Perception, 1990, volume 19, pages 531–543

Sensitivity to the displacement of facial features in negative and inverted images

Richard Kemp ¶, Chris McManus #
Department of Psychology, University College London, Gower Street, London WC1E 6BT, UK
Tara Pigott
University College and Middlesex School of Medicine, London W1P 7PN, UK
Received 6 July 1989, in revised form 10 January 1990

Abstract. Subjects have previously been reported to show difficulties in recognising faces which are either inverted or in photographic negative. Experiments are reported in which a two-alternative forced-choice technique was used to measure sensitivity for distinguishing faces which have been modified by having the eyes moved vertically or horizontally. Subjects were less sensitive to such changes for inverted faces or negative faces, and were even less sensitive for faces that were both inverted and negative. No such effects were found for a control stimulus consisting simply of three solid circles in the same positions as the eyes and mouth of a face. When the stimuli consisted of eyes, nose, and mouth, but without a surround, no evidence of inversion or negation effects was found, which suggests that a facial surround is necessary. When the stimulus consisted of a facial surround with the eyes, nose, and mouth replaced by solid circles, effects of negation were found, but no effects of inversion. This dissociation of the effects of negation and inversion may suggest that they are the result of different underlying mechanisms.

1 Introduction

Faces are important visual stimuli from a biological and social perspective, being responsible for person-recognition and the perception of emotion. They also constitute a class of visual objects in which the characteristics that allow one to distinguish between members are very slight: that is, they are close to the Weber function for discriminability. This combination of factors has inevitably led to speculation that there may be some form of specific processor which is responsible for facial recognition. Ellis (1975) described three types of evidence for such a hypothesis: the early ontogeny of facial recognition; the existence of patients showing the specific defect of prosopagnosia; and the disruption of recognition by inversion. Certainly, given the important biological role of faces, it is at least conceivable that selective evolutionary pressures could have resulted in a specific face identification mechanism.

Different groups of workers have proposed theoretical models (eg Bruce and Young 1986; Ellis 1986; Hay and Young 1982; Rhodes 1985) which explain much of the data from the wide range of experiments in face recognition conducted to date. A common characteristic of such models is that they typically assume that the first stages of face perception involve extraction of visual primitives by a mechanism which is common to that used for non-face visual processing, and that the characteristics especial to face perception occur after feature or primitive extraction. Thus for example both Ellis (1986) and Bruce and Young (1986) included a module entitled 'structural encoding', and Hay and Young (1982) included processes entitled 'representational processes' and 'visual processes', in each case the functions explicitly or implicitly being common to all visual inputs.

¶ Also at Faculty of Business Management and Social Sciences, Polytechnic of Central London, Regent Street, London W1R 8AL, UK
# Also at Department of Psychiatry, St Mary's Hospital Medical School, Norfolk Place, London W2 1PG, UK

This important theoretical assumption, of a common visual processing mechanism for facial and non-facial stimuli, has not been adequately tested empirically, and here we report results which are compatible with the hypothesis that face perception may involve the extraction of visual primitives which are specific to this process.

Face perception can be disrupted by several manipulations. Yin (1969) was the first to point out that inverted faces are disproportionately difficult to recognise. The literature has recently been reviewed by Valentine (1988) who concludes there is no compelling evidence that inverted faces are processed differently from upright faces. Valentine argues that there is no need to infer the existence of a unique process in face recognition, and prefers to explain the existing results from face-inversion studies in terms of differential expertise in processing the highly homogenous class of facial stimuli.

A second manipulation, long recognised by workers in photographic laboratories who spend many hours looking at negative films, and first assessed systematically in the psychological literature by Galper (1970) and Galper and Hochberg (1971), is that faces in photographic negative are also disproportionately difficult to recognise. The effects of making a photographic negative upon facial processing have been further studied by Bradshaw and Wallace (1971), Phillips (1972), Luria and Strauss (1978), and Hayes et al (1986). Surprisingly, as Valentine (1988, page 483) comments, there have been no studies comparing the relative effects of face inversion alone with face negation alone. Neither, to our knowledge, have there been any studies aimed at finding out whether facial inversion and negation together produces an additional decrement in performance.

Studies using either inversion or negation are characterised typically by being concerned with measures of recognition, in which subjects either learn names of a training set of faces, and then have to identify particular faces they are shown, or else have to classify whether particular faces in an experimental set were those previously included in a training set. Such methods not only inevitably impose some memory load upon subjects, but also do not distinguish the perception of small differences in faces from the classification and categorisation of faces as different one from another. In part this problem is a technical difficulty due to experiments using real photographic stimuli, and the difficulty of manipulating such images to produce small changes in facial configuration whilst retaining the essential integrity of the image. We have therefore attempted to examine only the detailed perception of small configural changes, in a face that remains within the same identification category, by using a psychophysical procedure for measuring sensitivities to such changes in normal, inverted, and negative faces.

The only previous studies in which faces have been manipulated in this way are those of Haig (1984, 1986) and Hosie et al (1988), who used a sophisticated image processor to alter facial configurations in photographs. We preferred to use thresholded images in which only two grey levels were present, so as to avoid the creation of artefactual contours when features are moved.

The experiments of Haig (1984, 1986) and Hosie et al (1988) produced very similar results, showing that subjects were very sensitive to small displacements of the eyes, nose, and mouth. Hosie et al found subjects to be equally sensitive to inward and outward movement of the eyes of the famous faces that were used as stimuli. In contrast, Haig (1984) used faces unknown to the subjects and found that detection of inward displacements of the eyes was more accurate than that of outward displacements. Hosie et al (1988) explained this difference in terms of the relative familiarity of the faces used. Neither of these studies dealt with the effect of inversion and negation on the detection of feature displacement.

In experiment 1 of our series of studies we compared the perception of horizontal and vertical movements of the eyes within a face, when the face is upright, when it is inverted, and when it is normally oriented but in photographic negative.

2 Experiment 1

2.1 *Subjects*

Twenty-nine subjects took part, all of whom were medical students at University College London. None of the subjects was familiar with the individual shown in the images.

2.2 *Method*

2.2.1 *Preparation of stimuli.* All images were modifications of a single image showing the face of a member of staff in the Psychology Department of University College London. The original image from which the modified versions were produced was captured by means of a video-camera, with the subject seated in front of a matt-black background, and illuminated from a single source slightly above and to the right of the camera. The subject looked full-face into the camera which was adjusted until the face almost filled the frame. The image was digitized to 256×256 pixels with 8 bits of grey level information (256 grey levels). The image was thresholded such that the main features were identifiable and clearly separated, so that individual features could readily be moved relative to one another; this meant that 70% of pixels were black and the remaining 30% were white.

Coordinates of the key features (right eye, left eye, nose, mouth, chin, and facial surround) were measured and 'cut out' so that novel composite images could be produced by 'pasting' these features back into the face outline in new positions. The position of the features could be determined to an accuracy of one pixel in a 256×256 pixel image.

Negative images were produced by substituting black pixels for white and vice versa. Inverted images were produced by simple rotation through 180°. The original image as well as negative and inverted versions of it are shown in figure 1.

The images were output to a laser printer that printed directly onto acetate sheets suitable for use on an overhead projector.

2.2.2 *Design.* On each trial an acetate sheet was projected with an overhead projector. A typical example of the presentation as seen by a subject is shown in figure 2. Each sheet contained three images: the centre top image always had the features in their original positions; the two lower images were presented alongside each other, with the left image somewhat lower on the slide, to prevent subjects making direct comparisons of the images by scanning the stimuli horizontally. On each trial either one of the two lower images was modified by moving the original features, while the other conformed to the original, top image.

Each subject completed a series of 120 trials. On each trial only the eyes of the modified image were moved, the direction of movement being either horizontal or vertical. The sign of the movement was either negative (inwards, with the eyes moved closer together for horizontal movements, or downwards, with the eyes moved closer to the nose and mouth for vertical movements), or positive (in the opposite directions to those just described). Feature displacements were either of 1, 2, 4, 6, or 8 pixels from the original positions (see figure 1). Stimuli were of three types: normal, negative or inverted. On each particular trial all three of the images were always of the same type, that is, both the top image and the two lower images were, say, negative. The modified version of each image occurred equally often to each side, in the lower right and the lower left position. The study used a fully balanced $3 \times 5 \times 2 \times 2 \times 2$

design, with each subject seeing all three types in all five displacements in both directions and with both signs presented on the two sides.

2.2.3 *Procedure.* Subjects were tested in groups of approximately ten. All subjects sat at about the same distance from a clearly visible projection screen in a dimly lit room. Stimuli in each trial were projected so that the 256 pixels across each image subtended a visual angle of about 1.7 deg. A 1 pixel displacement is therefore equivalent to a displacement of 24 s arc. The centre of the upper image was 2.75 deg above the centre line of the lower images, which were vertically separated by 0.65 deg; the centres of the lower images were separated horizontally by 2.35 deg. In the original image, the centres of the eyes were 56 pixels apart (0.37 deg), and hence a 1 pixel movement inwards of each eye results in a 3.75% change in the

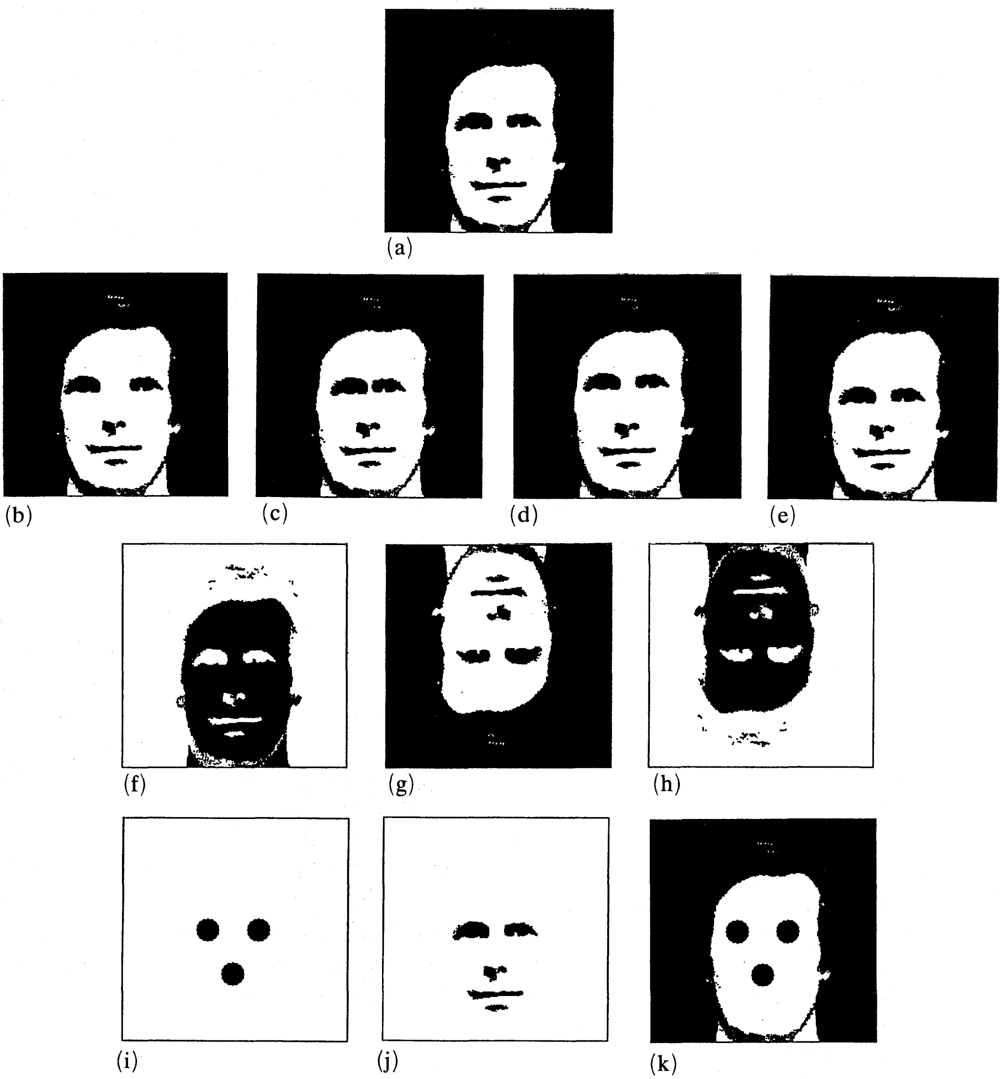

Figure 1. Top: the original unmodified face with the eyes in their normal positions (a). Second row: the normal face with the eyes moved +6 pixels horizontally (b), −6 pixels horizontally (c), +6 pixels vertically (d), and −6 pixels vertically (e). Third row: examples of the negative (f), inverted (g), and negative-inverted (h) face types. Fourth row: examples of the types of stimuli used in experiment 3 (i), experiment 4 (j), and experiment 5(k).

relative positions of the eyes. Likewise the centres of the eyes were 51 pixels (0.34 deg) above the centre of the black pixels making up the 'nose', and hence a 1 pixel movement downwards of the eyes changed the relative vertical distance between eyes and nose by 1.96%.

Subjects were told that they would be shown a series of overhead slides in each of which there would be one image of a face in which the position of the eyes had been altered, either upwards, downwards, inwards, or outwards. Each manipulation was clearly visible on a series of demonstration slides, which included normal, negative, and inverted types of stimuli. Subjects were asked to indicate which of the lower two images was the same as the top image, which they were told was always unmodified and had its eyes in the original position, and hence was always available for comparison. Subjects responded on special answer sheets by making a cross on a six-point scale which indicated on each trial how certain they were that it was the left or right image that had been modified.

Before the experiment proper, subjects carried out ten practice trials to ensure that they understood the instructions; the practice trials were randomly selected from the experimental slides.

Each slide was shown for about 5 s with about 5 s between trials for the subjects to respond, the overall rate being determined by that at which subjects felt comfortable. Each experimental session typically lasted about 30 minutes, after which subjects were debriefed and thanked for their cooperation.

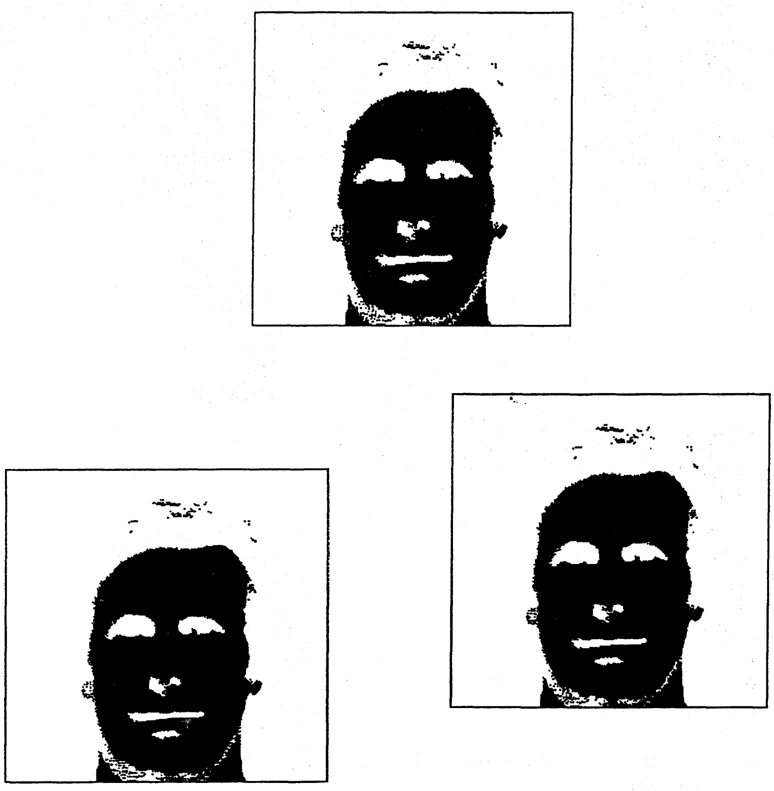

Figure 2. A typical presentation for a single trial in experiment 1. Here the negative face on the right has been modified by having its eyes moved down by 1 pixel.

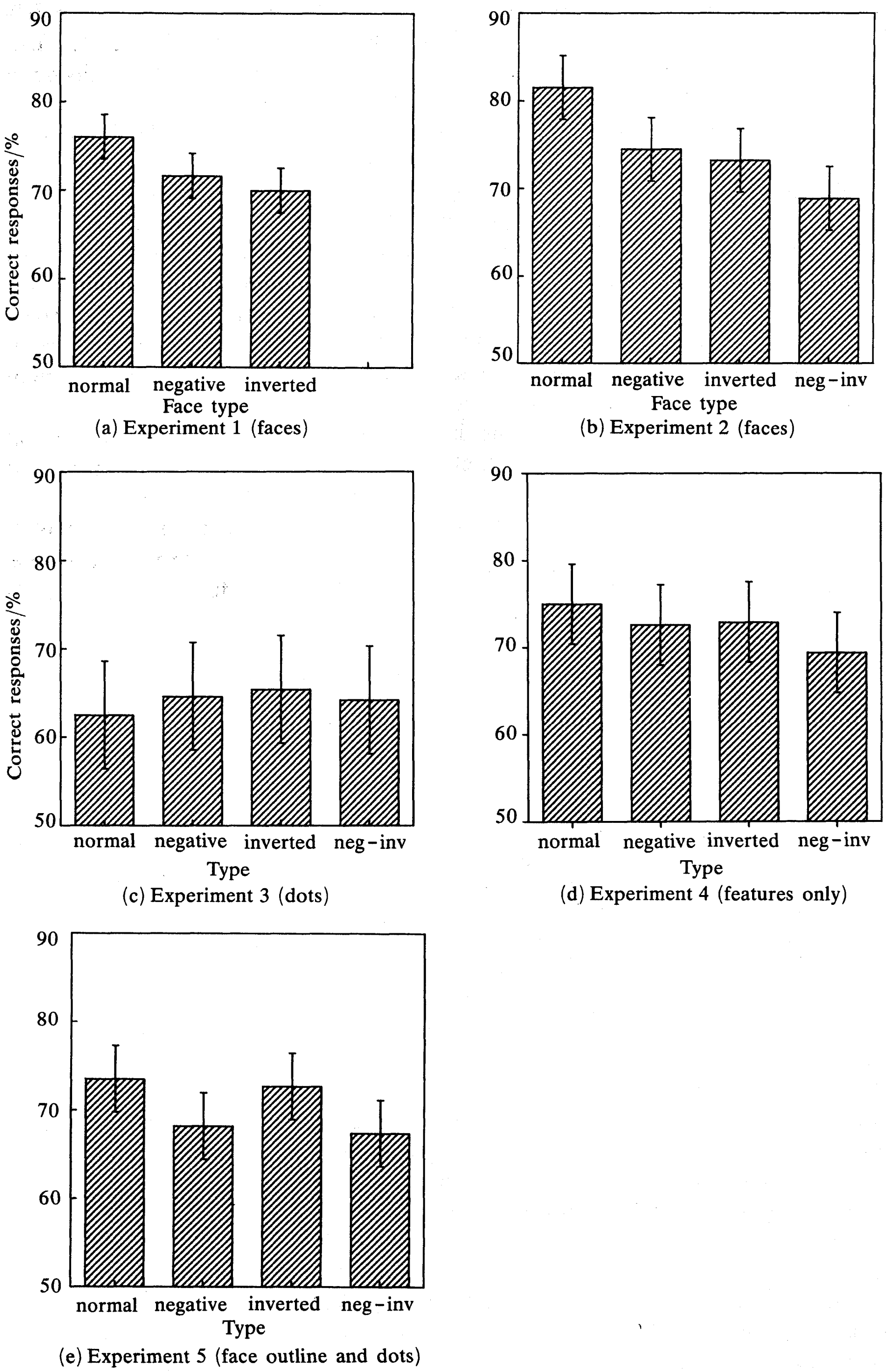

Figure 3. Percentage of correct judgements made by subjects in experiments 1, 2, 3, 4, and 5 (error bars show 95% confidence intervals).

2.3 *Results*

Data were analyzed by a three-way repeated-measures analysis of variance, with main effects of stimulus type, direction, and sign; the side of the modified image was not included, a preliminary analysis having shown the absence of any effects. The six-point scale used by subjects was recoded according to whether the response was correct or incorrect; these two scales showed similar results, and therefore only the correct–incorrect responses are reported here.

Overall 72.6% of judgements were correct. There were significant differences in proportion of correct responses to the three types of stimuli ($F_{2,56} = 5.86$; $p < 0.01$; figure 3a). Detection of feature displacement was most accurate for normal images, and less accurate for negative and inverted images. A posteriori analysis showed no significant difference in accuracy between negative and inverted images. In addition, horizontal displacements were more accurately detected (86.0% correct overall) than were vertical displacements (59.1% correct overall) ($F_{1,28} = 150.82$, $p < 0.001$). There was also a significant interaction between direction and sign ($F_{1,28} = 6.39$; $p < 0.05$) in which an inwards (negative) movement of the eyes was detected better than an outwards (positive) movement, whereas no difference was found between upwards and downwards vertical displacements of the eyes.

The only other significant interactions in the analysis were between type and direction ($F_{2,56} = 3.34$, $p < 0.05$), in which the differences between the stimulus types were greater for vertical directions of movement than for horizontal, and between stimulus type, direction of movement, and sign ($F_{2,56} = 3.79$, $p < 0.05$), which was not readily interpretable.

The proportions of correct responses varied with the extent of the displacement: 53.0, 70.3, 79.3, 82.8, and 94.8% correct for displacements of 1, 2, 4, 6, and 8 pixels in the normal images, compared with 55.6, 64.2, 76.7, 78.5, and 83.2% correct for negative images, and 53.0, 66.4, 74.1, 76.8, and 79.8% correct for inverted images.

2.4 *Discussion*

The results of experiment 1 for the normally oriented, non-negative images are broadly compatible with those of previous workers (Haig 1984, 1986; Hosie et al 1988), who have used eight-bit grey-level images, rather than the one-bit, black-and-white images that we have used.

Of particular interest is that experiment 1 suggests that subjects are significantly less sensitive to the displacement of features in negative or inverted faces than they are in normal faces, the extent of the impairment being equal in both types of manipulation. The problem in making such judgements is principally perceptual in origin as the subjects were making direct comparisons between simultaneously presented images of the same type (inverted, negative or normal), and hence there was no memory load placed upon them.

The fact that horizontal displacements were more accurately detected than vertical displacements was to be expected. As has already been noted, a horizontal movement of each eye by 1 pixel produces a change in the distance between the eyes of 3.75%, whereas a 1 pixel movement of both eyes in the vertical direction produces a change in distance between the eyes and the nose of 1.96%.

3 Experiment 2

In experiment 1 we did not study how subjects detect feature displacement in faces that are both inverted and in photographic negative. If, however, as has been suggested, faces are harder to recognise when presented upside-down or in photographic negative because subjects are unable to use face-specific encoding mechanisms, then the combination of these two manipulations should be unable to produce a further decrement in performance. That is, it might be predicted that the effects of inversion and negation reported in experiment 1 should not be additive. A further degrading of the 'faceness' of the stimuli should have no additional effect, since any face-specific encoding mechanisms available for use with normal faces should not be available to non-face patterns, such as negative, inverted, or negative-inverted faces. It cannot merely be claimed that because inverted faces are recognised as faces per se their recognition as faces—as opposed to buses or sealions, for example—means that therefore they must have access to the full range of specific processing mechanisms which might be available for upright faces. The perception of 'faceness' (i.e. distinguishing a face from a non-face object) is not necessarily the same process as distinguishing between two faces.

In experiment 2 we tested this hypothesis by including a fourth stimulus type, faces which are both inverted and negative.

3.1 *Subjects*
The twenty-three subjects were all undergraduate students of psychology at North East London Polytechnic, and were not familiar with the person depicted in the images. All were about 20 years old and had normal vision, with or without correction.

3.2 *Method*
3.2.1 *Preparation of the stimuli.* The images used in experiment 2 were almost identical to those used in experiment 1, and were prepared and presented in a similar fashion. The only modification was that the stimulus set included images which were both inverted and in negative ('negative-inverted', see figure 1h).

3.2.2 *Design.* The design of experiment 2 was similar to that of experiment 1 except that (i) only three displacements were used, features being moved either 2, 4, or 6 pixels from their original positions; and (ii) there were four types of stimulus: normal, inverted, negative, and negative-inverted.

The experiment was fully balanced with all subjects presented with the 96 stimulus combinations in a $2 \times 2 \times 2 \times 3 \times 4$ design.

3.2.3 *Procedure.* Subjects were tested in a single group, and sat similar distances from the screen on which the slides were projected in a dimly lit room. The 256-pixel wide stimuli each subtended a visual angle of approximately 2.4 deg, so that a 1 pixel displacement in this experiment was equivalent to an angular displacement of 34 s arc.

The instructions given to the subjects were identical to those in experiment 1 except that, because of comments made by subjects in the previous experiment, these subjects were told to identify the stimulus which was *different* from the top stimulus, this modification reducing response confusion. Subjects were shown examples of each type of stimulus and were allowed 10 practice slides. In other respects the procedure was identical to that used in experiment 1.

3.3 *Results*
Four-way repeated-measures analysis of variance of the effects of inversion, negation, and the direction and sign of the displacement showed that feature displacement was less well detected in negative than in positive stimuli ($F_{1,22} = 10.83$, $p < 0.01$), and less well in inverted than in upright stimuli ($F_{1,22} = 12.51$, $p < 0.01$). These effects do appear to be additive as there was no evidence of an interaction between negation and inversion ($F_{1,22} = 0.97$, NS) (see figure 3b). The only other significant results were, as in experiment 1, that the direction of displacement affected detection, stimuli being better detected when features were moved horizontally than vertically ($F_{1,22} = 239.8$, $p < 0.001$) and when moved in a negative direction than in a positive direction ($F_{1,22} = 7.28$, $p < 0.05$).

3.4 *Discussion*
The overall pattern of results in this experiment is broadly similar to that in experiment 1. Of greatest interest is that although both negation and inversion of the image produced a decrement in performance, there was no evidence of an interaction

between the two effects; that is, the effects are additive. The additional impairment in performance for negative–inverted images over and above that for either negative or inverted images was therefore counter to our hypothesis that negation and inversion simply acted to disrupt a single specific face-detecting process.

4 Experiment 3

Thus far the effect we are describing has not been shown to be specific for faces, rather than for any image involving, say, a triangular representation approximating to a mouth and two eyes. This is of particular importance since in general the effects of inversion and negation upon recognition performance are particularly pronounced for faces as compared to other types of stimuli (see however Diamond and Carey 1986). If, as we have implied earlier, the effects of inversion and negation are due to a failure of specific visual processes which are dedicated to the extraction of spatial primitives found typically in upright, positive faces, then it is important to be able to demonstrate that the effect is indeed confined to face stimuli. This question has been addressed in experiment 3 by using non-face stimuli.

4.1 *Subjects*

Ten subjects, all of whom were students at North East London Polytechnic, took part in the experiment under similar conditions to those described earlier.

4.2 *Method*

Experiment 3 was essentially similar to experiment 2 in its design and procedure except that the stimuli consisted not of faces, but of a set of three solid circles, each of the same area as the eyes in the face image used in experiments 1 and 2, and arranged in a triangle corresponding to the positions of the two eyes and the mouth in that original face (see figure 1i).

4.3 *Results*

A four-way repeated-measures analysis of variance of the accuracy of detection of the displaced feature showed only a single significant result: displacements were detected more easily when they occurred horizontally than vertically ($F_{1,9} = 28.48$, $p < 0.001$). The effects of negation and inversion were both not significant ($F_{1,9} = 0.03$ and $F_{1,9} = 0.12$ respectively) (see figure 3c).

4.4 *Discussion*

The results confirm that the effect found in experiments 1 and 2 does not generalise to any symmetric approximation to a face, but instead seems to be specific to stimuli which are more truly face-like. That experiment 3 revealed a similar effect to those found in experiments 1 and 2 for the superiority of horizontal rather than vertical displacements not only is to be expected (on the basis of a similar argument to that already given in experiment 1), but also confirms the power of the technique for detecting potential effects of negation or inversion.

This experiment cannot, of course, demonstrate that it is the 'faceness' of the stimuli in experiments 1 and 2 which produces the effects of negation and inversion but it does show that these effects do not generalise to all stimuli in which the location of two horizontally placed blobs must be assessed. That is true despite the two blobs being of similar areas and locations to the eyes in the face of experiments 1 and 2, and the third blob being placed at the centroid of the nose and mouth of the face in experiments 1 and 2. The potential for construing these three blobs as a primitive face (as for instance would probably be done by neonates), is insufficient to produce the effects found for negative and inverted faces.

5 Experiment 4

The demonstration of a decreased sensitivity for detecting the displacement of eyes in negative or inverted faces, combined with the absence of such an effect for the structurally very similar stimulus of three dots arranged in an inverted triangle, raises the question of which components of a face are particularly important in generating the effect. Experiments 4 and 5 have been designed to approach this problem by asking whether the surround of the face is particularly important for the effect, and whether the effect is dependent upon the eyes and mouth appearing like true facial features.

5.1 *Subjects*

Twelve subjects, all of whom were medical students at St Mary's Hospital Medical School, took part in the experiment under similar conditions to those described above.

5.2 *Method*

The stimuli in experiment 4 consisted of the eyes, nose and mouth of the original facial image but without any facial surround (see figure 1j). Otherwise the experiment was identical to experiments 2 and 3.

5.3 *Results*

Four-way repeated-measures analysis of variance found significant main effects of the direction of displacement ($F_{1,11} = 142.83$, $p < 0.001$) and the sign of displacement ($F_{1,11} = 31.29$, $p < 0.001$). However, there were no main effects of negation or inversion ($F_{1,11} = 1.16$, NS; $F_{1,11} = 1.94$, NS, respectively) (see figure 3d). Analysis of the remaining interactions revealed a significant interaction between direction and sign ($F_{1,11} = 8.43$, $p < 0.05$), similar to that found in experiment 1, and also interactions between negation and direction ($F_{1,11} = 13.57$, $p < 0.01$), and negation, inversion, and direction ($F_{1,11} = 5.39$, $p < 0.05$).

5.4 *Discussion*

The results from experiment 4 do not demonstrate any effect of inversion and negation when true facial features are displaced in the absence of a facial surround. This would seem to suggest that the effects of inversion and negation found in the previous experiments are not solely dependent on the features which are being dispaced being actual images of eyes. Similarly, the lack of effects in experiment 3 does not then seem to be caused by the use of dots rather than of true features. The implication is that the facial surround is of crucial importance in the genesis of the effects. If this is so, then a prediction would be that a real facial surround containing simply three dots in the positions of eyes and mouth would be sufficient to produce the effects found earlier. This prediction was tested in experiment 5.

6 Experiment 5

6.1 *Subjects*

Eleven subjects, all of whom were postgraduates or staff in the Department of Psychology at University College London, took part under similar conditions to those of previous experiments.

6.2 *Method*

This experiment was similar to experiment 2 with the exception that the stimuli consisted of the facial surround derived from the original image, but with eyes and mouth replaced by solid circles, as in experiment 3 (see figure 1k).

6.3 *Results*

Four-way repeated-measures analysis of variance showed a significant main effect of negation ($F_{1,10} = 11.36$, $p < 0.01$), but no main effect of inversion ($F_{1,10} = 0.12$, NS). There was no significant interaction between negation and inversion ($F_{1,10} = 0.00$, NS) (see figure 3e). In addition there were main effects of direction of displacement ($F_{1,10} = 63.83$, $p < 0.001$) and of sign of displacement ($F_{1,10} = 49.28$, $p < 0.001$). As in previous experiments there was a significant interaction of direction and sign ($F_{1,10} = 6.90$, $p < 0.05$), and interactions were also found between negation and sign ($F_{1,10} = 7.27$, $p < 0.05$), and negation and direction ($F_{1,10} = 10.02$, $p < 0.05$).

6.4 *Discussion*

The finding of a significant effect of negation upon the detection of characteristic displacements in a stimulus consisting of a real facial surround with simple dots for eyes and mouth, confirms the prediction made after experiment 4 that the facial surround is an integral characteristic of the effects we have been describing. However, the absence of an effect of inversion is very surprising, since, to our knowledge, this is the first demonstration of a manipulation which affects one process without affecting the other. This dissociation is potentially of great theoretical significance, especially if a further manipulation could be discovered which produces the inversion effect without showing a negation effect, and results in a double dissociation of function, and the inference of separate underlying processes. Although the facial surround is clearly important in determining the above effects, those effects clearly cannot be entirely attributed to the presence of a surround, as otherwise one would expect that experiments 1, 2, and 5 would have produced identical results.

7 General discussion

There seem to be four distinct conclusions that can be drawn from our results. First, the effects of inversion and negation are independent of a memory load and are truly perceptual phenomena. It is worth reiterating that at all times subjects were able to compare the trial stimuli with one that was of the same type and known to be in the unmodified configuration. Second, the two effects are additive in that performance is most disrupted for faces that are both inverted and negative. Third, the effects of inversion and negation are dependent on certain critical features of the stimulus, which must in some sense be face-like; the facial surround seems to be of particular importance here. Fourth, the results from experiment 5 seem to emphasise the independence of the effects of inversion and negation, a facial surround containing artificial internal features producing the effect of negation but not of inversion.

In the past the relative difficulty in perceiving inverted or negative faces has been mainly ascribed to factors based on memory or experience [see Valentine (1988) for review], since inverted and negative faces rarely occur in the natural visual world. Such interpretations are supported by the observations of Diamond and Carey (1986) who showed that individuals, such as dog breeders, with specific expertise for certain classes of complex visual stimuli, also show effects of inversion for those stimuli. Despite such evidence, it is still conceivable that there may also be specific perceptual mechanisms which are more sensitive to face-like structures in their normal orientation and contrast polarity.

Neurophysiological work has suggested that there may be specific cells in the cortex of several species (eg, Kendrick and Baldwin 1987; Baylis et al 1985) that are sensitive to faces of conspecifics, and at least one group (Perrett et al 1988) reported that the cells were less sensitive to inverted faces. Such results, taken together with the large literature on the syndrome of prosopagnosia (see, eg, Bruyer 1986), strongly support the suggestion that humans might also have specific cortical mechanisms for face perception. Thus, it might be the case that there are higher-level cells which act as 'face detectors'. Such cells might be less sensitive to inverted faces, to negative faces, or to faces without a surround, and hence detection would be less effective.

Of course, such faces could still be identified by using the normal, nonspecific mechanisms for form and shape perception, which are presumably in operation in experiment 3.

It seems that the results we report here could be interpreted as supporting the existence of a specific 'face detector'. However, an explanation of the results could also be couched in terms of subjects' differential expertise in perceiving very face-like and less face-like stimuli. These two explanations may not be as different as they at first seem, since to talk in terms of differential expertise implies an underlying mechanism which is itself modifiable by experience.

Although the procedure adopted in this series of experiments was quite adequate to demonstrate the phenomena reported, it would be advantageous to compare subjects' thresholds for the detection of 'feature' displacement in experiment 3 with, say, experiment 2, and hence ascertain whether subjects are more sensitive to feature displacement in normal faces than in the face-like arrangements of dots used in experiment 3. We have resisted the temptation to make any such comparisons as viewing conditions were not rigorously controlled either within or between experiments. Such control would be necessary before we could make a more detailed analysis of the thresholds produced by the different types of stimuli employed in this series of experiments. We are at present carrying out formal psychophysical studies of the thresholds.

Acknowledgment. We are grateful to Professor Michael Morgan for allowing us to distort his physiognomy in the interests of science.

References

Baylis G C, Rolls E T, Leonard C M, 1985 "Selectivity between faces in the responses of a population of neurons in the cortex in the superior temporal sulcus of the monkey" *Brain Research* **342** 91-102
Bradshaw J L, Wallace G, 1971 "Models for the processing and identification of faces" *Perception & Psychophysics* **9** 443-448
Bruce V, Young A W, 1986 "Understanding face recognition" *British Journal of Psychology* **77** 305-327
Bruyer R (Ed.), 1986 *The Neuropsychology of Face Perception and Facial Expression* (Hillsdale, NJ: Lawrence Erlbaum Associates)
Diamond R, Carey S, 1986 "Why faces are and are not special: An effect of expertise" *Journal of Experimental Psychology: General* **115** 107-117
Ellis H D, 1975 "Recognising faces" *British Journal of Psychology* **66** 409-426
Ellis H D, 1986 "Processes underlying face recognition" in Bruyer (1986) pp 1-27
Galper R E, 1970 "Recognition of faces in photographic negative" *Psychonomic Science* **19** 207-208
Galper R E, Hochberg J, 1971 "Recognition memory for photographs of faces" *American Journal of Psychology* **84** 351-354
Haig N D, 1984 "The effect of feature displacement on face recognition" *Perception* **13** 505-512
Haig N D, 1986 "Exploring recognition with interchanged facial features" *Perception* **15** 235-247
Hay D C, Young A W, 1982 "The human face" in *Normality and Pathology in Cognitive Functions* Ed. A W Ellis (London: Academic Press) pp 173-202
Hayes T, Morrone M C, Burr D C, 1986 "Recognition of positive and negative bandpass-filtered images" *Perception* **15** 595-602
Hosie J A, Ellis H D, Haig N, 1988 "The effect of feature displacement on the perception of well-known faces" *Perception* **17** 461-474
Kendrick K M, Baldwin B A, 1987 "Cells in the temporal cortex of conscious sheep can respond preferentially to the sight of faces" *Science* **236** 448-450
Luria S M, Strauss M S, 1978 "Comparison of eye-movements over faces in photographic positives and negatives" *Perception* **7** 349-358

Perrett D I, Mistlin A J, Chitty A J, Smith P A, Potter D D, Broennimann R, Harries M, 1988 "Specialised face processing and hemispheric asymmetry in man and monkey: evidence from single unit and reaction time studies" *Behaviour and Brain Research* **29** 245-258

Phillips R J, 1972 "Why are faces hard to recognise in photographic negative?" *Perception & Psychophysics* **12** 425-426

Rhodes G, 1985 "Lateralised processes in face recognition" *British Journal of Psychology* **76** 249-271

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

Yin R K, 1969 "Looking at upside-down faces" *Journal of Experimental Psychology* **81** 141-145