78 inverted; for mouths they were 9.44 and 9.11.

The detection-time analyses in experiment 1b reveal a main effect of cue ($F_{1,34} = 38.477$, $p < 0.001$), with subjects responding faster for cued than uncued images. This again shows an effect of attention, since the reduced need for attentional strategies in the cued experiments leads to faster performance. Unlike in experiment 1a, there was no interaction between cue and part, suggesting that cueing equally facilitates detection of changes to the mouth and the eyes. In the cued control, mean detection times for eyes were 4.56 s upright and 4.71 s inverted; for mouths they were 3.74 s and 4.20 s.

This leads to several interesting possibilities. Previously, it was discussed that contrast negation may lead to a visual hysteresis effect whereby visual system impairments have a lasting effect on both positive and negative contrast trials. A disruption to a lower-level visual process may affect higher-level processing so that face-specific processes may not be applied to the images, and therefore endogenous attentional strategies for faces may not be invoked. Even if attention does seek out the eyes before the mouth, as evidenced in experiment 1a, in this case the mouth would not experience a greater advantage from the cue than the eyes since no endogenous processes were used.

Another possibility lies in the nature of the contrast-negated stimuli. Since the colors of the images seem anomalous, it may have encouraged subjects to focus on low-level visual elements and adopt an exogenous scanning strategy. This would again eliminate a preference for the eyes, and thereby eliminate an extra advantage for the mouth with the addition of cues. Both cases suggest the possibility of an interesting difference in attentional strategies for inverted and negated face images.

3 Experiment 2: Featural changes

In experiment 1a we found that inversion impairs attention to facial configuration. This might contribute to the effect, found in several studies, that inversion impairs face recognition if the faces to be discriminated differ only in configural properties.

Several studies also found that inversion does not impair recognition if the faces differ only in local features. The question naturally arises, then, whether inversion impairs attention to local features. Experiment 2a addressed this question. Using the change-detection task of experiment 1, we restricted changes to local features: the mouth or right eye were rotated in place by 180° ('thatcherized'). Such rotations minimally alter the facial configuration.

There has been little prior study of the effects of negation on the perception of the local features of faces. To study whether photographic negation impairs attention to local features, in experiment 2b we used negated versions of the thatcherized stimuli of experiment 2a.

3.1 *Method*

3.1.1 *Subjects.* Nineteen undergraduates from the University of California, Irvine, participated in experiment 2a, and eighteen in experiment 2b. All had normal or corrected-to-normal acuity, and all were naïve to the purposes of the experiment.

3.1.2 *Materials.* The stimuli were as in experiment 1, except that changes were made to local features rather than to facial configuration.

Three types of changes were made to the face images: eye, mouth, and 'other'. For the eye change, the right eye was inverted, leaving the eye brow unchanged. For the mouth change, the entire mouth was inverted. These changes in upright and inverted faces are illustrated in figure 10, and in positive and negated faces in figure 11. The 'other' changes were the same as in experiment 1: either the nose was inverted, a mole was added, or an ear was slightly detached from the head, as shown in figure 1.

3.1.3 *Design.* The designs for experiments 2a and 2b were identical to those of experiments 1a and 1b, respectively.

3.1.4 *Procedure.* The procedure was the same as for experiment 1, except that 11 practice trials were given rather than 18 and, since the alterations to the faces were not as subtle as in experiment 1, no feedback was given during the practice trials.

3.2 *Results*

3.2.1 *Accuracy.* For the part-change factor, only the eye and mouth levels were of theoretical interest and included in the analysis. The number of correct choices, out of 10, was computed for each subject for each level of the experiment.

Experiment 2a: Data were discarded from one subject who scored less than 6 correct on the eye or mouth for upright faces. A 2 (part change) × 2 (orientation) repeated-measures ANOVA of number of correct choices found a significant effect of part change ($F_{1,68} = 6.72$, $p = 0.0117$) and of orientation ($F_{1,68} = 22.72$, $p < 0.0001$), but no significant interaction ($F_{1,68} = 1.573$, $p > 0.2140$). Figure 12 shows that accuracy was greater for the eye than for the mouth, and for upright than for inverted faces.

Experiment 2b: All subjects scored at least 6 correct on the eye or mouth for normal faces, so no data were discarded. A 2 (part change) × 2 (contrast) repeated-measures ANOVA of number of correct choices found no significant effect of part change ($F_{1,68} = 0.0$, $p = 1.0$), a significant effect of contrast ($F_{1,68} = 85.53$, $p < 0.00001$), but no significant interaction ($F_{1,68} = 3.421$, $p = 0.0687$). Figure 13 shows that accuracy was greater for positive than for negative faces.

3.2.2 *Detection time.* Again, for the part-change factor, only the eye and mouth were of theoretical interest and included in the analysis. Mean detection times were computed for each subject for each level of the experiment, based only on those trials in which a change was correctly detected.

Experiment 2a: Data were discarded from one subject who scored less than 6 correct on the eye or mouth for upright faces. A 2 (part change) × 2 (orientation) repeated-measures ANOVA of detection times found a significant effect of orientation ($F_{1,52} = 10.95$, $p = 0.0017$), but not of part change ($F_{1,52} = 1.66$, $p = 0.2033$), and no significant interaction ($F_{1,52} = 0.003516$, $p = 0.9529$). Figure 14 shows that detection times were faster for upright than for inverted faces.

Experiment 2b: All subjects scored at least 6 correct on the eye or mouth for normal faces, so no data were discarded. A 2 (part change) × 2 (contrast) repeated-measures ANOVA of number of detection times found no significant effect of part change ($F_{1,44} = 0.6893$, $p = 0.4109$), a significant effect of contrast ($F_{1,44} = 16.79$, $p = 0.0002$), but no significant interaction ($F_{1,44} = 0.3916$, $p = 0.5347$). Figure 15 shows that detection times were faster for positive than for negative faces.

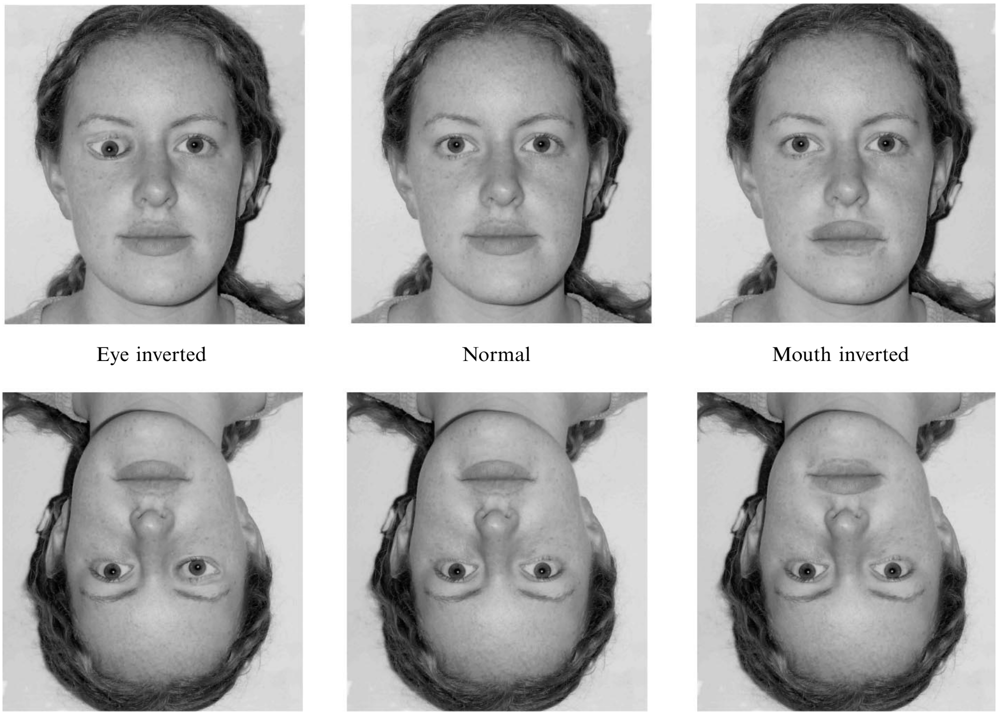

Figure 10. Changes to the eye and mouth in experiment 2a. The top row shows an eye inverted on the left, no change in the middle, and the mouth inverted on the right. The bottom row shows the corresponding faces inverted.

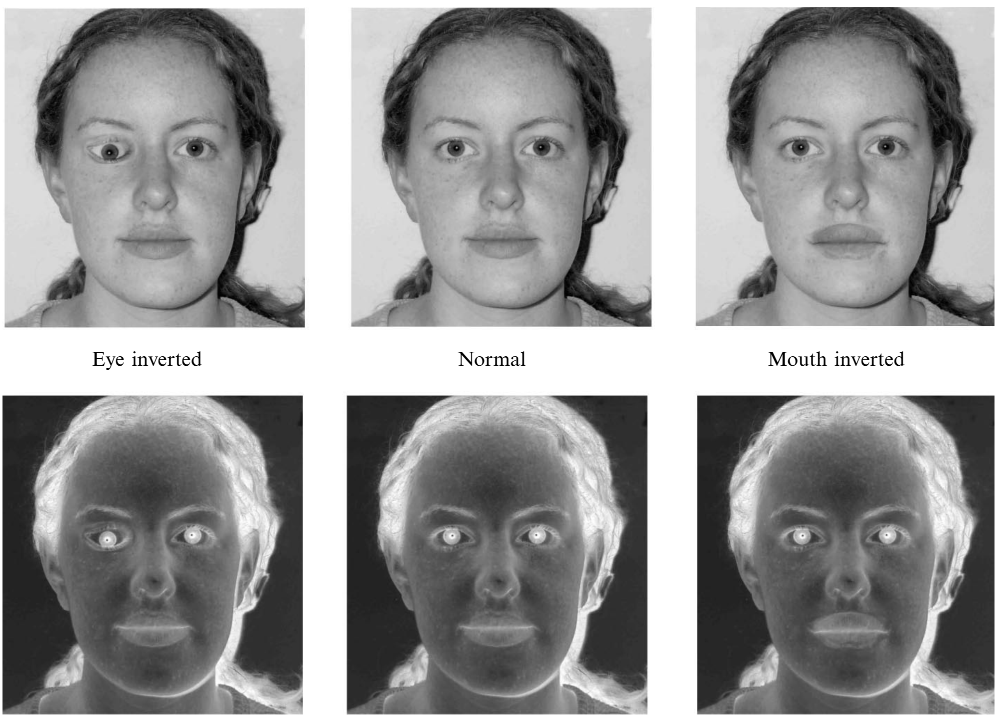

Figure 11. Changes to the eye and mouth in experiment 2b. The top row shows an eye inverted on the left, no change in the middle, and the mouth inverted on the right. The bottom row shows the corresponding faces negated.

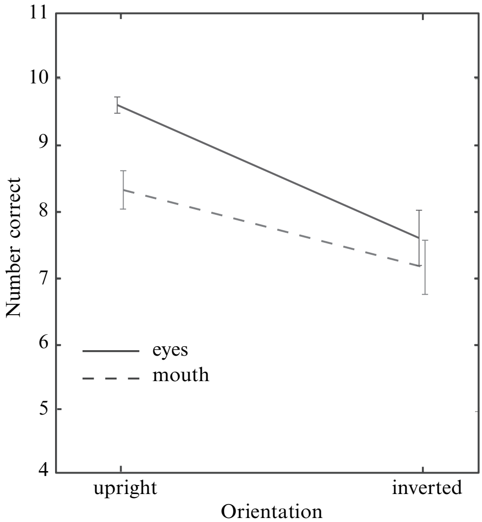

Figure 12. Detection accuracies in experiment 2a. Inversions of the mouth or right eye are detected more accurately if faces are upright than if they are inverted. Moreover, inversions of the right eye are detected more accurately than inversions of the mouth.

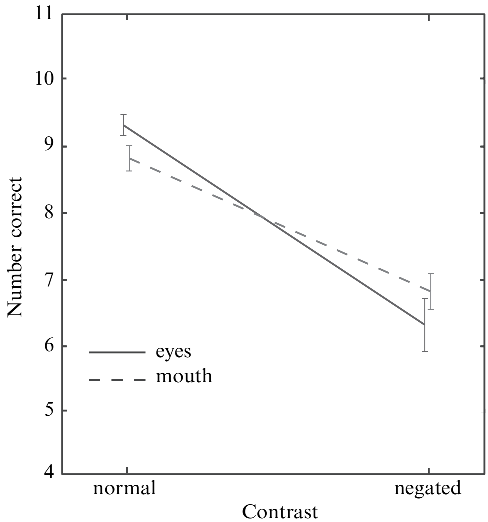

Figure 13. Detection accuracies in experiment 2b. Inversions of the mouth or right eye are detected more accurately if faces have normal contrast than if they are negated.

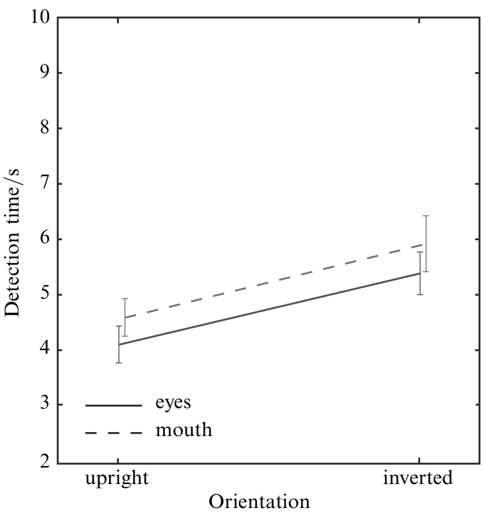

Figure 14. Detection times in experiment 2a. Inversions of the mouth or right eye are detected more quickly if faces are upright than if they are inverted.

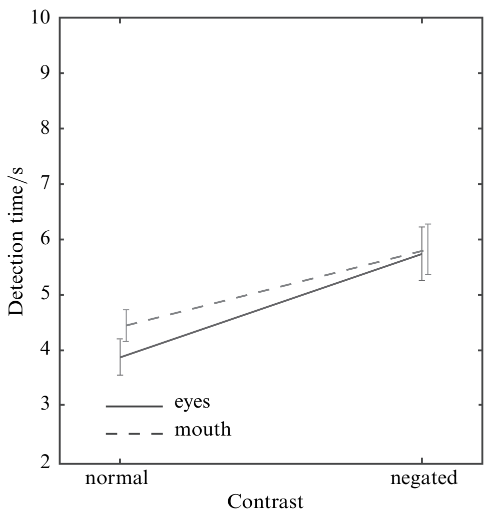

Figure 15. Detection times in experiment 2b. Inversions of the mouth or right eye are detected more quickly if faces have normal contrast than if they are negated.

3.3 *Discussion*

3.3.1 *Experiment 2a.* This experiment provides evidence that, in a change-detection task with local featural changes, the right eye receives more attention than the mouth, and that upright faces receive more efficient attention than inverted faces.

The data show that changes to the right eye are detected more accurately than changes to the mouth. This difference cannot be dismissed as due to implicit demands of the task, since the probabilities of a change to the mouth or to the right eye were equal. Nor can this difference be dismissed as due to a greater image area involved in right-eye changes than in mouth changes: the mean number of pixels involved in right-eye changes was 29 238.5 (or 13.29% of the image), whereas the mean number of pixels involved in mouth changes was 30 688.0 (or 13.95% of the image); the mean squared difference in images for right-eye changes was 3.43 million, whereas the mean squared difference in images for mouth changes was 4.24 million. If detection results were due simply to the size of the image change, then one would predict that changes to the mouth would be more easily detected than changes to the right eye, which is contrary to what we found.

In change-detection tasks, changes are perceived only when attention is focused on the part being changed (Rensink et al 1997). Therefore a natural interpretation of this result is that, when engaged in a change-detection task with featural changes, human vision gives greater attention to the right eye than to the mouth. This interpretation comports well with the finding of Althoff and Cohen (1999) that, when judging the fame or emotion of a face, subjects spend the majority of their time viewing the eyes. It also fits with the bubble-technique finding of Gosselin and Schyns (2001) that human subjects rely more heavily on some facial features than others, in a manner that depends on the task in which they are engaged. Our data leave open, of course, the question of why subjects attend more to the eye than to the mouth in our task. It could be due to exogenous factors driven by such low-level determinants of image salience as brightness, contrast, or color. It could be due to endogenous factors, such as scanning strategies designed to maximize the task-relevant information obtained from a face (Klein et al 1992; Shore and Klein 2000; Yarbus 1967). Or it could be due to the asymmetry induced in the face by thatcherizing one eye but not the other. However, we also found greater attention to the eyes than the mouth in the configural changes of experiment 1a, where there is no such asymmetry.

The data also show that local changes to the face are detected more quickly and accurately if the face is upright than if it is inverted. This suggests that endogenous factors influence how subjects attend to local features of the face. This is remarkable, because it is not what one might predict from recognition experiments, which show little effect of inversion for faces that differ only in local features. The recognition results have been interpreted as implying that little or no attention is required to encode local features of a face, but that attention is necessary to encode the configural relations between local features (Reinitz et al 1992, 1994). Our results indicate, by contrast, that attention to local features is required to successfully encode them and detect their changes.

It is fair to ask if the inversions of eye and mouth used in experiment 2 change only 'local' features, or if, instead, they also change facial configuration. Lewis and Johnston (1997), for instance, use thatcherizations of eyes and mouth as configural changes in their studies of the face inversion effect. And Thompson's (1980) paper introducing thatcherization notes that the disruption of configural information by inversion interferes with seeing the full effect of the thatcherizations in inverted faces. So there is precedent for claiming that thatcherizations change the configuration of the face. We acknowledge this, but claim that the configural changes due to thatcherization are fewer and of smaller magnitude than those due to the translations of eyes and mouth used in experiment 1. There are two reasons for this claim. First, our thatcherizations rotated the eye or the mouth in place, without any translations. This leaves the spatial relationships between facial features unchanged, or much less changed, than the feature translations used in experiment 1. Second, the faces in our experiment all had neutral expressions, so thatcherizations did not lead to big changes in the positions of key features of the eyes or mouth. For instance, the corners of a smiling mouth, when thatcherized, change position substantially, and appear to be the corners of a frowning mouth. The corners of a neutral mouth, when thatcherized, change position little, and don't appear to change the emotional expression.

Thus, although the changes to features in experiment 2a are not entirely local, they are far more local and far less configural than the changes in experiment 1. Our logic here is similar to that of Freire et al (2000) who used replacement of an entire feature, such as an eye or nose, as a local change. They argued that by putting the replacement part in the same location, and at the same size, as the original they were making minimal changes to the configural properties of the face.

One method to make the changes even more local would be to restrict them to color or brightness changes, as was done by Leder and Bruce (2000). We expect that this would give the same pattern of detection results as obtained in experiment 2a.

3.3.2 *Experiment 2b.* This experiment provides evidence that, in a change-detection task with local featural changes, positive-contrast faces receive more efficient attention than negative-contrast faces.

The data show that negation reduces accuracy of change detection, and that inversions of the right eye and mouth are detected with equal accuracy. This latter result contrasts with experiment 2a, where inversions of the right eye were detected with greater accuracy than inversions of the mouth. This difference in observed attentional patterns may reflect a difference in processing between negated and inverted faces. In particular, negated faces display physically impossible 3-D shading patterns, whereas inverted faces display a physically possible orientation that can, on occasion, be encountered in our natural environment.

Since we have little experience in nature with color-negated images, and since color is processed early in the visual system, such images might disrupt the normal visual processing of hue, luminance, form, and motion. In consequence, such images might disrupt normal processing of faces, and in particular the endogenous control of attention to faces. In this case attention to the face would no longer be guided by meaning, but would instead be captured by the most salient aspects of the image. So face features that are the most informative for face processing might no longer have an attentional advantage over other features of the face. It is also possible that, since negated images present an unexpected spectrum of colors for faces, color becomes a focus of attention and initiates low-level attentional scanning, driven by image hues and contrasts.

In experiment 2b the positive-contrast stimuli were the same as the upright stimuli for experiment 2a. However, the right eye received greater attention than the mouth in experiment 2a but not in experiment 2b. This suggests two possibilities, both involving hysteresis. Viewing negated images might cause impairment hysteresis: the attentional disruption caused by viewing negated images might last long enough to impair attention to normal face images, a possibility that we mentioned before. Or viewing negated images might cause a learning hysteresis: an exogenous scanning strategy newly learned for processing negated images might persist for processing normal face images.

Negation has been cited as a transformation similar to inversion (see Valentine 1988 for a review), but recent studies have shown that the two effects are additive, such that a negated inverted face is more disruptive than either a negated or an inverted face alone, and that negation and inversion may have independent causes (Bruce and Langton 1994; Kemp et al 1990; Lewis and Johnston 1997). Our data offer further support for dissociation between effects of inversion and negation since attentional patterns to features observed in a change-detection task with inverted faces (right eye attended to more than the mouth) were not found in a change-detection task with negated face images (equal attention for the right eye and mouth). Although this does not entail that attention in general is more disrupted by negation than inversion, it does suggest that endogenous attention to faces is disrupted more by negation than inversion, or that different attentional mechanisms are used for negated faces than for inverted faces.

The data also show that local featural changes to the face are detected more quickly if the face is shown in positive contrast than in negative contrast. Although many studies have investigated effects of negation on configural information (Hayes 1988; Kemp et al 1990; Sergent 1984), few have explored effects of negation on local features. Bruce and Langton (1994) note that local features of the face are affected by negation, since eyes become a white pupil against a black sclera, eyebrows glow, and a brunette becomes an apparent blond.

In addition to these local coloring effects of negation, other attributes of face features might also be difficult to perceive. For instance, in a negated face edges and spatial layout are preserved, but shape-from-shading is disrupted (Kemp et al 1996; Liu et al 2000). This disruption not only impairs perception of the complex 3-D shape of the entire face, but also perception of the local depths of face features. For example, deep-set eyes differ significantly from eyes that protrude, but without shape-from-shading cues to construct a 3-D representation of the face, discriminating these differences is more difficult. This could account for our finding that inversions of local features are more difficult to detect when the face is negated.

3.3.3 *Perceptual controls.* As with experiment 1, we ran cueing controls for experiment 2 to determine if our inversion and negation results were due to attention, or just to difficulties in perception.

For accuracy levels in experiment 2a, in which we studied detection of local changes made to upright and inverted faces, the perceptual control experiments reveal a main effect of cueing ($F_{1,34} = 23.361$, $p = 0.003$), with subjects performing better with cued than uncued images. Since cued trials direct subjects' attention to the location of a change, significantly reducing and possibly eliminating the need for attentional strategies, improved performance with cues shows that the original results from experiment 2a were largely a result of attention and not just perception. There is also a significant interaction between part and cue ($F_{1,34} = 15.336$, $p < 0.001$), with subjects' performance improving more for the mouth than for the eye during the cued trials. This suggests that the observed advantage of the eye over the mouth in the original experiment 2a was largely an attentional effect since subjects had little difficulty perceiving the mouth change once the need for attentional search was reduced by the cues. In the cued control, mean accuracies for eyes were 9.44 upright and 8.17 inverted; for mouths they were 9.39 and 8.94.

For the detection times in experiment 2a, there is also a significant interaction between part and cue ($F_{1,29} = 6.049$, $p = 0.02$) with cueing improving the detection times for the mouth more than for the eye. It is interesting to note that with the cued trials, subjects not only show more improvement for the mouth than the eye, but they also have faster detection times for the mouth than the eye. This is an opposite result from the uncued experiment, in which there was a nonsignificant trend for the eye to produce faster reaction times than the mouth. This suggests that, once attentional factors are reduced, mouth changes may actually be perceptually easier to see than eye changes. This again supports the original findings that the eye has an attentional advantage over the mouth. In the cued control, mean detection times for eyes were 4.31 s upright and 4.98 s inverted; for mouths they were 4.07 s and 4.46 s.

For accuracy levels in experiment 2b, in which we studied local changes made to positive-contrast and negative-contrast images, the perceptual control experiments reveal a main effect of cueing ($F_{1,34} = 19.575$, $p < 0.001$), with subjects performing better on cued than uncued trials. This suggests that the original results from experiment 2b are not solely a reflection of perceptual impairments, but can be explained, at least in part, by attentional impairments. There is also a significant interaction between cue and contrast ($F_{1,34} = 16.542$, $p < 0.001$), with subjects having greater improvements on negative rather than positive contrast images. In the cued control, mean accuracies for eyes were 9.44 upright and 7.67 inverted; for mouths they were 9.33 and 8.94.

For detection times in experiment 2b, there is a nonsignificant effect of cueing ($F_{1,26} = 2.451$, $p = 0.130$): there is a trend for subjects to be faster on cued than uncued trials. There is a significant part-by-cue interaction ($F_{1,26} = 6.479$, $p = 0.017$): subjects show greater improvements in speed for changes made to the mouth than to the eye. This suggests that the advantage of the eye over the mouth in the original experiments was largely due to attention, and that once the need for attention is significantly reduced, the mouth changes are perceptually easier to see. In the cued control, mean detection times for eyes were 4.11 s upright and 5.47 s inverted; for mouths they were 3.93 s and 4.06 s.

4 General discussion

Previous studies have failed to find an effect of inversion on detection of changes in a flicker task, and have concluded that the flicker task can be used to study the exogenous, but not the endogenous, control of attention (Shore and Klein 2000). Our study finds, to the contrary, that inversion and negation each significantly impairs detection of facial changes in a flicker task. This demonstrates that the flicker task can be used effectively to study the endogenous control of attention to faces. Our study also finds that cueing in a flicker task can be used to dissociate impairments due to attention from impairments due to perceptual encoding.

It is well known that inversion impairs face encoding (Searcy and Bartlett 1996; Valentine 1988) as does negation (George et al 1999; Lewis and Johnston 1997), and that inversion impairs face identification (Diamond and Carey 1986; Tanaka and Farah 1993), as does negation (Liu and Chaudhuri 1997; Liu et al 1999, 2000). Our study shows that, in addition, inversion and negation both impair attention to local and configural features of faces. That inversion impairs attention to local features is particularly striking, because it is not what one might predict from recognition experiments, which show little effect of inversion for faces that differ only in local features. The recognition results have been interpreted as implying that little or no attention is required to encode local features of a face, but that attention is necessary to encode the configural relations between local features (Reinitz et al 1992, 1994). Our results indicate, by contrast, that attention to local features of the face is required to successfully encode them and detect their changes.

Since negation and inversion impair recognition memory for faces, one might wonder if the differences we find in detection performance between upright and inverted faces, and between normal and negated faces, result simply from differential memory across the blank interval of the flicker task, rather than from differential attention during the display presentation? However, our finding that cueing significantly improves detection performance is not easily explained by differential memory apart from differential attention. It is hard to see how cueing could improve recognition memory, unless the improvement was due to better encoding as a result of increased attention.

Psychophysical studies using the 'bubbles' technique (Gosselin and Schyns 2001) and using eye movements (Althoff and Cohen 1999; Borod et al 1988; Lansing and McConkie 1999; Mertens et al 1993) indicate that different parts of the face can receive different amounts of attention. Our results confirm this and indicate that, for our detection task, the eyes receive more attention than the mouth.

Our experiments show that the flicker task can be used to study endogenous attention to static faces with neutral expressions. It will be interesting to extend this result, and use the flicker task to study endogenous attention to dynamic faces, and to faces with emotional expressions.

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