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Evidence for holistic processing of faces viewed as photographic negatives

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Abstract. Inversion and photographic negation both impair face recognition. Inversion seems to disrupt processing of the spatial relationship between facial features ('relational' processing) which normally occurs with upright faces and which facilitates their recognition. It remains unclear why negation affects recognition. To find out if negation impairs relational processing, we investigated whether negative faces are subject to the 'chimeric-face effect'. Recognition of the top half of a composite face (constructed from top and bottom halves of different faces) is difficult when the face is upright, but not when it is inverted. To perform this task successfully, the bottom half of the face has to be disregarded, but the relational processing which normally occurs with upright faces makes this difficult. Inversion reduces relational processing and thus facilitates performance on this particular task.

In our experiments, subjects saw pairs of chimeric faces and had to decide whether or not the top halves were identical. On half the trials the two chimeras had identical tops; on the remaining trials the top halves were different. (The bottom halves were always different.) All permutations of orientation (upright or inverted) and luminance (normal or negative) were used. In experiment 1, each pair of 'identical' top halves were the same in all respects. Experiment 2 used differently oriented views of the same person, to preclude matches being based on incidental features of the images rather than the faces displayed within them. In both experiments, similar chimeric-face effects were obtained with both positive and negative faces, implying that negative faces evoke some form of relational processing. It is argued that there may be more than one kind of relational processing involved in face recognition: the 'chimeric-face effect' may reflect an initial 'holistic' processing which binds facial features into a 'Gestalt', rather than being a demonstration of the configurational processing involved in individual recognition.

1 Introduction

Two stimulus manipulations have been popular with researchers investigating the processes underlying face recognition: inversion (presenting the face upside down with respect to the viewer) and negation (presenting the face in a version in which the normal grey-level values are reversed, so that blacks become whites and vice versa).

Faces are difficult to recognise when they are presented upside down (Yin 1969; review in Valentine 1988). While the disruption of normal shape-from-shading relations is a factor in this effect (eg Johnston et al 1992; Enns and Shore 1997), the main reason for difficulty seems to be that there is some kind of processing of the spatial relations of a face that is routinely used with upright faces, but which cannot be applied as easily to inverted faces. The precise characteristics of this form of 'relational' processing remain unclear (Searcy and Bartlett 1996)[(1)]: however, it appears likely that face

[(1)] We refer the reader to Searcy and Bartlett's (1996) excellent summary of the various theoretical interpretations of 'relational' processing, and the multitude of terms used to describe it. 'Relational' processing stands in contrast to 'piecemeal' processing, which would be based on details of the individual facial features rather than their spatial relationships. [See Rhodes et al (1993) and George and Hole (1998) for further discussion of the difficulties of distinguishing between 'features' and 'configurations' in the context of face processing.]

In essence, Searcy and Bartlett distinguish three different subtypes of 'relational' processing that could be used in face recognition: (i) 'configurational' or 'configural' processing, a form of

(*continued over*)

recognition normally depends heavily on being sensitive to subtle individual differences between faces in the spatial relationships of their component features—a process that we shall refer to as 'relational' processing. The impairment of face recognition by inversion seems to demonstrate the effectiveness of relational processing in normal circumstances as an aid to individual recognition: relational processing is thought to be evoked automatically by normally oriented (upright) faces, but to be difficult to use with inverted faces.

There are now numerous studies suggesting that sensitivity to the relational attributes of faces is reduced when they are inverted compared with when they are upright. For example, using very different methods, Bruce et al (1991) and Kemp et al (1990) have demonstrated that subjects are less sensitive to small displacements of the internal facial features when a face is upside down than when it is upright. In the Thatcher illusion (Thompson 1980), inverting the eyes and mouth in an otherwise upright face produces a grotesque impression which is not noticeable if the entire image is viewed upside down. In a variant of this illusion, Bartlett and Searcy (1993) showed subjects faces which had been made grotesque by applying comparatively gross distortions to the spatial relations between the features; again, these manipulations were obvious when the faces were shown upright, but much less noticeable in upside-down faces. One interpretation of the Thatcher illusion (Bartlett and Searcy 1993; Lewis and Johnston 1997) is that, when a face is upright, relational processing makes the incongruity between the orientation of the features and the rest of the face highly apparent; however, when the face is inverted, relational processing is disrupted, piecemeal feature-by-feature processing occurs, and it takes more time to detect the fact that the internal features and the rest of the face are in different orientations.

Perhaps the clearest demonstration of relational processing in upright faces is the 'chimeric-face effect' first reported by Young et al (1987). If the top and bottom halves of different faces are joined together, a 'chimeric' face is produced which gives a strong impression of being a 'new' face. When presented upright, it is very difficult to perceptually isolate either half for identification purposes. However, if the chimera is inverted, it becomes much easier to perceive either half of it in isolation. The chimeric-face effect is good evidence that upright faces are subjected to some kind of relational processing which is harder to use with inverted faces.

Faces are also hard to recognise when they are presented as negatives (Galper 1970). However, the reasons for this are less clear. One possibility is that negation and inversion affect different aspects of the processes underlying face recognition. For example, Bruce and Langton (1994) have suggested that negation disrupts recognition by affecting the pigmentation properties of a face (changing the colour of the eyes, hair, etc).

[1] (*continued*)
processing which uses information about the spatial relationships between the facial 'features' (eg eyes, nose, and mouth) as conventionally defined (eg Diamond and Carey 1986; Young et al 1987; Bartlett and Searcy 1993); (ii) 'template'-based processing, which conceives of faces as being encoded in terms of their deviations from a prototype or norm (eg Rhodes et al 1987; Valentine 1988); and (iii) 'holistic' processing, in which the internal representations of faces are considered to consist of 'Gestalt'-like representations which are inherently unparsable, in the sense that they cannot be meaningfully decomposed into their constituent parts or 'features' (Tanaka and Farah 1993).

At present, it is unclear to what extent these terminological differences reflect fundamental differences in the processes underlying face perception, but it seems worthwhile maintaining the distinctions between them. Therefore, throughout this paper, we shall use the terms 'configurational' and 'holistic' processing in the specific senses defined above. These terms thus carry with them certain theoretical assumptions about the processes they describe. In contrast, the term 'relational' will be used as a generic descriptive term, to refer to *some* kind of processing of the spatial relations of a face, making no strong claims about the nature of the processing involved. Our use of 'relational' thus potentially subsumes senses (i), (ii), and (iii) above, and corresponds to the use to which the term 'configurational' has sometimes been put previously.

In contrast, Johnston et al (1992) and Kemp et al (1996) have suggested that negation makes it difficult for shape-from-shading processes to arrive at a correct interpretation of the three-dimensional (3-D) properties of the face. As one of our reviewers pointed out, these are not mutually exclusive explanations: the effects of negation may arise from both of these factors, ie pigmentation changes *and* problems in the recovery of shape from shading. However, while these researchers disagree over the source of the negation effect, they all suggest that inversion and negation may exert their influences at different stages of the recognition process.

An alternative possibility is that negation might disrupt recognition for the *same* reasons as inversion: in other words, because negation makes it difficult to extract relational information from a face. There seems to be relatively little evidence on this point. Kemp et al (1990) have provided some data suggesting that one result of negation might indeed be to impair relational processing. They investigated the effects of inversion and negation, both separately and in combination, on subjects' sensitivity to the displacement of features within a face. Both inversion and negation reduced subjects' ability to detect small horizontal or vertical shifts of the eyes, a result which implies that relational processing is impaired with negative faces. However, inversion and negation appeared to have separate and additive effects on performance, results which Kemp et al interpreted as evidence that inversion and negation affect different underlying mechanisms in face processing.

More recently, Lewis and Johnston (1997) have attempted to use the Thatcher illusion as a tool to examine whether relational processing is disrupted with negated faces. Their argument is that any manipulation which makes 'thatcherising' a face less noticeable will have done so for the same reasons as inversion—because it has impaired relational processing. Lewis and Johnston presented subjects with pairs of faces and measured the time it took for them to decide that one of the faces had been 'thatcherised'. For normal-contrast (positive) faces, reaction times were faster when the faces were upright than when they were inverted—in line with the usual Thatcher illusion. A similar pattern of results was obtained when the faces were presented in photographic negative, but it was reduced in magnitude. Lewis and Johnston interpreted this to mean that relational processing was impaired by negation, but not to the same extent as it was affected by inversion.

The studies by Kemp et al and Lewis and Johnston suggest that inversion and negation might produce the same end result (an impairment of relational processing), perhaps by disrupting different mechanisms. We took a different approach in order to see if relational processing occurs with negative faces. We made use of a modified version of Young et al's (1987) chimeric-face effect. Young et al asked their subjects to identify the top halves of chimeras that were constructed from the faces of celebrities (ie faces that were highly familiar). We previously investigated (Hole 1994) whether the chimeric-face effect extended to faces that were unfamiliar to the viewer, by presenting subjects with a series of pairs of chimeras and asking them to decide whether the top halves of each pair were from the same individual or different individuals. (The bottom halves were always from different individuals.) When a brief exposure duration was used (to preclude feature-by-feature comparison strategies), subjects were faster to decide whether the chimeras' top halves were the same or different when the faces were inverted than when they were upright.

A modification of this pair-matching technique was used in the present experiments. There are a number of reasons why a matching technique was used to investigate face processing with faces presented as negatives, rather than asking subjects to perform a task which directly involved recognition of negative faces. First, it circumvents the problem that negative faces are very difficult to recognise; it seemed likely that a straightforward replication of Young et al's (1987) studies with negative faces would be prone to floor effects in performance. Second, Liu and Chaudhuri (1997) have pointed out that the negation effect may have at least two components. Apart from any disruptive effects on face perception per se, some of the previously reported effects of negation might be attributable to incongruity between the stimuli at presentation and test: in most studies, subjects attempt to recognise faces in their negative versions after having first encountered them as positives. This is true whether subjects are trying to recognise faces that are represented in long-term memory (such as celebrities or individuals personally familiar to them), or trying to identify faces encountered previously during the experiment in which they are participating.

Asking subjects to match two negative or two positive faces, as in the present experiment, avoids this problem of stimulus incongruity: if any effects of negation remain, they are likely to be perceptual in origin, rather than due to the effects of these manipulations on memories for specific faces (Kemp et al 1990; Hill and Bruce 1996). In Kemp et al's experiments, three faces were shown simultaneously, and the subjects had to decide which two were the same. Since the stimuli being matched were present throughout each trial, the burden on memory was kept to a minimum. The matching task used in the present experiment similarly avoided the need for subjects to compare the stimuli to any representations of faces in long-term memory.

The rationale for the following experiments is as follows. If negative faces are processed relationally, they should be subject to the chimeric-face effect: one should obtain similar results to those of Young et al (1987) and Hole (1994). Subjects should be slower to make decisions about upright negative chimeras than they are to make judgments about inverted negative chimeras. If, on the other hand, negation disrupts relational processing, then the chimeric-face effect should either be absent or greatly attenuated with negative chimeras. In these circumstances, one might expect subjects to fall back on a strategy of trying to match the faces by piecemeal comparisons of salient individual features; if so, there is no reason why this strategy should produce different results as a consequence of the orientation of the stimuli being matched.

2 Experiment 1

2.1 *Method*

2.1.1 *Design.* There were four conditions, each with twenty trials. Each subject did all four conditions. On each trial, a subject saw two chimeric faces and decided whether their top halves were the same or different, attempting to ignore the bottom halves (which were always different). (See figure 1 for an illustration of the stimuli used in this experiment.) On ten of the trials for each condition the top halves of the faces were different and on the other ten trials they were identical. The four conditions were as follows:

(a) 'upright positive': the faces were in their normal orientation and contrast relationships;

(b) 'upright negative': the faces were normally oriented, but with reversed contrast relationships, so that dark areas were light and vice versa (for details, see below);

(c) 'inverted positive': these were the same faces as in condition (a) above, but presented upside down;

(d) 'inverted negative': these were the same faces as in condition (b), but shown upside down.

2.1.2 *Subjects.* The subjects were twenty-two undergraduates from the University of Sussex, aged between 19 and 38 years. Fourteen were male. All were unpaid volunteers, naive about the purpose of the experiment.

2.1.3 *Stimuli.* Subjects saw two sets of twenty cards, each bearing two monochrome grey-scale images of adult male faces. The two sets were identical, except that the faces

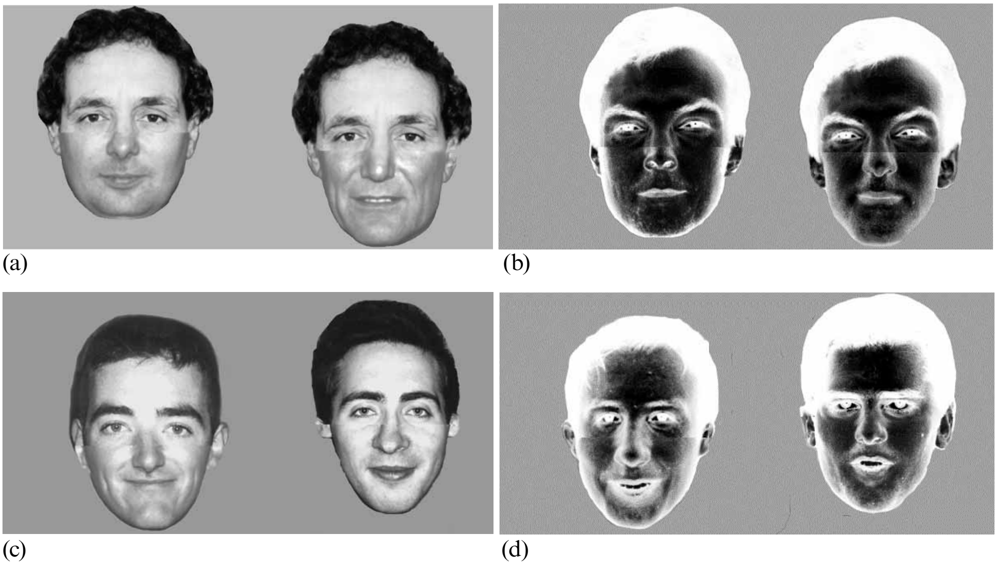


Figure 1. Examples of the chimeric faces used in experiment 1: (a) positive 'same' top halves; (b) negative 'same' top halves; (c) positive 'different' top halves; (d) negative 'different' top halves. (To see the inverted versions of these stimuli, turn the page upside down.)

in one set were reversed-luminance copies of the other set. Each set was seen once in an upright orientation and once upside down. Thus a subject saw the same twenty face pairs four times (once for each permutation of orientation and contrast).

Each face was a full-face view, produced by combining the top half of one face with the bottom half of a different face. Within each set, ten cards contained pairs of faces whose top halves were identical (ie taken from the same photograph of a single individual) and ten contained pairs of faces whose top halves were from different faces. No face appeared on more than one card within a set (although, of course, its top half might be used for both faces on a card or just one of them). The bottom halves on a card were always taken from different faces.

The two faces on each card were arranged diagonally: on half the cards in each set the face on the left was higher than the face on the right, while for the rest of the cards the face on the right was higher.

The chimeric faces were produced by using Adobe Photoshop software on an Apple Macintosh computer. Photographs of men (without facial hair or glasses) were scanned into the computer. Each face (including hair and ears, but excluding the neck and body) was 'cut and pasted' onto a white background, and then sectioned horizontally across the middle of the nose. One half of each face was randomly discarded; the remaining halves were then used to produce the chimeric faces. Where necessary, halves were altered slightly in size to produce a better join between the two halves; however, informal observation shows that the impression of a new face produced by joining halves together is quite powerful and easily withstands minor discontinuities and misalignments in contours between the two halves. Gross differences between the faces in contrast and overall luminance were reduced by using the brightness and contrast controls within Photoshop.

To produce the negative versions, the 256 grey-scale values of the images were reversed, so that level 256 became 1, 255 became 2, etc. Finally, each pair of faces was printed out on a BLP Eclipse laser printer, and laminated. Each face measured approximately 55 mm long by 40 mm wide (10.39 deg $\times$ 7.59 deg when viewed through the tachistoscope).

2.1.4 *Apparatus.* Stimuli were presented via a single-field tachistoscope (model CT IV Cambridge, manufactured by BRD Electronics Ltd). Stimulus presentations and reaction-time measurements were controlled by a BBC microcomputer connected to the tachistoscope. The computer measured the time in milliseconds between the onset of each stimulus presentation and the moment a subject depressed either of two buttons on a button box in front of them. (The interrupts of the BBC computer were disabled by means of software, in order to obtain a level of timing accuracy in the order of milliseconds.)

2.1.5 *Procedure.* Each card was presented for 600 ms. Each subject participated in all four conditions of the experiment (upright/positive, upright/negative, inverted/positive, and inverted/negative). A different random order of the four conditions was used for each subject. Stimuli were blocked by condition (ie a subject saw all twenty instances of a given condition before passing on to the next condition). Additionally, for each subject, stimuli were presented in a different random order within each condition.

Each subject was tested individually. On each trial, they had to press either of two response keys, according to whether the top halves of the faces on a card were identical or different. Subjects were asked to respond as quickly but as accurately as possible. Two stimulus cards, chosen at random, were shown to each subject in order to demonstrate 'same' and 'different' pairs, and these were then displayed via the tachistoscope to familiarise the subject with the tachistoscope and task requirements.

On each of the eighty trials the subject was warned of the impending stimulus by the experimenter saying "next"; a button was then depressed which caused the stimulus to be displayed and the timing routine of the computer to begin.

2.2 *Results*

For each stimulus (ie each pair of faces presented), a record was made of the subjects' reaction time to decide whether the top halves were the same or different from each other, and whether or not this was a correct decision.

Recall that the implications of the results of this experiment are as follows. First, for positive faces we would expect to obtain the normal chimeric-face effect: because inversion makes it easier to perceptually isolate the top half of each chimera, subjects should be faster to decide whether or not top halves of chimeric faces are identical when the faces are presented upside down than when they are shown upright. Second, in the case of upright chimeras, subjects should show a bias towards deciding that the top halves are different, even when they are identical. This is because the chimeras in this experiment always had different bottom halves; if they are processed as 'whole' faces, they should tend to appear different even when their top halves are in fact identical. We would therefore expect the number of 'different' decisions to be inflated in the case of the upright chimeric stimuli, compared with the inverted stimuli.

The effects of relational processing (or its absence, in the case of the negative faces) should thus be apparent both in latency and error scores. If negative faces are processed relationally, we should obtain a similar pattern of results as with the positive faces.

2.2.1 *Reaction times.* Eight mean reaction times were calculated for each subject, four for positive face stimuli and four for negative face stimuli: (a) the subject's mean reaction time for the ten trials with upright faces, where the top halves were from the same face; (b) the subject's mean reaction time for the ten trials with upright faces where the top halves came from different faces; (c) the mean reaction time for the ten trials with upside-down faces where the top halves came from the same face; and (d) the mean reaction time for the ten trials with upside-down faces where the top halves came from different faces. As in the experiments reported in Young et al (1987) and Hole (1994), only the data from correct decisions were used in calculating these values.

These means were then averaged across subjects to produce means for each of the eight experimental conditions. These are displayed in figures 2a and 2b. Two things are apparent. First, subjects were slower to decide whether the top halves of face pairs were the same or different when the faces were presented upright then when they were presented upside down. This replicates the chimeric-face effect shown by Young et al (1987) and us (Hole 1994). Second, although reaction times for negative faces were consistently faster than for positive faces, the pattern of effects for faces presented in negative versions is very similar to that for the same faces presented as positives: in other words, there is a strong chimeric-face effect for negative faces. For both positive-contrast and negative-contrast faces, inversion reduced reaction times by approximately 30%.

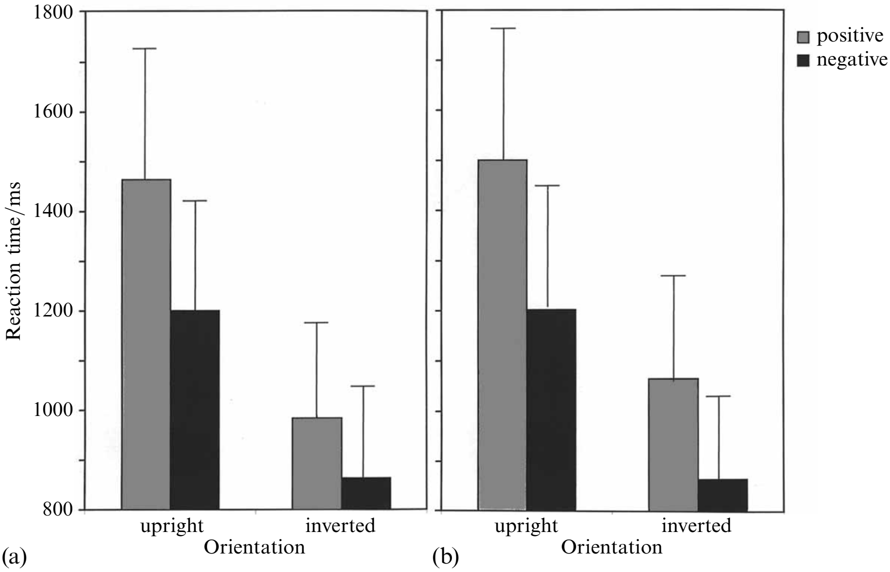


Figure 2. Experiment 1: mean latency, in ms, to make correct decisions that the top halves of chimeric face pairs were (a) identical or (b) different, as a function of the contrast and orientation of the face pairs presented. Error bars represent +1 SD.

A pair of two-way repeated-measures ANOVAs was performed on these data. One ANOVA compared subjects' reaction times for 'same' decisions; the other compared reaction times for 'different' decisions. In each ANOVA, one factor was orientation of the face (normal or inverted) and the other was face contrast (negative or positive). (Before the ANOVAs were calculated, we took the precaution of transforming the reaction times into their natural logarithms in order to ensure normality, since reaction-time data often display positive skew. However, figures 2a and 2b show the untransformed means, rather than the mean logarithm of reaction times, since the former are easier to understand intuitively, and the degree of skew in the untransformed data proved to be so small that the same pattern of results was obtained whichever measurement scale was used.)

For the 'same' judgments, there were highly significant main effects of orientation ($F_{1,21} = 281.40$, $p < 0.0001$) and contrast ($F_{1,21} = 20.22$, $p < 0.0001$). The interaction between orientation and contrast failed to reach statistical significance ($F_{1,21} = 3.22$, $p < 0.10$). The same pattern held for the 'different' judgments: again, there were significant effects of orientation ($F_{1,21} = 345.52$, $p < 0.0001$) and contrast ($F_{1,21} = 54.20$, $p < 0.0001$) and no significant interaction between orientation and contrast ($F_{1,21} = 0.56$, ns).

2.2.2 *Accuracy.* For each subject, a record was made of the number of correct 'same' responses in each condition, ie the number of times (out of ten trials for each condition) he or she decided correctly that two faces on a card shared the same top half. Each subject similarly provided data on the number of correct 'different' responses made in each experimental condition. Figures 3a and 3b express these data as mean percentages of the number of trials per condition, for same-top-half and different-top-half trials, respectively. Mean accuracy levels were high in all conditions, but there were clearly some effects on accuracy of the different permutations of orientation and contrast.

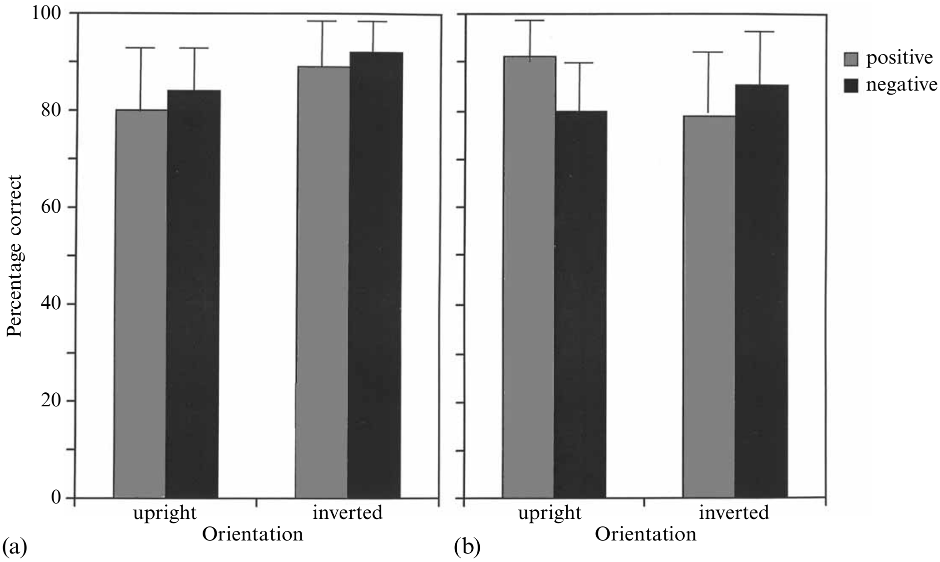


Figure 3. Experiment 1: mean percentage of correct decisions that the top halves of chimeric face pairs were (a) identical or (b) different, as a function of the contrast and orientation of the face-pairs presented. Error bars represent +1 SD.

A pair of two-way repeated-measures ANOVAs was performed on these data. One ANOVA compared subjects' accuracy scores for 'same' decisions; the other compared accuracy scores for 'different' decisions. In each ANOVA, one factor was orientation of face (normal or inverted) and the other was face contrast (negative or positive).

For the number of correct 'same' decisions, there was a highly significant main effect of orientation ($F_{1,21} = 31.66$, $p < 0.0001$). The main effect of contrast approached statistical significance ($F_{1,21} = 4.19$, $p < 0.06$). The interaction between orientation and contrast was not significant ($F_{1,21} = 0.17$, ns). The impression obtained from the accuracy scores complements that provided by the latency data: subjects were more accurate at deciding that face pairs had the same top halves when they were presented upside down than when they were presented upright. This effect of orientation was found for both positive and negative faces. However, there is some indication that subjects were generally more accurate with negative faces, irrespective of their orientation.

For the data on the number of correct 'different' judgments, the main effects of orientation and contrast were not significant ($F_{1,21} = 2.71$ and $F_{1,21} = 1.66$, respectively, both ns) but, as can be seen from figure 3b this was due to the presence of a significant interaction between orientation and contrast ($F_{1,21} = 16.18$, $p < 0.001$). Subjects were more accurate at deciding that positive faces had different top halves when the faces were upright than when they were inverted (dependent-means t-test, comparing upright and inverted positive conditions: $t_{21} = 3.81$, $p < 0.001$). For negative faces, there was little effect of orientation on the number of correct 'different' decisions (dependent-means t-test, comparing upright and inverted negative conditions: $t_{21} = -1.48$, ns).

2.3 *Discussion*

Both the reaction-time and (to a lesser extent) the accuracy data indicate that the chimeric-face effect occurs with negative faces in much the same way as it does with their positive counterparts. In both cases, subjects were faster to match the top halves of pairs of chimeric faces when they were presented upside down than when they were shown upright. However, an unexpected finding was that subjects were consistently faster to respond to the negative faces than to their positive counterparts (by 12% when the chimeras were upright with identical top halves and by 20% for all the other conditions).

It is clear that, for some reason, subjects found it easier overall to make decisions about the similarity or otherwise of negative chimeric faces than they did for positive chimeras. Examination of the stimuli suggests that the process of negation may have affected the relative saliency of parts of the face: for example, the shape of the hair mass and the general shape of the shaded region under the eyebrows seemed more noticeable in the negative stimuli than in their positive counterparts. However, it is unlikely that subjects were merely using these features in order to perform a 'piecemeal' feature-by-feature comparison between negative chimeras. If this were so, one would not expect to find an effect of inversion. In contrast, whatever it was about negative faces that made them easier to respond to quickly did not affect the operation of the chimeric-face effect, since the effects of inversion were as pronounced for the negative faces as they were for the positive faces.

The pattern of results obtained from the accuracy data is consistent with what one would expect from the operation of the chimeric-face effect in this particular experiment. The face pairs presented to subjects always had different lower halves; therefore, if upright chimeras are processed relationally, the effect of the different lower face halves should be to give subjects the impression that they are viewing two different faces, even when the top halves are in fact identical. The chimeric-face effect should consistently bias subjects towards responding that the top face halves are different when the faces are presented upright.

It seems likely that it is this bias which gives rise to our observed pattern of results, at least with the positive chimeras. A consistent bias towards seeing faces as different will mean that subjects produce most errors when the top face halves are in fact the same and are viewed upright (when the chimeric-face effect is at its strongest). Inverting the faces reduces the chimeric-face effect, and hence *increases* subjects' accuracy by removing the bias to respond "different". When the top face halves are actually different, an inherent bias to decide that they are different in any case gives rise to an apparent increase in accuracy.

This explanation accounts satisfactorily for the accuracy data obtained with positive faces. The pattern of results for the negative faces is somewhat different, but can be explained if one accepts that, for some reason, subjects have an initial tendency to see negative faces in a pair as similar even when they are not. This tendency reduces the effects of the bias produced by the chimeric-face effect. This would explain why, in the case of correct 'same' responses, mean accuracy scores are higher for negative faces than for positive faces, in both orientations. If subjects start off with an intrinsic bias towards perceiving negative chimeric faces as identical, they will by chance produce more correct 'same' responses and hence produce higher levels of apparent accuracy when the correct response actually *is* "same". The chimeric-face effect nevertheless operates on the negative chimeras in the same way as it does on the positive versions; as a consequence, upright negative faces appear less similar than their inverted counterparts, and accuracy suffers as a result. When the top face halves are in fact different, the bias towards perceiving negative faces as identical gives rise to apparently lower levels of accuracy—ie subjects are more likely to decide that the top face halves are the same, even when they are not.

3 Experiment 2

The results of experiment 1 show that subjects were slower to decide whether or not the top halves of two simultaneously presented chimeric faces were identical when the faces were presented upright than when they were presented upside down. This was the case regardless of whether the faces were presented as positives or negatives. This is good evidence that the chimeric-face effect occurs with negative faces, and implies that they are subjected to some form of relational processing. This in turn suggests that the difficulties in recognising chimeric faces do not arise principally because relational processing of some kind is impossible with negative faces.

However, a problem with experiment 1 is that, on each trial, subjects were presented with two top halves of faces which were either identical or not. In the context of face-recognition experiments in which subjects are asked to decide whether or not a face is one that has been seen before, Bruce (1988) has drawn attention to the difficulties of making inferences about face perception from studies in which identical pictures are used at presentation and test: such studies carry the risk that subjects might respond on the basis of accidental properties of the pictures used, rather than on the basis of properties intrinsic to the faces portrayed in the pictures.

In experiment 1 it is conceivable that subjects might have performed the task by some form of pattern matching of isolated elements between the two images, a strategy which was rather different from those used with 'real' faces. This explanation would account for the pronounced reaction-time advantage of negative chimeras over positive ones, although such an explanation would have difficulty in explaining why the chimeric-face effect was obtained in experiment 1, since one might expect a pattern-matching strategy to work equally well with upright and inverted faces.

To ensure that the 'negative-chimeric-face effect' was not merely an artifact of the particular procedure used in experiment 1, we performed experiment 2; this used a procedure which was designed to make it difficult for subjects to use any straightforward 'pattern-matching' strategies with the stimulus faces. Two chimeric faces were presented on each trial, as in experiment 1; however, this time the two chimeras differed in head orientation, one showing a full-face view and the other a three-quarters profile view. Subjects now had to compare the two heads, and decide as quickly as possible whether or not the top halves were views of the same individual or not. This required the subject to make a match on the basis of the *individuals* shown in the pictures, rather than on the basis of whether the *pictures* were the same.

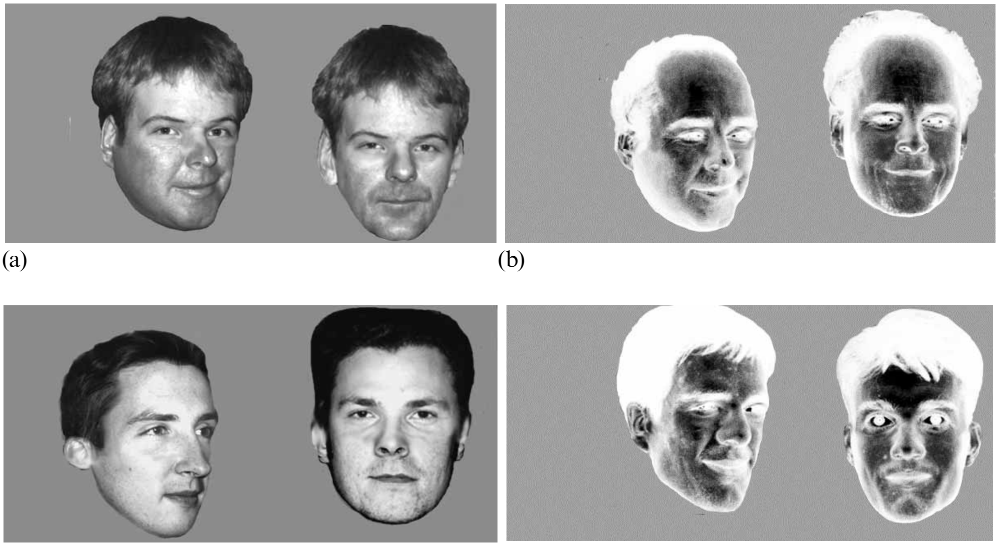
3.1 *Method*

This was similar to that of experiment 1, except for the differences noted below.

3.1.1 *Subjects.* There were forty-five subjects, aged between 18 and 46 years, mostly undergraduate students from the University of Sussex. Sixteen were male and twenty-nine were female. All were naive about the purpose of the experiment, and none had participated in experiment 1.

3.1.2 *Stimuli.* There were four conditions, representing all permutations of orientation (two levels, upright or inverted) and contrast (two levels, normal or negative). The stimuli were produced by methods similar to those previously described for experiment 1: chimeras were produced from scanned photographs of faces, by using Adobe Photoshop to perform the image manipulations. (See figure 4 for examples of the stimuli used in this experiment.)

For each of the four experimental conditions, fourteen pairs of chimeric faces were shown. In seven of these pairs, the two faces displayed were chimeras whose top halves were different views of the same person: one view was full face and the other was a three-quarters profile view. In the remaining seven pairs, the top halves were



(a) (b) (c) (d)

Figure 4. Examples of the chimeric faces used in experiment 2: (a) positive 'same person' top halves; (b) negative 'same person' top halves; (c) positive 'different person' top halves; (d) negative 'different person' top halves. (For inverted versions of these stimuli, turn the page upside down.)

different views of different people. In all cases, the bottom halves of the chimeras for each pair were from different individuals (matched, of course, to the top half as far as viewpoint of photograph was concerned).

The same fourteen pairs of chimeras were used in all four experimental conditions: each subject thus participated in fifty-six trials, seeing each face pair four times, in all four permutations of orientation and contrast. Trials were blocked by condition (ie upright/positive, upright/negative, inverted/positive, and inverted/negative), with the order of blocks (and order of stimuli within each block) determined randomly for each subject. Practice trials were given before the experiment proper, to familiarise subjects with the procedure and use of the button box. Subjects were informed before the start of a block which condition would follow, and shown an example of the kind of stimulus they would see in that condition.

3.2 *Results*

For each stimulus (ie each pair of faces presented), a record was made of the subjects' reaction times to decide whether the top halves were the same or different from each other, and whether or not this was a correct decision.

3.2.1 *Reaction times.* As with experiment 1, for each subject, mean reaction times were computed for each of the permutations of orientation and contrast. This was done separately for trials on which the top halves of the chimeras were views of the same individual and for trials on which they were views of different people. As in experiment 1, only the data from correct decisions were used in calculating these values. These eight means per subject (each based on a maximum of seven trials) were used as the raw data for subsequent analyses, and are displayed in figures 5a and 5b.

A pair of two-way repeated-measures ANOVAs was performed on these data. One ANOVA compared subjects' reaction times for 'same' decisions; the other compared reaction times for 'different' decisions. In each ANOVA, one factor was orientation of face (normal or inverted) and the other was face contrast (negative or positive).

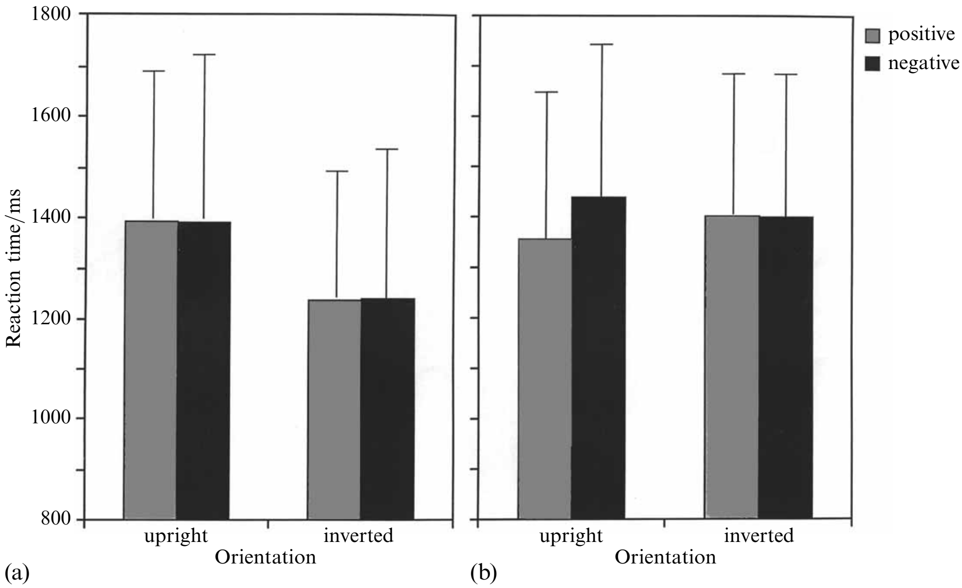


Figure 5. Experiment 2: mean latency, in ms, to make correct decisions that the top halves of chimeric face pairs were views of (a) the same person or (b) different people, as a function of the contrast and orientation of the face pairs presented. Error bars represent +1 SD.

(As in experiment 1, the ANOVAs were calculated on the logarithm-transformed data to compensate for skew, but figures 5a and 5b show the untransformed means. Again, essentially the same impression would be obtained whichever measurement scale was used.)

For the 'same' judgments there was a highly significant main effect of orientation ($F_{1,44} = 32.28$, $p < 0.0001$) but not contrast ($F_{1,44} = 0.11$, ns). The interaction between orientation and contrast failed to reach statistical significance ($F_{1,44} = 0.07$, ns). As can be seen from figure 5a precisely the same effects were obtained with both negative and positive faces: subjects were faster to decide that a face pair showed the same individual when the faces were presented upside down than when they were shown upright—results consistent with the operation of the chimeric-face effect. The difference between the upright and inverted conditions was, however, smaller than in experiment 1: reaction times to inverted faces were 11% faster than reaction times to upright faces in this experiment, compared with 30% in experiment 1.

For the 'different' judgments, there were no significant main effects of orientation ($F_{1,44} = 0.04$, ns) or contrast ($F_{1,44} = 1.54$, ns), and the interaction between orientation and contrast failed to reach significance ($F_{1,42} = 3.54$, $p < 0.07$). Dependent-means t-tests used to make specific comparisons between reaction times to upright and inverted positive stimuli, and negative upright and inverted stimuli, were nonsignificant ($t_{44} = 1.18$ and $t_{44} = 0.16$, respectively). All differences between conditions were fairly small. Inspection of figure 5b suggests that the marginally significant trend arose because subjects performed differently with positive and negative chimeric faces which displayed views of different individuals: when the faces were presented as positives, subjects were slightly quicker to respond when the faces were upright than when they were inverted (by 46 ms, or 3%). When the faces were presented as negatives, subjects showed the opposite pattern: they were faster to decide that the faces were different when the stimuli were inverted than when they were upright (by 39 ms, or 3%). Thus, for the 'different' reaction-time data in this experiment, only the *negative* chimeric stimuli produced a pattern of results consistent with the operation of the chimeric-face effect, albeit a nonsignificant one.

3.2.2 *Accuracy.* As in experiment 1, for each subject a record was made of the number of correct 'same' and 'different' responses in each condition. These data are displayed in figures 6a and 6b, expressed as percentages of the number of trials (seven per condition).

Compared with experiment 1, overall accuracy was clearly reduced, owing presumably to the additional demands of having to match different views of the same face; however, accuracy was clearly still well above chance levels with both the positive and the inverted faces. A pair of two-way repeated-measures ANOVAs was performed on these data. One ANOVA compared subjects' accuracy scores for 'same' decisions; the other compared accuracy scores for 'different' decisions. In each ANOVA, one factor was orientation of face (normal or inverted) and the other was face contrast (negative or positive).

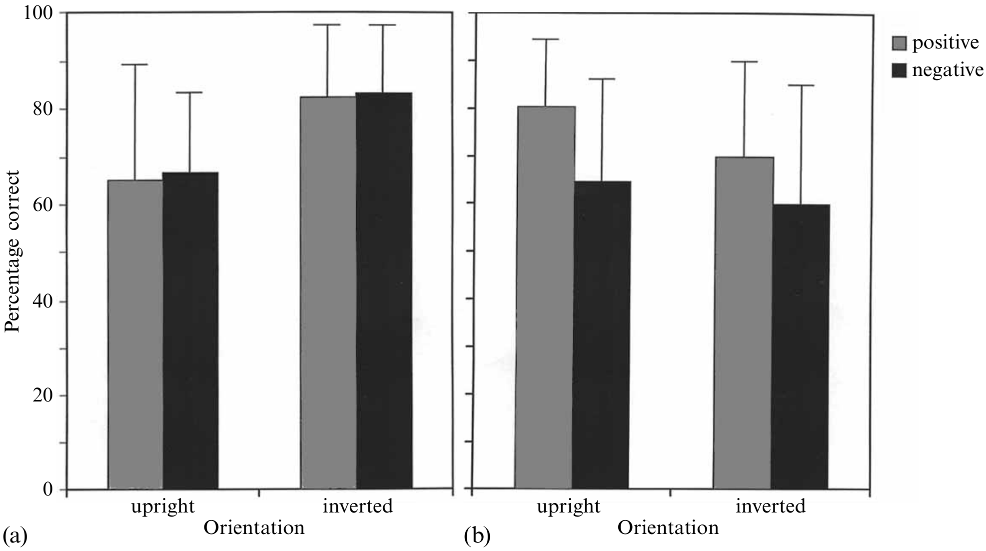


Figure 6. Experiment 2: mean percentage of correct decisions that the top halves of chimeric face pairs were views of (a) the same person or (b) different people, as a function of the contrast and orientation of the face pairs presented. Error bars represent +1 SD.

For the number of correct 'same' judgments, there was a significant main effect of orientation ($F_{1,44} = 43.89$, $p < 0.0001$). Contrast was not significant either in isolation ($F_{1,44} = 0.29$, ns) or in interaction with orientation ($F_{1,44} = 0.02$, ns). As can be seen from figure 6a, subjects were more accurate at deciding that different views were of the same face when the stimuli were presented inverted than when they were shown upright; and precisely the same pattern of results was obtained for negative faces as for positive faces. These results are what one would expect to be produced as a consequence of the chimeric-face effect.

For the number of correct 'different' decisions, there were significant main effects of orientation ($F_{1,44} = 7.30$, $p < 0.01$) and contrast ($F_{1,44} = 20.64$, $p < 0.001$). The interaction between orientation and contrast was not significant ($F_{1,44} = 1.36$, ns). Dependent-means t-tests were used to make specific comparisons between conditions. With positive chimeras, subjects were more accurate at deciding that face halves were from different people when the stimuli were presented upright than when they were inverted ($t_{44} = 2.61$, $p < 0.01$). With negative chimeras, there was no significant effect of orientation on accuracy ($t_{44} = 1.05$, ns).

3.3 *Discussion*

While there are a number of differences between the results of experiments 1 and 2, the second experiment does provide further evidence for the existence of a chimeric-face effect with negative faces, and hence evidence that negative faces are subject to some form of relational processing. The chimeric-face effect persists with negative faces, even when simple pattern matching is precluded by using two different views of the faces being matched.

A novel finding from experiment 2 is that subjects can match different views of the same face rapidly and accurately even when the faces are presented in negative: when the top halves of the chimeric faces were different views of the same person, performances with positive and negative chimeras were identical in terms of both speed and accuracy. A number of studies have investigated the effects on subjects' recognition performance of changes of pose between initial presentation and test, with positive (nonchimeric) faces as stimuli (see eg Bruce 1982; Troje and Bülthoff 1996); to our knowledge this is the first study to investigate performance with negative faces (albeit chimeric ones).

There are at least two ways in which one could compare two different views of the same face: one way would be to mentally rotate various features (probably serially) in one face to determine whether they map onto corresponding features in the second. Another way would be to encode the 3-D structure of the head, in order to cope with the many changes in grey levels, edges, and visible surfaces that are induced by alterations of viewpoint (Hill and Bruce 1996). The present study does not provide any direct evidence to choose between these alternatives. A feature-matching strategy is certainly a possibility, especially given the task demands of the chimera-matching task—the subject knows that the bottom halves of all faces seen are irrelevant to the task and that only the tops have to be compared, so there is in principle less to be compared (and hence mentally rotated). However, the use of some form of 3-D representation seems more likely. Although we cannot eliminate the possibility that some degree of pattern matching was occurring—as opposed to 'face recognition' per se—the same argument applies as with experiment 1: any explanation in terms of pattern matching has to explain why performance was affected by the orientation of the chimeric faces. One would not expect a serial feature-by-feature comparison strategy to be affected by inversion of the faces concerned.

Experiment 2 also shows that the chimeric-face effect is not restricted to the full-face views used in previous studies (eg Young et al 1987; Hole 1994, and experiment 1 of the present paper) but is also quite evident with three-quarters profile views. This was not necessarily to be expected: full-face views emphasise the two-dimensional characteristics of the face and reduce information about the 3-D shape of the face and head. For normal-contrast faces, Bruce et al (1987) found that three-quarter views were recognised best. Troje and Bülthoff (1996) suggest that the optimal orientation for recognition seems to be between 25° and 40° (where 0° is full face and 90° is full profile with respect to the viewer). Three-quarters views should therefore have been more likely to make any discrepancies between the donor halves more apparent than was the case in experiment 1: however, the chimeric-face effect persists despite this additional information.

The magnitude of the effect was, however, reduced in experiment 2 compared with experiment 1. For chimeras displaying top halves from different individuals there were no appreciable effects of inversion on reaction times for positive or negative stimuli, and no effects of inversion on accuracy in the case of negative stimuli. The biggest effects of inversion were found when the chimeric faces being compared showed top halves of the same person: for both positive and negative stimuli, inversion led to an 11% reduction in mean reaction time, much less than the 30% reduction obtained in experiment 1. Interestingly, using a rather different method (identification of top halves of full-face photographs of celebrities), Young et al (1987) found a reduction in mean reaction time of 11% for inverted chimeras compared with upright ones.

4 Overall discussion

This study provides a replication of the chimeric-face effect that was first reported by Young et al (1987) and demonstrates that it is also obtained with faces presented as photographic negatives. The results of experiments 1 and 2 differ in various respects, but are generally consistent with the conclusion that upright faces evoke some form of processing which does not occur with inverted faces, and that this is true for both positive and negative faces.

The clearest indications that a chimeric-face effect occurs with negative faces come from the data obtained in experiment 2 with pairs of chimeric faces that shared the same top half but had different bottom halves. Remarkably similar results were obtained with positive and negative faces. When these stimuli were displayed upright, subjects were slower to decide that the top halves were identical than when the faces were presented upside down. Subjects were also less accurate with upright faces, being more inclined to decide that the top halves were different when in fact they were the same. This pattern of results is what one would expect if the chimeras were being processed in such a way that their component halves were difficult to isolate perceptually.

As mentioned in section 1, Young et al's (1987) theoretical interpretation of the chimeric-face effect is that it occurs because obligatory relational processing ('configurational' processing, in their terminology) is evoked by upright, but not inverted, faces. Information concerning the individual identity of a face is normally provided not only by the facial features (eyes, nose, and mouth etc), but also by the relational properties of the face, ie the features' spatial interrelationship. Normally, relational processing aids recognition. However, in the case of upright (positive) chimeric faces, the relational processing which is evoked interferes with the subject's experimental task of attending only to the top parts of the faces. Inversion largely eliminates this interference, and hence facilitates performance on this particular task.

The fact that the effects of inversion with positive and negative chimeras are similar in many respects is strong evidence that some form of relational processing occurs with upright negative faces. It is tempting to infer from these results that negation and inversion must therefore exert their disruptive effects by affecting different aspects of the systems involved in face recognition; and that, consequently, whatever the reason for the difficulties in recognition normally experienced with upright negative faces, those difficulties do not arise because negation impedes the use of relational processing. However, there are some difficulties with this interpretation that need to be accounted for. First, as mentioned earlier, Kemp et al (1990) have demonstrated that sensitivity to feature location is reduced in negative faces, implying that *some* form of relational processing is impaired by the process of negation. Lewis and Johnston (1997) have also provided evidence that relational processing may be impaired with negative faces. They demonstrated that drastic disruptions to facial configurations induced by 'thatcherising' a face (inverting the eyes and mouth while leaving the rest of the face unchanged) are detected less readily in negative faces than in positive faces. Finally, Carey and Diamond (1994) found different developmental time courses for the chimeric-face effect and the inversion effect. The chimeric-face effect is observable in six-year-olds as well as in adults. In contrast, the inversion effect with normal faces becomes more pronounced with increasing age. This discrepancy is hard to explain if the chimeric-face effect simply reflects the operation of the same processes in face perception as those disrupted by inversion.

One explanation for these apparently conflicting results is that there might be more than one type of 'relational' processing performed with faces. The terminological differences in describing 'relational' processing described by Searcy and Bartlett (1996) and summarised in section 1 of this paper might reflect genuinely different types of processing. Carey and Diamond (1994) have suggested that the chimeric-face effect reflects a form of *holistic* encoding that serves merely to establish that it is a *face* which is being perceived, as opposed to some other kind of object. This type of encoding takes place at all ages. In contrast, the usual 'inversion effect' (ie problems with recognition of individual intact faces as opposed to parts of chimeric faces) reflects the development of more sophisticated *configurational* processing with increasing age (or, probably more importantly, with increasing experience of faces; see Diamond and Carey 1986). This latter form of relational processing might underlie the recognition of individual faces. Configurational processing may be more fine grained than holistic processing: whereas holistic processing is evoked by anything that roughly corresponds to the basic plan of a face, configurational processing deals with small differences between faces in terms of the precise relative locations of facial features, possibly allowing the comparison of seen faces with norms or prototypes stored in memory (eg Valentine 1991).

Our results are compatible with this notion that there may be at least two types of relational processing. Upright negative chimeric faces are sufficiently 'face-like' to evoke the holistic form of processing; inverted chimeras (and intact inverted faces) are not. Perhaps inversion disrupts both holistic and configurational processing, whereas negation disrupts configurational processing (as shown by Kemp et al's study) but leaves holistic processing intact. It is holistic processing that renders the viewer susceptible to the chimeric-face effect, by perceptually 'binding' the facial features into a single Gestalt. This explanation would account for why negative faces demonstrate the chimeric-face effect, but are nevertheless hard to recognise. It would also be compatible with demonstrations that faces are classified as faces faster when they are presented upright than when they are inverted (eg Purcell and Stewart 1988; Gorea and Julesz 1990).

Donnelly et al (1994), on the basis of experiments comparing subjects' responses to normal, moderately scrambled, and highly scrambled faces, have suggested that there may be "coarsely coded upright face template(s)" that aid in the rapid categorisation of a stimulus as a face or nonface (see also Davidoff 1986; Davidoff and Donnelly 1990). These templates seem to be relatively unselective in terms of what they will accept as a suitable input: in their experiments, subjects' responses were similar to normal faces and to faces in which the internal facial features had been replaced by nonface objects (cars, telephones, and flowers) as long as these were in the correct approximate locations within the face outline. By the present terminology, these experiments are demonstrations of holistic processing in operation.

The function of this initial holistic processing might be to engage systems which subsequently process the face as a face. An initial analysis which established that a face was being viewed might facilitate the subsequent use of more detailed analyses of individual features (for example, giving the viewer some idea of where to look for the eyes, nose, and mouth) and configurational processing of the spatial relations between them. [See Yuille (1991) for a discussion of related issues within the specific context of face recognition; Watt (1988) for a discussion of the advantages of coarse-to-fine processing strategies in visual processing generally; and Parker et al (1996) for a more recent and critical review of these ideas.] Paradoxically, however, a side effect of this initial processing might be to make it more difficult for the perceiver to consciously 'parse' the face into its constituent features. Aside from the chimeric-face effect, there is other evidence that individual features are difficult to isolate from their surroundings once they are perceived as being in a 'face', even when this face is highly schematic (eg Mermelstein et al 1979; Suzuki and Cavanagh 1995).

This account still leaves unanswered the obvious question: why are negative faces hard to recognise? Why do they give rise to difficulties in configurational processing? Liu and Chaudhuri (1997) have pointed out that some of the previously reported effects of negation might be attributable to incongruity between the stimuli at presentation and test. In most studies subjects attempt to recognise faces in their negative versions after having first encountered them as positives. Liu and Chaudhuri showed that subjects' recognition performance could be improved if faces were shown in the same format at presentation and test than if the format differed. In fact, subjects who were presented with negative faces initially and then subsequently tested with the same negative faces performed almost as well as subjects who had been exposed to positive faces at presentation and test.

Liu and Chaudhuri conclude from their results that at least part of the negation effect may arise from difficulty in matching 3-D representations derived from negative faces to stored 3-D representations that have been derived originally from positive-contrast stimuli. The results of experiment 2 of the present study show that subjects have little difficulty in matching different views of top halves of negative faces, implying that subjects are able to produce adequate 3-D descriptions of negative faces. However, these representations are inadequate for recognition purposes, possibly because their 3-D structure is so apparently different from that of the original (positive) faces to which they should be linked for recognition to occur. The visual system seems to operate on the 'assumption' that lighting comes from above (Ramachandran 1988) and clearly violation of this assumption plays a large role in the negation effect (Johnston et al 1992; Hill and Bruce 1996; Enns and Shore 1997). In short, negation may give rise to 3-D face representations which are so different from those produced by positive stimuli that it is difficult to establish a match between them.

Liu and Chaudhuri's explanation does not account for Kemp et al's (1990) data, which suggest that some of the effects of negation persist even when the experimental paradigm makes minimal demands on stored 3-D representations of the faces concerned. Kemp et al also found that subjects showed a reduced sensitivity to configurational information even when there was no mismatch in contrast between the faces being compared. However, Liu and Chaudhuri's results do draw attention to some important issues which need to be kept in mind when trying to understand face recognition by making use of stimulus manipulations such as inversion or negation. Stimulus manipulations which disrupt face recognition may be relatively simple in terms of their physical effects on the stimuli but complex in terms of their psychological effects. (In Fourier terms, negation and inversion merely affect the phase of the component spatial frequencies in the image, leaving their amplitudes unchanged.) As Liu and Chaudhuri point out, there are many psychological processes intervening between perception of a face and production of a behavioural response to it. In principle, negation might affect face recognition by disrupting the sensory processing involved (for example, negative faces may not constitute adequate input for face-processing neurons in the inferotemporal cortex) or by making it difficult to establish a match between the presented face and a stored representation of the person whose face it is. Liu and Chaudhuri opt for the latter possibility (a mismatch between stimulus and internal representation), but do not rule out the former.

On a more general note, manipulations such as negation or inversion may disrupt recognition by disrupting processes specifically concerned with processing faces or by disrupting object recognition generally (see Bruce and Humphreys 1994 for a detailed discussion of the relationship between face and object processing). At present, there is reasonably good evidence to suggest that inversion has fairly specific effects on face processing as opposed to generalised object recognition—or, at least, fairly specific effects on the process of making fine-grain discriminations between individual members of a perceptual category with which we have expertise (Diamond and Carey 1986; Bruce and Humphreys 1994). Indeed, the contrast between the disruptive effects of inversion on face recognition as opposed to other classes of objects is what brought inversion to the fore as a technique for investigating face perception in the first place (eg Yin 1969).

It remains to be determined whether the same is true of negation: in other words, whether negation impairs face recognition by virtue of its effects on face-specific processes or—as argued above—by affecting generalised object-recognition processes involved in deriving shape-from-shading information (so that the problems in recognising faces are secondary to this disruption rather than being problems with face recognition per se). These issues obviously require further research. However, the results from the present experiments do support the notion that, at least in some respects, faces presented as negatives and normal-contrast faces are subjected to similar kinds of perceptual processing.

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