Face Perception:
Sensitivity to Feature Displacement in Normal,
Negative and Inverted Images

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Abstract

Previous research on face recognition has focused mainly on the factors that affect our memory for faces. Two such factors are image inversion and negation which have been shown to affect our memory for faces more than for other objects. This has led to the suggestion that face recognition utilises special processes not involved in the recognition of other objects. This thesis investigates the perception of faces and seeks to establish whether face perception is also affected by these image manipulations and whether there is any evidence of face-specific perceptual processing.

A procedure is developed in which subjects are asked to identify which of two images has been modified through the introduction of a small displacement to the location of the features. It is demonstrated that subjects are more sensitive to feature displacement in normal than in either inverted or negated facial images, but that these transformations do not affect the perception of non-facial images. Further experiments seek to identify the causes of these effects by systematically replacing the facial features with geometric shapes and by developing novel colour transformations.

It is suggested that the inversion and negation effects could be considered as examples of the object-superiority effect whereby the presence of a coherent context allows for the more accurate perception of the components of an image. This suggestion is supported by the demonstration that subjects are more sensitive to feature displacement in face than non-face images, and that the effects of the negation and inversion transformations is to reduce the level of performance to that achieved with non-face images. These concepts are incorporated into a provisional model of face perception in which prior knowledge of the structure of the human face allows for a deeper, and hence more accurate processing of the image.
Dedication

To Joseph and Penelope. Now I can come out to play.
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Preface

The oldest work reported in this thesis was undertaken in 1988, and the first five studies were published in 1990 (Kemp, McManus & Pigott, 1990). This presents a problem. In the introductory chapters to this thesis I have attempted to provide a comprehensive account of background literature to the first studies reported. However, in doing so I have inevitably cited work undertaken since the publication of the very studies I am seeking to justify. Indeed, a few of the papers I cite, themselves cite the Kemp et al. (1990) paper.

It would have been possible to avoid this problem by writing this thesis as if it was submitted in 1990. I rejected this approach because it would have made the production of the thesis a rather futile exercise, and because I am not sure that I would be able to resist the opportunities for time-travel that this approach would have afforded. It would have been very easy to "steal" someone else's ideas before they had them!

The approach that I have adopted is to cite all relevant work except the Kemp et al. paper. Where it is necessary to discuss this paper, for example because it is cited in the publication under consideration, I have indicated this in footnotes to the main text. The problem with this approach is that it is possible to justify the design of experiments undertaken in 1988 by reference to papers published in the 1990's. I have tried to avoid this, but it is undoubtedly the case that at times my arguments have been influenced by work that was not published when the experiments were conducted.

I hope that the approach that I have adopted makes for a readable document that does not misrepresent historical trends in the literature.
The regulations of the University of London require me to make the following statement:

The first experiment reported in this thesis was designed by my supervisor, Dr I.C. McManus, using software that I had written and following discussions with me. The data for this experiment were collected by Tara Pigott, a medical student at University College London, under the supervision of Dr McManus.

All the other experiments presented in this thesis were designed by me. Experiments 12 and 13 were conducted with the assistance of Graham Pike, Peter White and Alexandra Musselman.

Signed........................................(candidate)

Signed........................................(supervisor)

Richard Kemp.

June 1995
Chapter 1

Are faces special?
Chapter 1

Are faces special?

"It is the common wonder of all men, how among so many millions of faces, there should be none alike."

Sir Thomas Browne (1643) Religio Medici pt. 1, sect. 2

"He approached these faces - even of those near and dear - as if they were abstract puzzles or tests. He did not relate to them, he did not behold. No face was familiar to him, seen as a 'thou', being just identified as a set of features, an 'it'. Thus there was formal, but no trace of personal, gnosis. And with this went his indifference, or blindness, to expression. A face, to us, is a person looking out - we see, as it were, the person through his persona, his face. But for Dr P. there was no persona in this sense - no outward persona, and no person within. (Sacks, 1985 page 12.)

1.1 Are faces special?

In many ways faces are very special visual stimuli. Homo sapiens is a social animal living in very close proximity to other members of the species and having complex social structures to regulate the behaviour of members of the social group. The face is used to signal motivation and emotion to other group members as well as to allow individuation between members of the group. For these reasons, the perception of the face is of very special importance to humans. This observation leads to the question of whether this function is performed by special processes not involved in the perception of other objects, and if so, what is the nature of these processes?
Chapter 1

Are faces special?

The question of whether the face is processed in a qualitatively different way from
other visual stimuli has become central to much of the psychological literature relating
to face recognition. Much of the research addressing this question has employed
techniques that examine our memory for faces. In this thesis I intend to focus more
directly on the perceptual processes that underlie that recognition, and to try to address
the question of whether there are special perceptual processes that facilitate the
accurate recognition of the human face.

Ellis (1975) suggested that there were three distinct lines of evidence that could be
used to support the notion of a special process; the ontogeny of facial recognition, the
existence of clinical conditions such as prosopagnosia that affect face recognition, and
the disproportionate effect of stimulus inversion on face recognition. In this chapter
I will briefly consider these three lines of evidence. In chapter 2 I will consider the
effect of stimulus inversion on face recognition in more detail.

1.2 The development of face processing skills

1.2.1 The perception of faces by neonates and infants

Most research undertaken with neonates and infants has focused on the question of
whether the newborn has an innate ability to recognise a face as a socially important
pattern and if so what the underlying mechanism behind this ability is. Relatively little
work has focused on the infant's ability to discriminate individual faces.

Goren, Sarty & Wu (1975) demonstrated that infants of less than one day old spent
more time looking at face-like patterns than either scrambled faces or blank head
patterns, (a finding replicated by Dziurawiec & Ellis, 1986), but Johnson, Dziurawiec, Ellis & Morton (1991) showed that this preference for face-like patterns declined during the second month of life. Morton & Johnson (1991) proposed a two process explanation for this result. They coined the terms conspec and conlern to describe the two separate processes involved, proposing that conspec is a hard-wired and innate sub-cortical process that provides information about the structure of faces, leading to the infant’s preferential tracking of the more face-like patterns. They argue that conlern is responsible for learning about the visual characteristics of conspecifics, hence allowing for the identification of individual members of the species. Conlern is presumed to be activated by cortical maturation during the second month of life and they suggest that this causes the decline in preferential tracking of faces at this stage in the infant’s development.

This model seems to provide some support for the concept of face-specific processors, but it is possible that the infants’ preference for looking at faces is determined not by the extent to which the pattern is face-like, but rather the sensory characteristics of a face-like pattern. Kleiner (1987) tested infants with a mean age of 1.7 days on a number of stimuli using a preferred-looking paradigm. She presented the infants with either schematic faces, lattice patterns (gratings) or combinations of the spatial frequency amplitude and phase components of these two stimuli. For an adult, a combination of the amplitude spectrum of one image and the phase spectrum of another image most closely resembles the image from which the phase spectrum was taken (see Piotrowski & Campbell, 1982). With this in mind we would predict that infants who are shown a combination of grating patterns and face schematics would prefer to look at the image containing the phase of the schematic face. Kleiner found the reverse, with infants’ preferences best being predicted by knowledge of the amplitude
Chapter 1  

Are faces special?

spectrum. Kleiner therefore argued that a "sensory hypothesis" provided a better explanation of the infant's behaviour than did a "social hypothesis". The babies may have been influenced by the large amplitude spectra that are not filtered out by the infant's contrast sensitivity function. Kleiner & Banks (1987) showed that after 2 months of age the infants started to demonstrate a preference for patterns that looked face-like to adults (i.e., the infants preferences were best predicted by knowledge of the phase spectrum of the image).

Thus, it is possible that very young infants are not influenced by the "faceness" of a stimulus, but the extent to which its amplitude characteristics penetrate the child's infantile visual system. It is only after two months that the behaviour of the child becomes more adult-like, and the infant shows preference for images that adults see as face-like. It is interesting to note that this 2 month time period coincides with the decline in the preferential-looking noted by Johnson, et al. (1991).

1.2.2 Identifying individual faces

For the neonate or the infant there is usually only one "famous face" - that of its mother. For this reason, the majority of studies investigating the infant's ability to recognise individual faces have assessed the child's ability to distinguish its mother's face from that of other women. Bushnell, Sai & Mullin (1989) demonstrated that neonates as young as 2 days old are capable of reliably discriminating their mother's face from that of stranger. As Ellis (1992) points out, this result seems to undermine Morton & Johnson's model, as it suggests the infants can recognise a face before the proposed emergence of concern.
Dirks & Gibson (1977) showed that at 5 months of age infants could match a face and a photograph; however, it appears that this matching was occurring mainly on the basis of rather gross cues such as hair colour. Other studies have shown that at about 6 months of age infants can make gross categorical discriminations concerning the sex or age of a face (e.g., Cornell, 1974; Fagan, 1972; Miranda & Fantz, 1974), and Fagan (1976) showed that by 7 months infants could discriminate between images of both similar and dissimilar faces and could recognise that two photographs taken from different angles were of the same face.

It therefore appears that true face recognition performance cannot be demonstrated before 7 months of age. After 7 months of life a baby will have spent many hours examining faces and will have come to appreciate the social importance of this image. The fact that such young children can recognise faces is in some ways remarkable, but cannot be seen as evidence for any special ontogeny in the processing skills involved.

There are two other areas of developmental face recognition research which give some credence to the idea that face recognition is mediated by special processes. These are the evidence of a "dip" in face recognition performance at around 12 years of age, and the notion that adults and children employ different face encoding strategies. I will briefly consider the first of these suggestions here. The question of the processing strategies employed by adults and children will be considered in the next chapter.
1.2.3 A developmental dip in face recognition?

Carey, Diamond & Woods (1980) reported a "dip" in the face recognition performance of children at about 12 years of age. Their evidence suggested that children's face recognition accuracy rose steadily until about 12 years of age, at which point it began to decline, only to improve once again a few years later. It is not clear what the explanation for this phenomenon might be, but there is some evidence that it may be linked to hormonal changes occurring at puberty (Diamond, Carey & Back, 1983). Flin (1983) demonstrated a similar developmental profile for the recognition of non-face objects, so it seems unlikely that this pattern of development demonstrates face-specific processing. It is rather more likely that this pattern of performance is the result of general cognitive maturational process that affects the visual memory for all objects.

More social explanations of this phenomenon are also possible. The age range in question coincides with several important changes in the life of young children which are only an indirect consequence of puberty. In the UK these changes include important transitions within the educational system. It is possible that, with so many other interesting things going on in their lives, 12 year old children simply may be less motivated by psychological experiments than the younger and older subjects.

1.3 Prosopagnosia

Prosopagnosia is a clinical condition caused by brain injury that results in an inability to recognise even familiar faces. A detailed consideration of this condition is outside the scope of this thesis (although I shall briefly return to this topic in chapter 19), but
it is important to note at this point that there is a great deal of debate as to whether this condition can lead to an inability to recognise faces without involving more general perceptual or memory deficits that affect the recognition of other objects. In 1975 Ellis concluded that it was not certain that a truly face-specific prosopagnosia could be demonstrated, and this question is still widely disputed today (for example see Bruce & Humphreys, 1994; Davidoff & Landis, 1990; McNeil & Warrington, 1993, for a range of views).

Hay & Young (1982) pointed out that the question of whether face recognition is a special process can be sub-divided. Firstly, we can ask, does face recognition rely on special processes not involved in the recognition of other objects? A second, and separate question is, are there specific areas of the brain devoted to face recognition? As Valentine (1988) observed, the existence of a condition such as prosopagnosia, only suggests that there are special areas of the brain involved. Even if it could be demonstrated that, in some instances, prosopagnosia exclusively disrupts face recognition and leaves all other processes intact, this would not provide an answer to the question of specialness.

For these reasons, although the study of prosopagnosia and related clinical conditions is highly informative about the process involved in face recognition, it does not directly address the question of whether this is a special process.

1.4 The inversion effect

It has been shown that faces, like most other stimuli, are more difficult to recognise when inverted than when upright (Goldstein, 1965; Hochberg & Galper, 1967).
However, Yin (1969) made a rather more specific claim, arguing that the ability to recognise a face is more disrupted by inversion than is the ability to recognise other complex visual stimuli. This particular difficulty in recognising inverted faces has come to be known as the inversion effect, and has taken on a considerable importance in the face recognition literature as it is seen as providing some of the strongest evidence that faces are processed by special mechanisms.

1.4.1 Yin (1969)

Yin reported three studies. In the first two of these, photographs of faces and three other types of "mono-oriented" objects (houses, silhouettes of aeroplanes and stick drawings of "men in motion") were presented to subjects. These images were presented in either an upright or inverted orientation, and the subjects were then asked to identify which of a pair of images they had previously seen.

In experiment 1 the orientation of the images in the test phase was the same as in the learning phase, so, for example, a face originally shown inverted would also appear inverted in the test phase. In experiment 2 the orientation of the images in the test phase differed from that in the learning phase, giving rise to what Yin referred to as Up-Down and Down-Up conditions. The data from experiments 1 and 2 are presented in table 1.1 below.
Table 1.1: Data from experiments 1 and 2 (Yin, 1969)

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Experiment 1</th>
<th>Experiment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UPRIGHT</td>
<td>INVERTED</td>
</tr>
<tr>
<td>Faces</td>
<td>95.55</td>
<td>78.25</td>
</tr>
<tr>
<td>Houses</td>
<td>88.85</td>
<td>82.9</td>
</tr>
<tr>
<td>Aeroplanes</td>
<td>81.75</td>
<td>80.75</td>
</tr>
<tr>
<td>Men</td>
<td>88.25</td>
<td>83.65</td>
</tr>
</tbody>
</table>

In experiment 1 Yin reported significant main effects of orientation (inverted images were more difficult to recognise), and image type (apparently due to the difficulty subjects had in recognising the aeroplane stimuli), and a significant interaction between these factors. Yin attributed this significant interaction to the fact that faces were significantly easier to recognise than the other stimuli types when upright, and significantly harder to recognise than the other stimuli types when inverted. It is this result that is critical to Yin's argument that faces are processed by some special mechanism.

Yin argued that there was further evidence that the processing of faces differed from that of other stimuli. He observed that those subjects who were amongst the most accurate group for the inverted non-face trials, were also the most accurate for the upright non-face trials. However, with the face trials the reverse pattern emerged, with the subjects who were most accurate in the inverted trials being among the least accurate in the upright trials, and vice versa. This analysis has sometimes been

1The data in table 1.1 are presented in the form of % correct decisions. Yin originally presented this data as % error rates.
somewhat inaccurately reported as indicating a significant positive correlation between the performance on the upright and inverted non-faces, but a negative correlation for faces (e.g., Phillips & Rawles, 1979; Valentine, 1988). The analysis carried out by Yin merely demonstrated that the high-scoring group performed better than the low-scoring group for both the upright and the inverted non-faces, but that the subjects scoring highest on the inverted face trials were significantly less accurate that the low-scoring subjects on the upright face trials.

The results from experiment 2 revealed significant main effects of material (houses easiest) and trial type (performance was worse for the down-up than for up-down trials), but the interaction was not significant. A t-test revealed that the difference in performance between up-down and down-up trials was significant for faces, but not for any of the other image types.

Considering the results from experiments 1 and 2, Yin argued that two conclusions could be drawn:

"First, although all the materials were more difficult when viewed upside-down, faces were especially difficult (experiment 1). Secondly, although all the materials were more difficult when a subject was required to make a mental inversion, the upright face was disproportionately affected (experiment 2)." Yin (1969), page 144.

On the basis of the data presented, these conclusions seem to be largely justified, but Yin recognised that this disproportionate effect of inversion on the recognition of faces could be attributed to the superior performance with the upright faces. As inspection
of table 1.1 reveals, the effect of inversion was largest for faces, next largest for houses, smaller for men and smallest for aeroplanes. This ranking exactly matches that for the performance on the upright presentations, and thus it is possible that the size of the inversion performance decrement is determined by the level of performance on the upright stimuli.

In an attempt to disentangle these two interpretations Yin conducted a third experiment in which he compared recognition of drawings of faces and costumed figures. The costumed figures were selected in the hope that they would be as well recognised when upright as the faces. The data from this experiment revealed that the effect of orientation was significant for faces, but marginally non-significant for costumes. Furthermore, subjects were more accurate with the costumes than with the faces for both upright and inverted trials. On the basis of these results Yin argued that, although the faces were not the easiest material to recognise upright, they showed the largest decrement in performance when inverted, and the inversion effect for faces was not limited to photographs as it could also be demonstrated for drawings.

Yin concluded that faces were difficult to remember because of the operation of two factors:

1. A general factor of familiarity with mono-oriented objects which affects all such objects making them more difficult to recognise when upside-down.

2. A special factor involving only the face that makes faces disproportionately difficult to recognise when presented upside-down.
Yin speculated that this special factor might be due to the inability to identify a "general impression" of the face when it is inverted and that this might be related to the extraction of facial expression.

1.4.2 Other demonstrations of the inversion effect

Valentine (1988) noted that the finding of a disproportionate effect of inversion had been replicated many times, and appeared to be robust to changes in the experimental procedure adopted (for example, Carey & Diamond, 1977; Diamond & Carey, 1986; Scapinello & Yarmey, 1970; Valentine & Bruce, 1986; Yarmey, 1971). However, Valentine (1988) noted that attempts to demonstrate the inversion effect using a face-matching paradigm had been unsuccessful (Bruyer & Velge, 1981; Valentine, 1986), and suggested that the disproportionate effect of inversion might only emerge when "the task involves recognizing a face as one stored in memory" (page 474), and that there was a memory component to the effect.

Despite these demonstrations that faces do seem to be more affected by stimulus inversion than other stimuli, both Ellis (1975), and Valentine (1988) argued that Yin (1969) was not justified in his conclusion that face recognition is a special process. Ellis argued that faces are naturally more complex stimuli than most other images, and that until the effect of inversion had also been investigated using images of a similar level of complexity to faces, it was inappropriate to conclude that faces were being recognised through the operation of special processes not involved in the recognition of any other objects.
Valentine (1988) was of a similar opinion, arguing that there was little support for the suggestion that the inversion effect was face-specific. In support of this position he cited evidence that the familiarity and homogeneity of the stimulus class were critical factors in the emergence of the effect (for example, Diamond & Carey, 1986).

1.5 In conclusion

It appears that there is no uncontested evidence that face recognition is a "special" process. However, the evidence of the inversion effect does seem to suggest that the processing of the facial image, if not unique, is at least different from the processing of many other images.

The studies undertaken by Yin (1969), and many of the subsequent investigations of the inversion effect relied on a procedure that assessed subjects' memory for photographs of faces. This leaves two possibilities open; stimulus inversion could be interfering with either the memorial or the perceptual processes normally involved in face recognition. In the following chapter I will review the evidence concerning the causes of the inversion effect with a view to separating these two explanations. It is not my intention to replicate the thorough review of the literature undertaken by Valentine (1988), and so I will concentrate on the more recent evidence offered in support of the explanations of the inversion effect.
Chapter 2

Explaining the inversion effect
2.1 Explaining the inversion effect

On the basis of the evidence considered in the previous chapter it seems that face recognition is disrupted more by stimulus inversion than is the recognition of other objects. However, it is not obvious why this is. Stimulus inversion could be interfering with either the processes involved in representing a face in memory, or with the ability to perceive a face. This chapter will describe some of the explanations offered for the inversion effect and evaluate the empirical evidence offered to support these explanations. A very comprehensive review of the literature pertaining to the inversion effect was published by Valentine (1988), and it is not my intention to replicate this. Rather, I will review some of the explanations offered and focus on the more recent work published since Valentine's review.

2.2 The expression explanation

Kohler (1940) noted that it was very difficult to interpret facial expression when a face was presented upside-down, and Yin (1970) argued that it was the inability to discern expression in the face that led to the difficulty in recognition. This suggestion was further developed by Galper (1970) and Galper & Hochberg (1971). Galper argued that it was the ability to code and store an expression that lent the face its "special" qualities. There can be little doubt that it is difficult to extract facial expression from an inverted face (e.g. Parks, Coss & Coss, 1985; Sorce & Campos, 1974; Thompson, 1980; Valentine & Bruce, 1985) or that a change in facial expression between learning and test affects the recognition of inverted faces more than upright faces (Galper & Hochberg, 1971). However, this does not prove that the
difficulty in processing the facial expression in an inverted face is the cause of, rather than an effect of, the associated difficulty in recognising an inverted face.

As Phillips (1972) pointed out, in order to be able to recognise a face despite changes in expression, we need to be able to develop a representation of the face that is independent of expression, and it therefore seems very unlikely that faces are encoded in terms of expression. There is now considerable evidence from the study of prosopagnosic patients that the recognition of expression and identification are separate processes (for example see Benton, 1990), and this position is incorporated into several recent models of face recognition (e.g., Bruce & Young, 1986; Rhodes, 1985). The fact that the face is used to convey emotion as well as identification is usually seen as presenting a problem for the face recognition system and most models assume that the face needs to be normalised to remove the effects of such variables as expression and angle of view in order to create an object-centred description of the face (cf. Marr, 1982) before recognition can occur.

Valentine (1988) points out that it is possible that the processing of expression and identity are indeed independent, yet share some common early processing stage and hence the effect of inversion on expression analysis might be giving us some clue to the processes involved in person recognition. However, the evidence of Valentine & Bruce (1988) that the time taken to decide whether or not a face was familiar increased with inversion more than did the time to decide whether a face was smiling, seems to reinforce the view that these two process are independent.
2.3 The face schema explanation

Goldstein & Chance (1980) argued that the disproportionate effect of inversion on face recognition was due to the development of a rigid face schema. Goldstein & Chance argued that with repeated exposure to faces an increasingly rigid schema developed which enhanced the processing of faces of the type most normally encountered but disadvantaged the processing of all faces falling outside the scope of the schema. Thus less frequently encountered faces, such as inverted faces or other-race faces (Goldstein & Chance offered a similar explanation for the race effect) were processed with decreasing accuracy while upright, own-race faces were recognised ever more quickly and accurately.

The main evidence offered in support of this model comes from investigations of children’s recognition of upright and inverted faces. As this evidence is so crucial to the Goldstein & Chance model it will now be considered in some detail.

2.3.1 Children’s recognition of upright and inverted faces

The Goldstein & Chance explanation would predict that both the accuracy with which upright faces are recognised and the size of the inversion effect would increase with age. There is some evidence for this position. Carey & Diamond (1977) and Carey, et al. (1980) suggested that children under 10 years of age did not demonstrate an inversion effect. The accuracy with which children could recognise upright faces was found to increase steadily between about 5 and 10 years of age. However, the accuracy with which inverted faces were recognised remained constant across all age
groups tested, and six year old subjects recognised inverted faces as accurately as adults did.

As Carey (1981) acknowledges, these results seem to be at odds with the evidence from studies of infant face processing which have shown a preference for upright over inverted faces by about 16 weeks of age (e.g., Fagan, 1972). The picture is further complicated by the fact that more recent work suggests that children are affected by face inversion much earlier than 10 years of age. Young & Bion (1980, 1981) and Flin (1985) have shown that children as young as 7 years of age show an inversion effect, and Flin (1985) demonstrated that the recognition accuracy for inverted faces does improve with age, but not as fast as for upright faces.

Carey (1981) reported two personal communications (one from Mehler and one from Bertelson) which suggested an inversion effect for six year old subjects. Carey suggested that the earlier studies (Carey & Diamond, 1977; Carey, et al., 1980) failed to observe an inversion effect with children under 10 years because of floor effects in the data. Carey demonstrated that if the same stimuli are used, but the size of the set of faces to be learned is reduced, then an inversion effect does become apparent for all subjects (2,3,4,5,6, and 10 years old).

The studies discussed so far have all tested children's recognition memory for unfamiliar faces, but there have been a few studies of children's recognition for upright and inverted familiar faces. Goldstein (1975) showed that the ability to recognise inverted photographs of classmates actually declined with age. However, this data appears to contradict that provided by Brooks & Goldstein (1963) who reported that children's ability to recognise inverted photographs of classmates rose between
3 and 10 years of age. Carey (1981) sought to explain this contradiction by pointing to some procedural differences between these two studies. In particular Carey notes that the children in the Brooks & Goldstein study saw the photographs in the upright orientation one week before being tested with them in the inverted orientation. The children in the 1975 study, by contrast, only ever saw the photograph in its inverted orientation at test (being photographs of classmates no prior exposure was required). It is very difficult to see why such a minor procedural modification could have such a dramatic effect on the results, but Carey suggested that the older children are making greater use of pictorial cues.

Ellis (1990) observed that few studies had attempted to use recognition latency as the major dependent variable in developmental studies. One such study was conducted by Hole, Towell, Kemp & Pike (1993) who argued that the use of decision latency rather than accuracy provided a means of avoiding floor and ceiling effects. Hole et al. measured the speed of recognition in upright and inverted presentations with adults and children in the range 2 to 12 years. The adults and the older children showed the predicted inversion effect (longer latencies with inverted faces), but the youngest children (2 to 5 years old) actually showed the reverse pattern, with quicker responses to inverted than to upright faces. Hole et al. pointed out that this was not the first observation of an "inverted-inversion effect". As discussed above, Goldstein (1975) found that children's ability to recognise inverted photographs of classmates declined with age, and Carey (1992) cited unpublished evidence that, in a study using the composite face technique developed by Young, Hellawell & Hay (1987), the youngest children performed better overall in the inverted orientation.
Chapter 2 Explaining the inversion effect

It is clear from the evidence reviewed above, that there is a great deal of uncertainty about the true nature of the developmental trends in the emergence of the inversion effect. All that we can be confident about is that the accuracy with which upright unfamiliar faces are recognised increases with age. It is not clear whether young children recognise inverted faces, as accurately, less accurately, or even more accurately than upright faces. Thus the development of the inversion effect seems to provide little support for the Goldstein & Chance model.

2.3.2 Other evidence for the Goldstein & Chance model

Goldstein & Chance's model has also been used to explain the own-race effect. The model predicts that, with increasing age, children should show an increasingly large bias in favour of the recognition of own- over other-race faces. Although this developmental change has been reported (e.g., Chance, Turner & Goldstein, 1982) other authors have failed to find such an effect (e.g., Feinman & Entwisle, 1976).

The Goldstein & Chance hypothesis would also predict a negative correlation between subjects' ability to recognise upright and inverted faces. Yin (1969) reported such a pattern (though he did not assess the correlation directly; see chapter 1), but several other studies have either found no correlation, or a small positive correlation (for example, Flin, 1985; Phillips & Rawles, 1979).

Valentine (1988) draws parallels between Goldstein & Chance's concept of a face schema and the notion of a facial prototype (see below) arguing that both represent the acquisition of knowledge about the way faces vary. This is an interesting comparison, but there does seem to be an important difference between these two
mechanisms. Goldstein & Chance’s description of the action of the schema suggests a mechanism that directs the perceptual processing of the stimuli, whereas a face prototype is normally seen as fulfilling a role only in the memorial encoding of the face.

Flin (1985) offered a very similar explanation for the inversion effect, suggesting that with increasing expertise and experience of the upright form, an inverted image of any mono-oriented object would look increasingly odd. It is not clear how this explanation could be differentiated from that offered by Goldstein, and Diamond & Carey (1986) combined the two models into what they called the Goldstein-Flin hypothesis.

Although it is not possible to dismiss the Goldstein & Chance model, the available evidence offers little direct empirical support for it, and in some cases undermines its foundations. Goldstein & Chance do not specify exactly how the development of the facial schema hinders the recognition of the less-often observed face type, rather they simply argue that increasing expertise with the majority type will result in both an increase in performance with this type, and a decrease in performance with the minority type. This rather general statement is not entirely incompatible with two alternative, rather more detailed accounts of the causes of the inversion effect put forward by Diamond & Carey (1986) and Valentine (1991). These explanations will be considered in more detail in later sections of this chapter.
2.4 The lighting direction and shape-from-shading explanations

The pattern of shadow and shading across an image is one of the sources of information used by the visual system to provide detail of the surface geometry of an object. Stimulus inversion might disrupt the extraction of this information as a result of an apparent change in the direction of the lighting. This loss of shape-from-shading information could be disruptive to any recognition processes that are dependent on a detailed description of the surface geometry of the face, but there is some debate whether face recognition is mediated by such information. The loss of shape-from-shading information is more often offered as an explanation of the negation than the inversion effect, and so this literature will be discussed in detail in chapter 3.

2.5 The Second-Order Relational Features Hypothesis

Diamond & Carey (1986) observed that Yin (1969)'s "specialness" argument could be interpreted either in terms of a special process that has evolved in humans allowing them to individuate human faces, or alternatively it could be the result of something unusual about the kind of features that distinguish human faces. Diamond & Carey favoured the later position, calling this a "special-kind-of-features" hypothesis, and argued that the apparent uniqueness of faces was a result of the nature of the stimulus. In particular, they argued that faces are "special" types of stimulus in that they are best discriminated in terms of "relational distinguishing features", and they offer data from a series of experiments to support this position.

In experiment 1 Diamond & Carey compared the recognition of upright and inverted faces and landscapes. Face recognition was shown to be more disrupted by inversion
than was landscape recognition, and Diamond & Carey argued that faces were more sensitive to inversion than landscapes because faces, unlike landscapes, all share the same basic configuration (2 eyes above nose, above mouth etc). They pointed out that as few as 200 points located on the human face could serve to describe that face recognisably (for example, see Brennan, 1985; Benson & Perrett, 1993), and that many faces can be combined to form another face image. This they describe as the "superimposition test"; a test that acts as a definition of what is meant by the phrase "sharing the same configuration". Faces pass this test but landscapes do not. The landscape scenes are, according to Diamond and Carey, capable of being differentiated in terms of "first order-relational properties" (i.e., the spatial relationship among similar parts). As faces all share the same configuration these first-order relational properties are highly constrained and do not allow individuation. Faces can only be individuated on the basis of second-order properties that describe the relationship between these first-order properties. Thus, according to Diamond & Carey, what makes faces rather special is that they are individuated on the basis of second-order relational properties. They went on to speculate that the encoding second-order relational features might be more disrupted by inversion than the encoding of first-order relational features. This, they argued, would explain why faces are more sensitive to changes in orientation than most other classes of objects.

A prediction of this hypothesis is that any class of stimuli whose members all share the same basic configuration would be prone to a large inversion effect. In experiment 2 Diamond & Carey set out to test this prediction by assessing the effect of stimulus inversion on the recognition of dogs and faces.
Scapinello & Yarmey (1970) had previously studied the effect of inversion on the recognition of dog faces and found no disproportionate inversion effect. Diamond and Carey reasoned that this might be because the undergraduate subjects used by Scapinello & Yarmey did not normally have to individuate dog faces, and therefore might not have developed the expertise to identify the second-order relation properties that allow such individuation. To test this hypothesis Diamond and Carey recruited a combination of dog breeders and dog-show judges to act as "expert" subjects and tested their recognition performance with upright and inverted images of dogs and (human) faces. Both groups were more accurate with upright than inverted images, and for both groups inversion was more disruptive to the recognition of faces than dogs. However, there was no evidence of the predicted three-way interaction, with both experts and novices showing the same effect of inversion for both dogs and faces. The two groups of participants were equally affected by stimulus inversion with the dog pictures, and the novices performed as well on the dog images as the experts, regardless of orientation. This suggests that the "experts" had no more expertise at the task than the novices. Diamond & Carey explained that although the experts were very experienced at individuating some dogs, they each claimed expertise in only one breed of dog. As the procedure used several different dog breeds the experts were, on average, no more advantaged than the novices.

This problem was addressed in the design of experiment 3 where the materials used were matched to the expertise of the subject. This experiment revealed a significant main effect of inversion, but not of material, with dogs and faces being equally well recognised. There was also a main effect of expertise, with the novices performing better than the experts. On this occasion the critical, orientation x material x expertise, three-way interaction was significant, with the novices showing an effect of inversion
only for the faces, while the experts' performance was worse in the inverted condition for both faces and dogs.

The results of this experiment seem to support Diamond and Carey's hypothesis; however there are some major problems with this data. Most significantly, it is of some concern that the experts performed no better than the novices in the upright dogs condition. This suggests that there is no evidence of expertise. Diamond and Carey state:

"We suggest that with expertise comes the ability to exploit the second-order relational properties that individuate members of classes such as human faces and cocker-spaniels. Further, we suggest that representation of an individual in terms of these features is particularly vulnerable to stimulus inversion." (page 114)

This is a rather inappropriate claim given that it is based on data from "experts" who show no evidence of expertise. Diamond & Carey suggested that Scapinello & Yarmey (1970) failed to find the inversion effect with dog faces because their subjects were not experts, but it seems that there is no evidence of expertise for Diamond & Carey's subjects either.

Diamond & Carey suggest that both this result and the very much poorer performance of the experts on upright faces, might be due to the very high mean age of the experts (64 years). They cite the evidence of Bartlett & Leslie (1986) to show that face recognition ability declines in elderly subjects under certain conditions (see also Maylor, 1990; Maylor & Valentine, 1992). This might be the case, but this lack of
expertise is worrying. Either way, the performance of Diamond & Carey's "experts" can be characterised as that of someone who identifies human faces only as well as everyone else recognises dogs, and is very confused by inversion of dog and face stimuli. This is hardly a traditional definition of expertise. It is perhaps also worth noting at this point just how well the novice subjects performed on the dog trials, correctly recognising approximately 80% of the inverted images. The experts by comparison recognised a similar number of upright dogs, but only around 60% of the inverted dogs. One wonders whether the truth is that the undergraduate "novices" were, in fact, the real experts - experts in performing in psychological experiments.

Diamond & Carey contrasted their explanation for the inversion effect with those offered by Goldstein (1975) and Flin (1985) (see above). Goldstein and Flin both speculated that with increasing expertise the encoding of the features of an upright pattern would be enhanced relative to the inverted pattern. The major difference is that Diamond & Carey suggest that experts and novices encode different types of feature. For Diamond & Carey sensitivity to inversion is seen as a consequence of the increasing reliance on the encoding of second-order features that comes with experience of the stimulus class.

Diamond & Carey conducted a fourth experiment designed to distinguish between these two explanations. Subjects were required to decide as quickly as possible whether or not an image contained a pre-probed feature. Faces and non-face stimuli were found to be equally affected by stimulus inversion in this task. Thus faces were not disproportionately affected by inversion when the same features were being identified in the upright and the inverted images. This, suggested Diamond & Carey, implies that the normal advantage for the recognition of the upright face must be
based on the accurate identification of some other type of feature. Diamond & Carey concluded that:

"although admittedly indirect, this result is consistent with our view that the inversion effect on faces (and on dogs for dog experts) is attributable to the expert perceiver's greater ability to represent the upright stimulus in terms of the distinguishing second-order relational features." (page 115).

In conclusion Diamond and Carey argue that faces are and are not special. If the need to differentiate them in terms of second-order relational characteristics is seen as making them special then they share this specialness with several other classes of visual object - including dogs. Observers who are experienced with such a class of objects and who need to differentiate them will have learned to do so on the basis of these higher-order characteristics, and because (they claim) the encoding of such characteristics is particularly disrupted by stimulus inversion we would expect all such classes of object to show a "special" sensitivity to orientation. Diamond & Carey summarise this position by stating three conditions, which if met, will give rise to a disproportionate effect of inversion:

1. Members of the class must share a configuration (i.e., must pass the superimposition test).
2. It must be possible to individuate members of the class on the basis of second-order relational features.
3. Subjects must have the expertise to exploit such features.
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A critical feature of this explanation of the inversion effect is that it emphasises the nature of the visual stimulus (the face), and of the perceptual processes involved in the encoding of the stimulus. Rhodes, Brake & Atkinson (1993) identified some indirect evidence for this explanation. That evidence will be reviewed below before some rather more direct tests of the theory are considered.

2.6 Indirect evidence for the Diamond & Carey model

There seem to be three aspects of the Diamond & Carey model that are open to empirical testing:

1. Is it more difficult to encode second-order relational features in inverted than upright faces?
2. Is the encoding of second-order-relational features more disrupted by stimulus inversion than the encoding of first-order features?
3. Does increased experience with a class of stimuli lead to increasing reliance on second-order features to individuate the patterns?

Rhodes, et al. (1993) commented that:

"The interpretation of a disproportionate inversion effect as evidence for reliance on second-order relational features, however, depends critically on the assumption that perception of second-order relational information is more impaired by inversion than is perception of isolated features or first-order relational features. Only then will a
disproportionate inversion effect be diagnostic of reliance on relational coding" (page 28).

and:

"it has never directly been shown that inversion disrupts the coding of relational features more than isolated features" (page 25).

It is true that there is no direct evidence to support Diamond & Carey’s model, but there is some indirect evidence that the degree of expertise the observer has with the stimuli class and the configural properties of the stimuli both influence the size of the inversion effect.

2.6.1 Inversion and the Race effect

A number of studies have demonstrated that subjects are better able to recognise members of their own racial group than members of other racial groups (the so-called race, or own-race effect; see Brigham & Barkowitz, 1978). Several mechanisms for this effect have been proposed, but the amount of contact with the other-race group seems to be an important factor, and several studies have shown that the race effect is reduced in populations with more experience of the other-race group (Carroo, 1986; Carroo, 1987; Chance, Goldstein & McBride, 1975; Chiroro & Valentine, 1993). This "contact hypothesis" is attractive, in-part, because it fits well with explanations of face perception which emphasise the role of expertise in the extraction of features useful for individuation, such as Diamond & Carey’s model. This would seem to lead to the prediction that inversion should be more disruptive to the recognition of own- than other-race faces, as an efficient encoding of the second-order relational features of other-race faces will not be possible due to the lack of experience with this class of stimuli. If inversion disrupts configural encoding then the effect will be more
noticeable for own-race faces which are being recognised on the basis of such features than for the other-race faces. This predicted interaction between race of subject, race of face and orientation, was observed by Rhodes, Tan, Brake & Taylor (1989). However Valentine & Bruce (1986), have reported exactly the opposite result; inversion was found to disrupt the recognition of other-race more than own-race faces. Rhodes, et al. (1993) sought to explain this discrepancy in terms of a failure to match the stimuli sets, and Valentines's failure to test both black and white subjects. This criticism is justified, but given that Valentine (1991) and Valentine & Endo (1992) have recently reported the same result (increased inversion effect for other-race faces) and in the case of Chiroro & Valentine (1993) a fully crossed design was employed (both racial groups saw own- and other-race faces) it seems unlikely that this is the full explanation.

Clearly a consideration of the race-effect is only useful to our analysis of the causes of the inversion effect if we can assume that expertise is a causal factor in the race effect, and that lack of experience results in less successful encoding of other-race faces. However, it is not certain that this is the case (see for example Brigham & Malpass, 1985) and so it would be unwise to place too much emphasis on this data.

2.6.2 The effect of practice

It is central to the Diamond & Carey (1986) model that familiarity with a stimulus class leads to a greater reliance on the extraction of second-order characteristics. We might therefore expect the strength of the inversion effect to decrease with an increased exposure to inverted faces. As an adult subject has been exposed to a massively unbalanced number of upright and inverted faces over several decades, it
would clearly be difficult to attempt to redress this imbalance during the course of a normal psychological investigation. Very few studies have therefore looked for a change in the processing of upright and inverted faces after training, but one such study is that of Takane & Sergent (1983) who showed that after over 500 trials subjects seemed to show evidence of an increased "interactive" processing of the components of inverted faces.

Bradshaw & Wallace (1971) employed a rather different paradigm, but found evidence that with practice, subjects could significantly improve their success when searching for a target among inverted faces.

2.6.3 The Thatcher Illusion

Diamond & Carey (1986) argued that the Thatcher Illusion first demonstrated by Thompson (1980) was:

"(a) striking demonstration that spatial relations among features crucial in the perception of upright faces are not apparent when faces are upside down" (page 107).

In the Thatcher Illusion, Thompson graphically demonstrated that the inversion of the eyes and mouth gave rise to a remarkably sinister appearance that was not apparent when the whole image was additionally inverted. However Thompson never claimed that this illusion demonstrated the reliance on the spatial relationships within the face. Rather, Thompson's motivation in preparing this stimuli seems to have been an attempt to test Kohler's (1940) explanation of the inversion effect in terms of the ability
to discern facial expression. This illusion has inspired several investigations, including that of Parks, et al. (1985) who demonstrated that an inverted mouth alone can look bizarre. Parks et al. argued that the uppermost part of the mouth is always interpreted as the upper lip, and so on inversion the smile becomes an expression of "biting-intention". However, Valentine & Bruce (1985) demonstrated that the sinister appearance of Thatcher's face would become apparent in an inverted face if the position of the eyes and the mouth were exchanged; thus we are only sensitive to the grotesque appearance when the features are in their normal spatial arrangement relative to one another. Davidoff & Donnelly (1990) suggested that this was because the normal spatial location of the features was necessary to activate "specific face routines" (page 241). These specific routines allow recognition (and thus presumably the interpretation of expression) via the formation of "higher order object features" (page 241) rather than relying on the recognition of individual parts.

So, although Diamond & Carey (1986) believed that the Thatcher Illusion lent weight to their hypothesis of superior configural coding in the upright image, there is some doubt about how this striking illusion should be interpreted.

2.6.4 Composite faces and the inversion effect

Young, et al. (1987) demonstrated what they termed "a new facial composites technique" (p.747), in which the top and bottom halves of two different, familiar faces were combined. The subjects were asked to name the top, or bottom (experiment 1 only) halves of the composites. Response times were significantly slower to name the constituent parts of the composite when the halves were in alignment with each other (composite condition) than when out of alignment (non-composite condition). In
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experiment 2 it was demonstrated that this difference between the composite and non-composite conditions disappeared when the faces were inverted. Experiment 3 revealed similar results for unfamiliar faces, and finally Experiment 4 demonstrated that the same result emerged when the internal and external features of two different faces were combined.

Young, et al. (1987) claimed that this was "the world's first inverted-face superiority" (p.757), and that this result demonstrated the use of configural information in face perception, and as such was evidence to support Carey & Diamond (1977) claim that configural information cannot be encoded when a face is inverted:

"Our findings, then, demonstrate directly the importance of configural information to face perception, and that this configural information is only readily derived from an upright face." (p.757)

Rhodes, et al. (1993) argued that this conclusion was not entirely justified. It is possible that the composite faces were more difficult to recognise because of the presence of two sets of incompatible (in terms of person identity) features. In other words the effect might be rather similar to the Stroop effect (Stroop, 1935) where two conflicting sources of information give rise to interference, causing errors and slowing the response. It is therefore unwise to claim that this rather striking phenomenon is evidence of the greater sensitivity to orientation of the configural than the first-order features of a face.

If, as Diamond & Carey claim, it is more difficult to encode the second-order characteristics of a face when inverted than upright, we should also be able to
demonstrate this effect using a purely perceptual task that does not require the participants to compare a face to one represented in memory. To this end, Hole (1994) attempted to demonstrate the effect in a matching task using unfamiliar faces, but the results of his first experiment were not in agreement with those reported by Young, et al. (1987), in that subjects were no quicker at making judgements about the composite faces when presented upside down than the right way up. Hole explained this by suggesting that the subjects had adopted a feature-matching strategy (Hole provided some additional support for this suggestion by pointing out that this would explain why subjects took longer to make a "same" judgement than a "different" judgement if we assume that they were engaging in a serial, feature-by-feature search for differences, that terminated once a difference was encountered). In experiment 2 Hole shortened the exposure duration in an attempt to force subjects to use a rather more natural strategy, and, in line with Young, et al. (1987) found that subjects were quicker at making the same/different judgement for inverted than for upright face composites.

Thus, Young, et al. (1987) seems to have demonstrated a powerful effect, and Hole (1994) has shown that this effect generalises to a matching as well as an identification task. However, there is no direct evidence that this effect is due to the formation of new second-order features in the composite images. Rhodes, et al. (1993) pointed out that this result can also be explained in terms of isolated feature detection, and thus these studies should not be seen as offering any support to Diamond & Carey's (1986) position.
2.6.5 The perception of isolated features

Diamond & Carey do not claim that the perception of isolated features is unaffected by inversion, but rather that the encoding of such features is less affected by inversion than second-order relational features. It is therefore reasonable to ask if there is any evidence that isolated features are comparatively easy to detect in inverted faces. It is possible to argue that Hole's (1994) experiment 1 provides such evidence. Participants in this experiment were thought to be undertaking the matching task through a feature by feature comparison, and in this experiment the effect of the composites was not reduced by inversion. However as we cannot be certain that participants were relying on the recognition of isolated features to complete this task, it is unsafe to place too much emphasis on this result.

Bruyer & Coget (1987) and Endo (1986) have both provided some evidence that the recognition of isolated features is unaffected by inversion, but as Rhodes, et al. (1993) point out, in both these studies the overall recognition rate in the isolated feature condition was much lower than in the whole face condition, and so it is possible that the recognition of the more easily discriminated isolated features would be more affected by inversion. A far more fundamental problem is that we cannot be sure that an isolated feature is recognised through first-order relational characteristics. Clearly, all noses are very similar and share many first-order characteristics, so why should we assume that nose recognition, unlike face recognition, can be achieved without the use of second-order features. This point emphasises the lack of clarity in the definition of the terms being employed in this debate. There is no reason to assume that isolated features will be (or can be) recognised on the basis of first-order relational features.
Tanaka & Farah (1993) also examined the effect of stimulus inversion on the recognition of isolated features and concluded that the upright face, unlike the inverted face, was processed "holistically" in that the description was not parsed into its constituent parts. This notion of holistic processing is clearly very similar to what Diamond & Carey (1986) call second-order relational encoding, and Tanaka & Farah seem happy to accept that these two concepts are probably indistinguishable. They found that participants were less able to recognise parts of faces (isolated features) than whole faces, even when the whole face differed by the same single feature; however, this evidence of holistic processing was not present with scrambled faces, inverted faces or houses, and thus they concluded that face recognition is relatively more dependent on holistic representations than the recognition of other types of stimuli. In summary then, isolated features were recognised equally accurately whether upright or inverted, and the recognition performance with the isolated features was similar to that achieved with the inverted whole face. Only with the upright whole face did performance significantly improve. This result suggests that some form of processing advantage is provided by the upright face, giving rise to better recognition compared to the inverted and the isolated feature condition. This interpretation is compatible with the notion of more accurate encoding of second-order relational characteristics for upright stimuli, so long as we accept that isolated features cannot be encoded in terms of such characteristics. There is however, an alternative explanation for this result that does not require such an assumption to be made. Tanaka & Farah compared their results to the previously reported phenomenon of the face-superiority effect. The face-superiority effect is normally seen as an instance of a class of perceptual effects called context-superiority effects whereby the presence of a coherent context (such as an upright face) results in the faster and more accurate perception of the component parts of the context than when the context is either non-
coherent or absent (see Homa, Haver & Schwartz, 1976; Mermelstein, Banks & Prinzmetal, 1979). This literature is clearly critical to any discussion of the inversion effect, and will be considered in more detail in chapter 4. For the moment I will merely note that Tanaka & Farah (1993) considered this literature and concluded that their effect was independent of the face-superiority effect as it seemed to reflect the action of the processes responsible for the accessing of stored memory representations rather than the visual encoding of facial features. This is a curious distinction to draw as according to the Diamond & Carey (1986) model of inversion it is precisely this visual encoding of the facial features that is disrupted by inversion.

2.6.6 Summarising the indirect evidence

So although there is some indirect evidence to support Diamond & Carey's explanation of the inversion effect, none of it is very convincing.

Rhodes et al. (1993) stated:

"If disproportionate inversion effects are to be interpreted as evidence for reliance on relational coding..., then inversion must be shown to produce a significantly larger decrement for coding relational than isolated features in a single experiment. Furthermore, Diamond & Carey's claim, that the absence of a disproportionate inversion effect for complex non-homogeneous stimuli such as landscapes occurs because they are coded using first-order relational features, also stands in need of validation." (p. 32)

Two attempts at a more direct test of the theory are considered in the next section.
2.7 Direct tests of the Diamond & Carey model

A more direct test of the predictions made by the Diamond & Carey model is required. Two recent papers have set out to provide such a test. The evidence of these papers is critical, so they will be considered in some detail.

2.7.1 Rhodes, et al. (1993)

Rhodes, et al. (1993) reported three experiments designed to test the notion that the encoding of second order relational features is disproportionately affected by inversion. In each of these studies participants were required to identify which of two test images had previously appeared in a learning set. For each trial one of the two test images had been altered through a modification to one of the features. The nature of the image modifications (transformations) is critical, so they will now be described in some detail. Six different transformations were used in experiment 1, and each was given a letter code:

- **F1** - the presence or absence of glasses or a moustache. This was assumed to be an example of an isolated feature change.

- **F2** - Swapping an internal feature (eyes or mouth) with that of another face. Rhodes et al. considered this to be a "relatively isolated feature change", but this is very similar to the manipulation employed by Young, et al. (1987) in their experiment 4. Given the explanation of the effect found by Young et al., it is clear that such a change can be described as either an isolated feature change or a configural change.
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G - Global change to the face shape. In experiment 1 this was brought about by applying a trapezoidal stretch to the face image. Rhodes, et al. (1993) acknowledged that this transformation changed both isolated and relational features and therefore made no strong prediction about the effect of inversion on the detection of this type of manipulation.

RI - First order relational change. Brought about by swapping the positions of the eyes and the mouth, or the nose and the mouth, within the normally oriented frame of the external features. Rhodes, et al. (1993) argued that according to Diamond & Carey (1986) this is a change to the first-order relational features of the face, and therefore detection of this change should be less affected by inversion than changes to second-order features.

RI.5 - "Thatcherized" faces. The face was changed by inverting both the eyes and the mouth whilst maintaining their normal spatial relationship to each other. This manipulation is labelled R1.5 as Rhodes et al. were not certain whether or not it should be described as a second-order relational change, even though its detection had previously been shown to be highly orientation-specific (Thompson, 1980).

R2 - Change to the relative position of the eyes (together/apart), or to the position of the mouth (up/down). This was classified as a second-order relational change and as such its detection should be highly orientation specific.

Rhodes, et al. (1993) made a series of predictions about the effect of orientation on the detection of these transformations. These predictions are summarised below in table 2.1.

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2This transformation is almost identical to that previously employed by Kemp et al. (1990) in the paper that describes the first five experiments reported in this thesis.
Table 2.1  The predictions made by Rhodes, et al. (1993) concerning the effect of inversion on the detection of the transformations employed

<table>
<thead>
<tr>
<th>Prediction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2 &gt; F1</td>
<td>Strong prediction - detection of the R2 changes will be more affected by inversion than will the F1 changes</td>
</tr>
<tr>
<td>R2 &gt; F2 &gt; F1</td>
<td>Weaker prediction - detection of the F2 changes will be affected by inversion less than the R2 changes, but more than the F1 changes</td>
</tr>
<tr>
<td>R2 &gt; R1</td>
<td>Weaker prediction - detection of the R2 changes will be more affected by inversion than will the R1 changes</td>
</tr>
<tr>
<td>R1.5 &lt;= R2</td>
<td>The detection of the R1.5 changes should be affected by as much as, or less than (but not more than), the R2 changes</td>
</tr>
<tr>
<td>G</td>
<td>No prediction is made about the effect of the G changes</td>
</tr>
</tbody>
</table>

The results of experiment 1 are illustrated in figure 2.1 below.

Figure 2.1  The effect of inversion on the detection of a series of image transformations. Redrawn from Rhodes, et al. (1993); experiment 1.

Footnote: Figure 2.1 has been redrawn from Rhodes et al.’s figure 3, but the data are presented here in terms of the percentage inversion decrement rather than the absolute inversion decrement.
The results of this study were, on the whole, not consistent with the predictions made. As can be seen from figure 2.1, the R2 (feature displacement) changes that should have been most sensitive to inversion were only marginally less well detected when inverted than when upright. The only changes shown to be highly sensitive to orientation were the R1.5 (thatcherized) changes, and the F2 (feature swap) changes. The Thatcherized images were already known to be orientation-sensitive, and as Rhodes et al. point out, it is not clear whether this change represents an isolated feature change or a configural change. The high degree of sensitivity of the F2 change is more puzzling. As mentioned earlier, this transformation was similar to that used by Young, et al. (1987), and so we might have expected performance to have improved with inversion. In fact performance was virtually at floor level for the inverted presentation.

Thus, I would argue that none of the predictions was confirmed. It is possible that one reason for this confusing pattern of results was that some of the transformations involved changes to both isolated and configural feature types. To complete the task the subjects were only required to detect that the changed image was different from the unchanged image; there is no way of knowing which aspect of the transformation the subjects were detecting. This may also be a partial explanation of the R1 (internal features swapped round) result; inversion restores the correct relative location of the features and could therefore make certain second-order relational information available. The problem is that Rhodes et al. have no way of knowing what change is being detected and whether it is a first- or second- order type. This problem is illustrated by Rhodes et al.'s attempts to explain the large inversion decrement for the F2 (swapped internal features) transformation:
"either the F2 changes were not processed as isolated feature changes
or our hypothesis that such features are relatively unaffected by
inversion is incorrect." (p. 39)

The only conclusion that we can draw with total certainty is that the F1 (paraphernalia) and R1 (position of features swapped) changes produce small inversion decrements compared to the R1.5 (thatcherized) changes. Rhodes, et al. (1993) also claim that there is evidence that the detection of these two manipulations (F1 and R1) are less affected by inversion than is the R2 manipulation, but there is no real evidence of this, as it was not possible to compare the effects of these manipulations statistically.

In light of these unexpected results Rhodes et al. undertook two further experiments. Experiment 2 was similar to experiment 1 except that orientation was included as a within-subjects factor, and the inversion decrement for the detection of the F2 changes was investigated by the inclusion of two features-in-isolation conditions (conditions F2a and F2b). An additional set of stimuli (G*) was also included. These stimuli were produced by either a vertical stretch (increase the height by 10.5%) or a horizontal stretch (increasing the width by 21%). These new G* stimuli were introduced in the hope that they might be more natural looking than the G transformations.

The results of this experiment are reproduced below in figure 2.2. The arrows marked on the figure indicate a significant difference in the size of the inversion decrement. The solid arrows indicate a difference for $p<.05$; however Rhodes et al. report two differences as being significant where $p<.1$, and in these cases the difference is marked with a dashed arrow.
Figure 2.2 The results of Rhodes et al.'s experiment 2.

It should be noted that although the F2a and the F2b (eyes and mouth in isolation) transformations produced large inversion effects, these were improvements rather than decrements of performance in the inverted orientation. In other words the detection of changes to isolated features was easier when inverted than upright. It had been predicted that the inversion decrement would be smaller for the isolated features than for the F2 changes, and Rhodes et al. argued that these results confirmed this prediction (on the basis that a large negative number is less than a small positive number), but it seems unreasonable to ignore this unexpected reversal of the sign of the inversion effect. Rhodes et al. argued:

"when those component features were presented out of the context of a face, inversion no longer impaired performance... The F2 changes should therefore be interpreted as relational changes." (p. 44).
Thus, the large effect of inversion on the detection of what was originally thought to be a "relatively isolated feature" (page 32) was explained by concluding that this was in fact a configural change after all.

Rhodes et al. argued that, as the inversion decrement did not significantly differ between the F2, R1.5 and R2 stimuli classes, this further suggests that these are all second-order changes. However, given that the difference between the F2 and the F1 changes was only significant at the \( p < 0.1 \) level, and that the F1 transformations are clearly isolated feature changes, this argument seems rather weak. It would be more appropriate to note that the F2, R1.5 and R2 changes all produce similar sized inversion decrements. This cannot be taken as proof that these changes result in an inversion decrement for similar reasons.

Experiment 3 employed only the F2 (exchanged internal features), F2a (features in isolation) and R2 (displaced features) changes, but the difficulty was manipulated making a total of 6 sets (F2-easy; F2-hard; F2a-easy; F2a-hard; R2-easy; R2-hard). The logic for this manipulation of task difficulty was that large R2 type changes might have created isolated feature changes (e.g., a wide gap between eyes) which could explain the small inversion decrement observed in experiments 1 & 2.

The results of experiment 3 have been re-plotted in figure 2.3. The F2 and R2 sets both show significant inversion decrements, whereas the F2a set produced a significant inversion increment. Inversion affected the detection of the hard and easy R2 changes to a similar extent, and thus the manipulation of task difficulty did not provide an explanation for the surprisingly small effect of inversion on the detection of these changes in experiments 1 and 2.
Figure 2.3 The results of Rhodes et al.'s experiment 3.

In their concluding remarks Rhodes et al. stated:

"The overall pattern of results in the three experiments supports the idea that coding of second-order relational features is more affected by inversion than is coding of isolated or first-order relational features. Therefore, the interpretation of disproportionate inversion effects as evidence for the reliance on second-order relationships .... is also supported." (page 50).

I would argue that this conclusion is not warranted. All that can be concluded is that the detection of the presence or absence of paraphernalia (F1 change), is not greatly affected by inversion, and that the detection of "Thatcherization" is greatly affected by inversion. The detection of feature swaps (F2 changes) is also affected by inversion but it is not clear how this result should be interpreted. It is entirely circular and
fruitless to argue that this large inversion decrement demonstrates that these changes were detected as changes to the relational properties of the image.

Rhodes et al. went on to say:

"However some clear warnings signs are also present. Our attempts to manipulate isolated and relational features independently in these experiments and to interpret the results highlight the inherent ambiguity of the isolated-relational distinction." (page 50).

This statement is clearly a valid one. Changing the distance between the eyes would seem to be an obvious example of a change to a second-order relational feature, yet as we have seen from the discussion presented above, it is possible to argue that this manipulation creates new isolated features (e.g., the gap between the eyes). In effect we are saying that the distance between the eyes is an example of a second-order relational feature, yet the gap between the eyes is an isolated feature. Similarly, changing a single feature, the nose for example, has major effects on many possible relational features such as lip to nose distance or nose width to length ratio. This is not a useful position, and it seems unlikely that this debate can be advanced until these terms are defined less ambiguously.

2.7.2 Tanaka & Farah (1991)

Tanaka & Farah (1991) also attempted a direct test of Diamond & Carey’s attribution of the inversion effect to the affect of inversion on the encoding of second-order relational features. They argued that:
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"There is no \textit{a priori} reason to expect that second-order relational properties are more sensitive to inversion than are first-order relational properties... In addition, there is no direct empirical support for this conjecture, in the sense of a controlled experiment in which first-order versus second order relational properties were directly manipulated and the effect of this manipulation on recognition of misoriented stimuli measured." (P. 368).

Tanaka & Farah chose to study the effect of inversion on the detection of first- and second-order changes in dot patterns, arguing that studies using real faces were likely to be problematic until it was possible to clearly define these terms in the context of the human face.

In experiment 1, seven first order dot patterns were produced by randomly positioning nine dots into a 40x30 array of possible locations. The resulting patterns looked quite distinct as they did not share the same first-order characteristics. Each of these seven patterns then served as the "parent" for six second-order patterns which were produced by randomly displacing each of the dots within a 5x5 matrix of locations surrounding its original position. In this way 42 patterns were generated, consisting of seven families (that differed from each other in terms of first-order relational properties) of six patterns each (that differed from each other in their second order-relational properties).

In the second-order pattern condition, subjects were presented with the six members of one "family group" derived from (for example) pattern A. In the first-order condition, subjects were shown the "parents" of the six other families. Thus subjects
were never exposed to the template (parent) pattern for the second-order set that they learned. The subjects were presented with the patterns one at a time and learned either a male or female name to be associated with that pattern. This procedure was repeated until the subjects could correctly name the six patterns twice without error. In the second phase subjects were asked to name the patterns when presented either upright or inverted.

Predictably, subjects took significantly longer to reach criteria on the second-order than the first-order patterns. Tanaka & Farah argued that this difference in difficulty was not a problem for the design, but rather it is a necessary feature of it, as the second-order patterns are bound to be more difficult to discriminate - indeed if this was not the case one could conclude that first order differences alone could discriminate these patterns. For both the first- and the second-order patterns, inversion resulted in a performance decrement of 6%. There was no main effect of pattern type at test, but there was a main effect of orientation.

Thus, discrimination of second-order patterns was affected by inversion to the same extent as the first-order patterns. This appears to be a crucial refutation of the Diamond & Carey hypothesis, but to ensure that the subjects were encoding the second-order characteristics of the patterns, a second experiment was undertaken in which the second-order patterns were made more similar to each other by reducing the extent of the random displacement of the dots (to within a 3x3 element array around the original location). As in experiment 1, significantly more learning trials were required for the second-order than first-order patterns. The results from the test trials were also similar to experiment 1, with inversion decrements of 7% and 8% being
recorded for the first- and second-order patterns respectively. Again there was a main
effect of orientation, but not of pattern type.

Both of these experiments demonstrated that, although inversion made the patterns
more difficult to recognise, the effect was equally great for the first- and second-order
pattern sets. This must be seen as a very damaging result for Diamond & Carey’s
explanation of the inversion effect, but a few points should be borne in mind. Firstly
it is interesting to note that the size of the inversion effect (about 6%) was relatively
small compared to the typical performance decrement reported in face recognition
studies and is rather more in line with the effect of inversion observed for non-face
stimuli (see for example Yin, 1970). This suggests that the encoding being employed
by the subjects in these studies might be different from that employed with face
patterns. It is also worth noting that the paradigm employed, with the subjects being
trained up to criteria, is rather different from that usually employed in face recognition
studies. It may be that the subjects were not learning the second-order features of
these patterns. It is possible that the second order patterns were being recognised on
the basis of a single "feature". For example, member 2 of pattern family C might be
recognised on the basis of a particularly elongated triangle being formed by three of
the dots in the pattern. This is the argument that was raised earlier; are wide-set eyes
a first- or second-order feature? This argument is slightly weakened by the fact that
the more similar patterns used in experiment 2 produced much the same result. Tanaka
& Farah argued that the second-order patterns were "most easily discriminable on the
basis of second order relational properties" (p.372). This may be so, but this does not
prove that this is the basis on which they were discriminated.
An additional limitation of this study is that we don't know whether the participants formed a representation of the "parent" (prototype) pattern. Posner & Keele (1968) have shown that such shared configurations are spontaneously abstracted, but there is no way of knowing whether this was happening in this study. If Tanaka & Farah had demonstrated that the prototype of the second-order patterns was abstracted by the participants, then this would have been powerful evidence that they were utilising the configural features to individuate the patterns. Without this evidence the possibility that they were using first-order features cannot be discounted.

Finally, even if we accept that Tanaka & Farah's subjects were encoding the second-order relational properties of the second-order patterns, this does not offer a fatal blow to Diamond & Carey's theory. As Tanaka & Farah point out, there are two parts to this hypothesis. Part 1 states that because faces share the same basic configuration they must be differentiated on the basis of second-order relational features. It is the second part of this hypothesis which states that the encoding of second-order properties will be particularly affected by inversion. It could be claimed that before second-order relational encoding is employed a pattern must first be recognised as a member of a group of patterns that can only be differentiated on the basis of such features. It may be that we have to recognise that we are looking at a face (or a dog) in order to invoke the encoding of second-order relational properties. This kind of preprocessor is not necessarily a requirement for the system to work, as the second-order relational features would presumably emerge from a network trained to recognise such patterns, but it could still serve a useful purpose (see Bruce & Young, 1986).

Tanaka & Farah comment that testing the claims of Diamond & Carey's hypothesis with non-face stimuli is "not only permissable, but desirable" (p. 372). This may be
so, but in the end the use of such stimuli can only test the strongest form of the hypothesis - and refutation can easily be resisted by minor modifications of the sort described above.

Tanaka & Farah conclude:

"There is indeed a "special" orientation-sensitive process used in face perception, as well as in the perception of certain other highly similar stimuli when expertise is sufficiently high. However, the nature of that process is currently unknown." (p. 372).

2.8 The Diamond & Carey model: Some conclusions

Diamond & Carey (1986) offered an explanation of the inversion effect that was more precise than those previously offered and which emphasised the nature of the perceptual encoding of the facial stimulus. However, two factors have emerged from the attempts to test this hypothesis. Firstly, it rapidly becomes apparent that it is very difficult to classify features as being either first- or second-order, or to place any feature along a continuum between these two extremes. Secondly, when such a classification is attempted the empirical evidence seems to suggest that an explanation of the inversion effect based on this classification is flawed.

This is best demonstrated by Rhodes, et al. (1993). We might want to debate about where some of the transformations that Rhodes et al. employed might lie on this continuum, but there can be little doubt that an R2 change (moving the position of the eyes and/or mouth) is more likely to affect what Diamond & Carey would classify as second-order relational features than would an F2 change (swapping a feature), and
hence the detection of the R2 changes should be more affected by inversion than F2 changes. In fact one of the most reliable results from the three studies undertaken by Rhodes, et al. (1993) was that the reverse was true. Rhodes et al. make some attempt to argue that this means that the F2 change must be seen as a relational change also. This becomes a circular and fruitless argument, and still fails to explain why the F2 change should be affected by inversion more than R2 changes.

The study undertaken by Tanaka & Farah (1991) seems to be even more damaging to Diamond & Carey's explanation as they found no evidence that the detection of second-order features was more affected by inversion than first-order features.

In conclusion, the only direct tests of Diamond & Carey's explanation of the inversion effect have found no support for it; rather they have tended to highlight the limitations of the theory. It therefore seems appropriate to look for alternative explanations.

2.9 Valentine's face space explanation

Valentine (1991) sought to explain the inversion effect in terms of the representational processes involved in the memory of faces. His "framework" was designed as a unified explanation of the effects of inversion, distinctiveness and race. Valentine saw transformations such as inversion as increasing the error inherent in the process of encoding faces, and it is implicit in the framework that other transformations, such as negation, masking, adding visual noise and blurring, will all act in a similar way. Previous attempts to explain the inversion effect, such as that of Diamond & Carey (1986), had offered accounts that were specific to this transformation and therefore made only indirect predictions about the effect of other transformations, the effect of
combining transformations (such as performance on inverted negative faces) or the interaction between such factors as race or expertise and these transformations.

Valentine describes a representational system, in which a face is encoded as a point within a multidimensional space. The dimensions of the space represent the encoded features of a face, but no attempt is made to define what these features might be. These dimensions have their origin at the point of central tendency, so typical faces will be located within the space at some point relatively close to the origin, whereas less typical faces will be represented by a point further from the origin of the space.

Valentine distinguishes between two different forms of framework. In the first of these, which he terms the norm-based coding model, he describes a system whereby faces are encoded in terms of their deviation from a single norm that has been developed through a lifetime of experience with faces. In this form of the model, a single \( N \) dimensional vector (where \( N \) represents the number of features encoded) uniquely describes each encoded face.

Valentine describes the processes that are invoked by the perception of a face. Firstly, the \( N \) dimensional vector is encoded, and then this vector is compared to other faces represented in the face space. In this way a decision can be reached as to whether this face has been seen before. Importantly there is an explicit assumption that the encoding process is noisy and error prone. This means that under non-ideal viewing conditions there will be an area of uncertainty surrounding the coordinates of the perceived face. The confidence associated with the decision about the familiarity of the face will be affected by three factors:
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1. The error associated with the vector derived from the perceived face (i.e. the degree to which noise has crept into the calculation of this vector).

2. A measure of similarity between the vector for the perceived face and that of its nearest known-face neighbour in the face space.

3. The similarity between the vector of the perceived face and that of the next nearest neighbour (possibly an unfamiliar face).

The second form of this model is what Valentine calls the exemplar-based model. In this version it is assumed that encoding is veridical and the norm or prototype is not extracted. The faces are thus represented as points within the face-space rather than vectors, and the origin of the space is simply the point of maximum exemplar density. The similarity of two faces is a function of the distance between the two points in the face space. When a decision about familiarity of a face has to be made, the decision process is assumed to depend upon:

1. The estimate of the error associated with the encoding process

2. The distance between the location of the stimulus and the next nearest known face

3. The distance between the stimulus and the next nearest neighbour

The two versions of the framework have many similarities. The major difference is that in the norm-based version the origin of the space takes on a special significance in that it represents the extracted norm or prototype. In the exemplar-based model the origin is simply the point of maximum exemplar density. The other major difference is that in the norm-based model the comparison of two faces relies on the comparison of the N dimensional vectors, whereas in the exemplar-based version such a
comparison is made on the basis of the distance between the two points representing
the faces (i.e., distance from the origin is not taken into account in this case).

This framework has generated considerable interest, and much of the research
undertaken has sought to differentiate between the two forms of the model. Although
Valentine originally favoured the norm-based version, some more recent evidence
favours the exemplar-based version (see for example Valentine, 1995).

The distinction between these two forms of the framework is not crucial to the
discussion of the causes of the inversion effect because in both cases inversion is seen
as affecting the first of the factors listed above. Thus, Valentine sees inversion as
leading to increased error in the encoding of the crucial dimensions of the face. These
dimensions are not described, and there is no suggestion that some factors are more
affected by this transformation than others (in contrast to Diamond & Carey's
explanation). Furthermore, there is no suggestion that faces are encoded in a manner
that is qualitatively different from non-face objects. The suggestion is that inversion
disproportionately affects face recognition only because faces, being very similar to
one another, can only be reliably differentiated on the basis of the very accurate
encoding of several characteristics.

2.9.1 The predictions made by the framework

Valentine derives a series of predictions from this framework. In all cases the two
versions make the same prediction, though not always in the same way.
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1. Distinctiveness in familiar faces. Both forms of the model predict that distinctive familiar faces will be recognised more quickly and accurately than typical familiar faces. This prediction arises from a consideration of the density of exemplars in the face space. The distinctive faces will, by definition, be in a less densely populated area of the face space and thus the error in encoding will probably be small compared to the distance from the nearest neighbour, and recognition is therefore likely to be quick and accurate. A more typical face will be close to several other faces, and therefore the error in encoding will be larger relative to the distance from the next nearest neighbour, resulting in slow decision times and more errors.

2. Distinctiveness and unfamiliar faces. The model predicts that if subjects are required to decide whether or not they have seen a face before, distinctive faces will give rise to fewer errors and faster decision times than typical faces (as any errors in the encoding process are less likely to result on the region of uncertainty surrounding the representation encompassing a previously seen face).

3. Distinctiveness in a face classification task. The model predicts that if subjects are required to decide whether or not a pattern is a face, then the effect of distinctiveness will be to increase the decision time and increase the error rate. In the norm-based model this prediction relies upon the fact that typical faces will be closer to the origin of the face space. In the exemplar-based model the greater density of the exemplars surrounding a typical face will mean that a comparison to a known face neighbour can be rapidly made.

4. The effects of inversion and distinctiveness. Both forms of the model predict that inversion will lead to more recognition errors with typical than distinctive faces. In
the case of the exemplar-based model this is because the added encoding error will result in more false identifications where the exemplar density is highest. In the case of the norm-based version of the model, the inaccurate assessment of the vectors will result in an increased probability of a false recognition occurring as we move further away from the norm.

5. The race effect. It is assumed that the feature dimensions used to encode faces will have been optimised for the faces of the racial group most often encountered (the own-race). This will lead to other-race faces being tightly clustered within, but at some distance from, the origin of the face space. The norm-based model predicts that other-race faces will be more difficult to recognise because, the further two adjacent points are from the origin, the more similar their vectors become. Thus, any transformation that adds noise to the encoding of the vectors will increase the error associated with the recognition of other-race faces more than that of own-race faces leading to the further prediction that inversion will affect the recognition of other-race faces more than own-race faces. The exemplar-based model makes the same prediction, but here similarity is seen as a function of the distance separating the faces in the faces space, so if the other-race faces are more densely packed than the own-race faces the error introduced into the encoding process by stimulus inversion will act to increase the recognition error for other-race faces more than for own-race faces. Thus, the exemplar based model’s explanation is dependent on the assumption that own-race faces are less densely packed than other-race faces, whereas the norm based coding model relies on the assumption that other-race faces are represented by points further from the norm than own-race faces.
Valentine (1991) conducted a series of five experiments to test these predictions. All received strong support. Experiments 1 & 2 demonstrated that with previously unfamiliar faces, recognition accuracy for typical faces was more disrupted by inversion than for distinctive faces. Experiment 3 demonstrated the same effect of distinctiveness on the size of the inversion performance decrement for familiar (famous) faces. In contrast Experiment 4 confirmed that, in a face classification task, the inversion effect was greater for distinctive than for typical faces.

Experiment 5 examined the effect of inversion on recognition performance for own and other-race faces, and confirmed that the recognition of other-race faces is more disrupted by inversion than own-race faces. However, some caution is needed in interpreting this result because only Caucasian subjects took part in the experiment. However Valentine & Endo (1992) compared the ability of Japanese and British subjects to recognise distinctive and typical British and Japanese faces. This study confirmed that the recognition of other-race faces was more disrupted by inversion than own-race faces, and that this was true for both racial groups. However, as Valentine & Endo (1992) acknowledged, the presence of a main effect of race-of-face (British faces were more easily recognised) must be borne in mind when interpreting this result. Lindsay & Wells (1983) stress that great caution should be practised in interpreting the results of race studies where main effects such as this occur, as this leaves open the possibility that the faces of one racial group are more similar than another.

Thus the predictions made by this model all seem to have received some support, and this lends considerable credence to the model.
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2.10 Comparing the Valentine and Diamond & Carey models

One of the major differences between these two explanations is that Diamond & Carey describe the locus of the effect as being at the stage of the perceptual encoding of the face, whereas Valentine describes a process that affects the accuracy with which faces are encoded in memory. Valentine’s approach is explicitly designed as an attempt to account for several different phenomena, including race, inversion and distinctiveness. Diamond & Carey’s explanation of the inversion effect, on the other hand, is limited to specifically that effect. It makes no predictions about the nature of other transformations, or about the interactions between such transformations.

In Diamond & Carey’s model the disproportionate effect of inversion on face recognition is a consequence of the nature of the face as a visual stimulus. It is because all faces share the same first-order characteristics that they must be recognised through the encoding of second-order features. It is assumed that inversion disrupts the encoding of second-order features more than first-order features, and therefore faces are disproportionately affected by inversion. In Valentine’s model there is no attempt to classify features in this way or to suggest that faces are processed differently from non-faces.

The empirical evidence available seems to offer support for Valentine’s model, but largely undermines Diamond & Carey’s model. However, it should be noted that these two models are not necessarily mutually exclusive. Valentine makes no attempt to describe the type of features that are encoded as dimensions within the face space, but these would presumably include what Diamond & Carey classify as both first- and second-order features. Valentine’s model does not rule out the possibility that the encoding error introduced by stimulus inversion might be greater for some features
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than for others, and thus it would be perfectly possible to combine these two explanations.

Perhaps one of the major advantages of Valentine's model is that it makes testable predictions about the interaction between several different transformations. One such transformation is negation (the presentation of the image as a photographic negative). As Valentine (1988) comments, no comparison has been made of the effects of inversion and negation on face recognition, but it is clear that such comparisons could be of great theoretical importance. For this reason the following chapter reviews the available evidence concerning the effect of image negation on face recognition.
Chapter 3

Image negation and face recognition
3.1 Negation

Photographic technicians have long known how difficult it is to recognise the subject of a portrait photograph by studying the negative film. In a photographic negative all the grey level relationships are reversed; a black area becomes white and vice-versa. The effect of this grey level transformation (hereafter referred to as negation) on face recognition was first studied by Galper (1970). Galper's motivation in studying the effect of negation was to test the suggestion made by Hochberg & Galper (1967), and Yin (1969), that the inversion effect demonstrates that faces are processed differently from other images. Galper argued that the inversion effect could not be taken as evidence for the specialness of faces unless other transformations could be identified that also differentially affected face recognition. Galper found that presenting faces in photographic negative either at test, or at both training and test, resulted in a significant decrease in recognition performance relative to faces seen in positive at both training and test.

More recently, the effect of negation has also been demonstrated using a very different paradigm. Jeffreys (1993) demonstrated that the scalp-recorded "vertex-positive peak" evoked by images of faces in humans has a longer latency for negative than positive face images. This would seem to suggest that the effect of the transformation is not simply limited to an effect on recognition as measured using the traditional recognition memory procedure.

It is clear then, that faces are more difficult to recognise in negative than in positive: however, to date there has been no demonstration that faces are disproportionately affected by this transformation; it may be that face recognition is no more disrupted
by this transformation than is the recognition of non-face objects. The fact that there is no published evidence of a disproportionate effect of negation should be borne in mind when considering the possible causes of this transformation.

3.2 Three possible causes of the Negation effect

Phillips (1972) identified three possible explanations of the negation effect: the expression explanation, the many-greys explanation and the shape-from-shading explanation.

3.2.1 The expression explanation

The first of these explanations was offered by Galper (1970), and further developed by Galper & Hochberg (1971). Galper (1970) argued that her data offered support to the suggestion made by Kohler (1940), that the negation and inversion effects act by disrupting the encoding of facial expression. She suggested that what makes faces special is that they "can be described - and perhaps coded and stored - in terms of expression" (page 208). Galper & Hochberg (1971) reported that recognition accuracy for two different images of the same face that varied in expression, was better than that for different faces presented in negative.

Sorce & Campos (1974) demonstrated that expression was less well remembered from negative photographs than from positives, and that subjects were both less accurate and less confident in the recognition of expressions shown in negative than positive images. They concluded that: "Facial expression is therefore a parameter of facial recognition." (page 71). However, there is now considerable evidence that the
recognition of expression and person identity are independent processes (see for example Young, Flude, Hay & Ellis, 1993), and it therefore seems unlikely that the increased difficulty in specifying the facial expression in negative images is a causal factor in the negation effect.

3.2.2 The many-greys explanation

Phillips (1972) hypothesised that the difficulty in recognising negative faces was a consequence of the high number of grey levels present in such images. To test this hypothesis, recognition accuracy was compared for normal and negative images of faces prepared on either normal or lith film. Lith film renders images in only 1-bit of grey level information so that all parts of the image are either black or white. Although normal images were more accurately recognised than lith images the effect of negation on these two types of image was similar, suggesting that the number of grey levels present in a normal image of a face could not account for the difficulty in recognising negatives. This explanation is also undermined by the observation that thresholded images of faces are more difficult to recognise in negative than positive (Hayes, 1988).

3.2.3 The shape-from-shading explanation

The third explanation offered by Phillips (1972) was that negation might prevent accurate recognition by disrupting the shape-from-shading processes. Bruce (1988) argued that face recognition might be mediated by a knowledge of the 3-D structure of the face. If this is the case, then any transformation that disrupts the derivation of 3-D structure from an image is also likely to be disruptive to face recognition. The visual system makes extensive use of the information contained within the pattern of
shadows and shading in an image to compute the 3-D structure of the object (see for example, Ramachandran, 1988a; Ramachandran, 1988b; Johnston & Passmore, 1994a; Johnston & Passmore, 1994b), and Johnston, Hill & Carman (1992) argued that these are likely to be the most important sources of information used to derive a description of the surface geometry of the face. Since negation results in a pattern of shadow and shading that could never naturally occur, we might expect this transformation to be very disruptive to face recognition. The fact that recognition of lith and thresholded images of faces is affected by negation (Phillips, 1972; Hayes, 1988) is consistent with this explanation; lith and thresholded images retain some shadow information, and many "features" apparent in such images are actually shadow and shading boundaries.

Phillips (1972) pointed out that the many-greys and the shape-from-shading explanations are closely related. A difference is that the shape-from-shading explanation is not refuted by Phillips's data. Shading information, in the form of shadows, will still have been apparent in the lith images; indeed it is probably just this type of information that was best preserved by the lith process. Shape-from-shading can probably be more accurately extracted from an image containing a full range of grey levels, but negation would clearly be disruptive to this process even if only 2 grey levels were present in the image.

Given the clear failure of the expression and many-greys explanations the alternative, shape-from-shading explanation will be considered in more detail in the following section.
Chapter 3

The negation effect

3.3 Shape-from-shading and the negation effect

Cavanagh & Leclerc (1989) examined the information about 3-D structure afforded by shadow information. They state:

"it seems likely that the difficulty in recognising negatives of faces ... is due to the inappropriate luminance contrast for the shadows and shading in the face. The reverse contrast will produce inappropriate depth perceptions that disrupt the surface structure of the face." (page 22).

Bruce (1988) stressed that the 3-D shape of the face may contribute to a structural description mediating recognition. It is clear from the work of Cavanagh & Leclerc, that the presence of shading and shadows on the facial image can be important sources of such structural information. If our ability to recognise a face depends on the construction of a 3-D representation, then the negation effect might act by disrupting the recovery of 3-D structure.

This explanation was investigated by Johnston, et al. (1992) who argued that phenomena such as Gibson's crater illusion (Gibson, 1950) demonstrate the importance of shading, shadows and direction of illumination in perception. In the crater illusion, inversion of the image results in a change in the apparent direction of illumination and the crater is seen as a protuberance. In contrast, in Gregory's "hollow face" illusion (Gregory, 1973), a concave mould of a face looks convex, regardless of image orientation and lighting direction. It seems that we have a natural preference for assuming that a scene is illuminated from above, and make use of this assumption when deriving an understanding of the 3-D structure of objects from shading.
information. Apparently though, our preference for interpreting the face as a convex pattern is so strong that we see it that way, even in the case of the hollow face illusion, when to do so requires us to abandon the lighting-from-above assumption. Thus, Johnston et al. argued that a knowledge of the direction of lighting is essential to the process of constructing a 3-D representation from a 2-D pattern. Negating a top-lit facial image results in an image that, in some ways, resembles a bottom-lit positive. However, the negation of a front-lit face results in an image that is not explicable solely in terms of changes in lighting direction. In the case of areas of the face which are perpendicular to the plane of rotation of the light source, such as the cheeks, the change caused by negation of the image cannot be interpreted as a change in lighting direction, and instead must be seen as a change in the surface geometry of the face.

If Bruce (1988) is correct and the surface geometry of the face is an important cue to recognition, then negating the image of a front-lit face will severely disrupt recognition.

Johnston et al. offered data to support this view: they asked undergraduate subjects to decide if a facial image was that of a class-mate or not. The faces were presented in one of four possible modes: top-lit positive, bottom-lit positive, top-lit negative or bottom-lit negative. In the case of the positive images it was found that the effect of changing lighting direction from above to below acted to reduce the effect of inversion. With negative faces the effect of inversion was consistent between top- and bottom-lit images. They therefore argued that it is the actual direction of the lighting, rather than its perceived direction, that determines the size of the inversion effect (if the perceived direction was important then, with negative images we would expect to see the largest inversion effect for the bottom-lit faces). They state:
"Clearly, generating a photographic negative has more profound effects than simply changing the apparent direction of the light source. The manipulation reverses hair and eye brightness and also appears to alter the perceived geometry of the face." (page 373)

They point out that the changes in brightness caused by negation can be interpreted as a change in lighting direction for some areas of the face, but not in the case of others:

"In these regions of the face the effects of brightness reversal may well be interpreted as a change in surface geometry. Thus we suggest that brightness reversal (negation) introduces changes in the description of the facial shape as well as changes in the brightness of significant features, like the eyes and hair, which add stimulus noise to the decision procedures supporting familiarity judgements. This results in a reduction in the sensitivity of the face recognition process for faces presented as photographic negatives." (p. 373)

Johnston et al. are arguing that the negation effect probably has more than one cause, but that one such cause may be the tendency to interpret the strange shadow and shading effects caused by the brightness reversal as reflecting a radically different underlying 3-D structure. Indeed the implied 3-D structure might well significantly differ from the biological norm for the human face (i.e. overall convex, with some local concave features), resulting in great difficulty in constructing a 3-D representation of the face.
While offering some support for the shape-from-shading explanation, Johnston et al. are also reminding us that there are other crucial differences between the positive and negative form of the image. In particular, negation gives rise to rather unusual pigmentation for some features, notably the hair and eyes.

Bruce & Langton (1994) sought to separate these effects of pigmentation and shape-from-shading. In experiments 2, 3 and 4 subjects viewed 3-D representations of heads produced by using a laser scan technique developed by Linney and colleagues at University College Hospital. This technique allows heads to be scanned producing a set of some 20,000 x, y, and z coordinates that describe the 3-D structure of the head in great detail. These scanned heads were displayed on a computer screen in 3/4 view by applying a simple lighting model to the 3-D description of the head and assuming a single point light source. Bruce & Langton argue that this approach allows one to separate the effect of shape-from-shading and pigmentation, as the scanned heads contain no pigmentation detail and hence any effect of negation found with these head images is likely to result from a disruption of the shape-from-shading processes. In experiments 2 to 4 subjects were required to identify the scanned head images when shown in normal, inverted, negative or negative-inverted modes. In each case there were significant effects of inversion, but not of negation, with subjects recognising the negative images as accurately as the positive images (in one study there was an effect of negation but this was probably the result of a change in response bias). This seems to suggest, perhaps rather surprisingly, that it is the disruption of pigmentation, and not shape-from-shading information that is the major cause of the negation effect, at least in an identification task, as the shape-from-shading information was apparently preserved in the scanned heads. However, given that the effects of negation only just failed to reach significance in most of these experiments it seems likely that there is
some small effect of negation caused by the disruption of the shape-from-shading cues.

In previous studies Bruce, et al. (1993) and Burton, Bruce & Dench (1993) demonstrated that the ability of subjects to classify heads as either male or female was partly dependent on the perceived 3-D structure of the head. Bruce et al. showed that subjects' ability to classify the sex of photographs of real heads (with hair obscured by a swimming cap - without the cap performance was close to 100%) declined by about 11% when the photographs were presented in negative. Together, these two results seem to suggest that a sex classification task using the scanned head images might show an effect of negation where the identification task did not.

Bruce & Langton (1994) tested this prediction in experiments 6 and 7, and found little effect of negation on the performance in these two studies, with marginally significant effects emerging in the response latency, but not the accuracy data. It would therefore seem that sex classification, a process believed to be partly dependent on perceived 3-D structure, is slowed rather than prevented, by negation.⁴

This is rather damning of the shape-from-shading explanation of the negation effect, and Bruce & Langton conclude that negation acts to disrupt the use of pigmentation cues to identification. They further reason that, as negation produces an "impossible" lighting condition (a change to the position of the light source cannot account for all

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⁴This suggestion that, while sex-classification is partly reliant on perceived 3-D structure, person identification is not, would seem to lead to the conclusion that sex classification and person identification are independent processes. Although this position is in direct contradiction to early models of face recognition (e.g., Ellis, 1986), Bruce, Ellis, Gibling & Young (1987) provide some evidence that these two processes are indeed parallel and independent.
the shadows in the negative image if we assume a convex shape), then the absence of a negation effect in the identification task suggests that perceived surface geometry is not critical in facial identification. That is, most recognition is reliant on a 2-D description of the face. They state:

"Our results thus provide rather little support for the use of shape-from-shading in providing information for face identification". (Bruce & Langton (1994), page 821).

Bruce & Langton seem to accept that negation disrupts the shape-from-shading processes (and indeed have some evidence of this in the sex classification task data), but they argue that, as there is no effect of negation on the identification of the scanned heads, then this 3-D information cannot be contributing to the normal recognition processes.

It could, of course, be something peculiar about the scanned heads that gives rise to this pattern of results. Bruce & Langton have not directly demonstrated that the shape-from-shading explanation is false, but rather that, in the absence of pigmentation, the effect disappears (or, given that non-significant trends were present in the data from each of the studies, that the effect is much reduced). All we can be sure of is that non-pigmented, scanned heads show a much less marked negation effect.

One possible explanation for this failure to find an effect of negation might be that the lighting model used in the display of the scanned-head data, is a relatively simple one. In particular, no allowance is made for reflection from the skin surface. This results in rather strange looking images that appear somewhat flat and grey, and it is possible
that this lighting model might disrupt the shape-from-shading process. It may be significant that Bruce & Langton’s subjects had great difficulty in recognising the scanned heads in the normal, upright orientation, a surprising fact given the very high resolution of the representation. It is perhaps rather dangerous to draw conclusions about the role of shadow and shading information using images in which all such information is provided by a relatively simple computer model. It could be argued that Bruce & Langton were as much testing their lighting model as the role of shading and shadow information in the recognition process.

If the lighting model is at fault here, then further disruption of the 3-D cues (by negation for example), might have very little effect on recognition. In other words, Bruce & Langton’s conclusion that 3-D cues do not contribute to recognition is perhaps premature as it may be based on the use of images that are relatively impoverished in just such cues.

In order to separate the effects of pigmentation and shape-from-shading we need to be able to manipulate these two factors independently. Bruce’s scanned head images are remarkable stimuli, but ultimately their use might not have advanced this debate. Perhaps an easier approach would be to investigate negation in colour images where it is possible to manipulate hue and luminance independently. Cavanagh & Leclerc (1989) have demonstrated that the visual system readily interprets darker coloured regions as shadows even if these could not occur naturally. This approach will be pursued more fully in a later chapter, but for now we will turn to consider the other lines of evidence of the causes of the negation effect.
3.4 Additional evidence of the causes of the negation effect

3.4.1 Filtering, thresholding and drawing the face

Hayes, Morrone & Burr (1986) investigated subjects' recognition performance for spatial frequency filtered positive and negative images, by convolving facial images with a range of bandpass spatial frequency filters. The resulting images were presented at two different distances from the observer, allowing Hayes et al. to separate the effects of spatial frequency at the retina, from the effects of the spatial frequency at which the image components which allow recognition naturally occur.

The results clearly indicated that, for a positive image, recognition is most accurate when the bandpass filter is centred around 20 cycles face-width\(^{-1}\) and that, as this result is true for both short and long viewing distances, the critical dimension of spatial frequency for recognition is cycles face-width\(^{-1}\) and not cycles degree\(^{-1}\). More importantly for the discussion of the negation effect, they found that recognition was equally accurate for positive and negative images when only the high spatial frequencies were present. This result seems intuitive when it is remembered that these high-pass images look like line drawings. At the other end of the spatial scale, low-pass filtered images were much more difficult to recognise in negative than in positive. The negatives of faces convolved with bandpass filters centred around the critical 20 cycles face-width\(^{-1}\) region were recognised as well as the unfiltered negative images. In contrast, the positive unfiltered image was better recognised than any of the filtered positives, including the 20 cycles face-width\(^{-1}\) images.

Hayes et al. therefore conclude that
"it is the low-spatial-frequency components alone of unfiltered negative images which present difficulties for the visual system, and the clear implication is that there exist different processes operating at coarse and fine spatial scales. At high frequencies the visual system is tolerant of an 180° shift in relative phase\(^5\), where as at low frequencies it is sensitive to relative phase." (page 601)

The low spatial frequencies that Hayes et al. are implicating are the frequencies that encode gradual changes in luminance across the image, such as shading. The suggestion that the lower frequencies are more sensitive to a 180° phase shift than are the higher frequencies, is simply a more formal way of saying that the lower frequencies are coding gross features for which the true luminance value is required to allow correct identification. The higher frequencies are coding "sharp edges" or rapid changes in luminance over the spatial scale. Such features although useful for recognition, are not luminance-value-critical.

Hayes (1988), investigated the effect of negation on thresholded (what Hayes called bi-level quantised), high-pass and low-pass images. The data from this study are presented in Table 3.1. Thresholded faces were found to be more difficult to recognise in negative than positive, and Hayes took this to be a critical refutation of Sutherland (1971)'s suggestion that only images containing many grey levels (multi-tone images) will be difficult to recognise in negative. Critically, a two-tone image is also difficult to recognise when it is derived from a multi-tone image.

---

\(^5\)Negation results in a shift in spatial phase of 180°.
Thresholding an image creates new, artefactual, high frequency components that describe the "sharp" edges of the blocks produced by the change from one brightness level to the other. However, thresholding leaves the lower spatial frequency information relatively unaffected, and as Hayes, et al. (1986) showed us, it is these frequencies that are largely responsible for the disruptive effect of negation. It is therefore understandable that Hayes (1988) found that the performance on the low-pass filtered, thresholded image was very poor (as all the low frequencies are preserved by both the low-pass filter and the thresholding). Unfortunately no negative multi-tone condition was included, so it is not possible to see just how disruptive this transformation was. The fact that recognition performance was much worse for the high-pass thresholded images than for the high-pass original images was taken as

\[\text{High-pass of original} = 69\%\]

\[\text{High-pass of thresholded image} = 37\%\]

Table 3.1. Percentage recognition accuracy for photographs of faces after various transformation. Data from Hayes (1988).

<table>
<thead>
<tr>
<th>Transformation</th>
<th>% Correct Identification$^6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>100%$^7$</td>
</tr>
<tr>
<td>Thresholded</td>
<td>95%</td>
</tr>
<tr>
<td>Negative Thresholded</td>
<td>28%</td>
</tr>
<tr>
<td>Edges from Thresholded Image</td>
<td>19%</td>
</tr>
<tr>
<td>Low-pass of original</td>
<td>78%</td>
</tr>
<tr>
<td>Low-pass of thresholded image</td>
<td>63%</td>
</tr>
<tr>
<td>High-pass of original</td>
<td>69%</td>
</tr>
<tr>
<td>High-pass of thresholded image</td>
<td>37%</td>
</tr>
</tbody>
</table>

$^6$These values are estimated from the graphs provided by Hayes (1988).

$^7$This value does not indicate that all subjects identified all images, but rather this is a consequence of the fact that the performance for all other conditions was calculated by dividing performance in that condition by performance with the original image. Hence performance with the original will always appear to be 100%.
evidence of the fact that thresholding disrupts these high frequencies. Although there was also a significant difference between performance with the low-pass of the original and the low-pass of the thresholded image, this difference was small indicating that the processing of thresholding resulted in the loss of relatively little, low spatial frequency information.

Thus, negation seems to particularly disrupt the representation of the features best described by the low spatial frequencies, and thresholding an image largely preserves these same, low-frequency features.

The high-pass images produced by Hayes et al. (1986) closely resemble line drawings as only the outlines of the major features are marked. Davies, Ellis & Shepherd (1978) and Rhodes, Brennan & Carey (1987) have demonstrated that line drawings produced by tracing the main features from photographs are poorly recognised. This effect of line drawings seems to be fairly specific to faces, as it has been shown that other types of object are fairly well represented by such line drawings (Biederman, 1987). Bruce, Hanna, Dench, Healey & Burton (1992) suggests that the "poverty" of these line drawings might be due to a lack of 3-D information resulting from the lack of shadow and shading information. If this is the case, then line-drawings that include shadow and shading information as well as major feature outlines, should be more identifiable. Informal observation of the work of sketch artists suggest that this is indeed the case (see for example Aubrey Beardsley’s drawing "Garçon de Café" which forms figure 16b in Pearson & Robinson (1985) and is reproduced as figure 3.1

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"Although, as discussed above, Bruce later concluded that knowledge of the three dimensional structure of the face was not of great value in a recognition task."
Bruce, et al. (1992) reports that recognition accuracy for images of famous faces that contain both line elements and shadow (what Bruce calls the "mass" component) is almost as high as for photographs, whereas line-only, and shadow-only images are much less well recognised.

Figure 3.1 Aubrey Beardsley's drawing "Garçon de Café" reproduced from Pearson & Robinson (1985).

It would seem that both line drawings and high-pass filtered images of faces are neither well recognised, nor greatly affected by negation. The most likely explanation of these two observations is that negation particularly disrupts the recognition of the low spatial frequency "features" that are critical for recognition, and that it is these features that are missing in line drawings that contain no shadow (or mass) component. Thresholded images, on the other hand, contain very little information about true facial features, yet are remarkably well recognised (for example 77.4%)

9The images used were not produced by artists, but were the output of Pearson's valledge operator. This operator is discussed in more detail in a later section.
recognition relative to full photographs in the Bruce, et al., 1992 study). Many of the contours in thresholded images actually describe shadow edges and not feature edges. It seems that the information most likely to be usefully extracted from such images is shape-from-shading information.

The data from Hayes (1988), (see table 3.1 above), reinforces this point. The thresholded images are very poorly recognised after high-pass filtering (37% recognition). High-pass filtering a thresholded image will tend to emphasise the edges of the shadow regions (as can be seen from close inspection of figure 5(a) from Hayes, 1988). It seems that these edges are actually disruptive to recognition because they are interpreted as real contours and not shadow boundaries. Cavanagh & Leclerc (1989) have shown that the human visual system will readily accept a pattern as a shadow as long as the shadow region is darker than the non-shadow region and that there is consistent polarity contrast along the border. Neither of these two constraints hold true for these images, and as a result these images contain edges that mark shadow boundaries which the human visual system cannot interpret as being shadows.

Hence there is considerable indirect evidence that shading and shadow provide vital information in face recognition. It is therefore very surprising that Bruce & Langton (1994) seem to have demonstrated that the disruption of the shape-from-shading processes cannot adequately account for the negation effect.

3.4.2 Eye movements across negative images of faces

Luria & Strauss (1978), studied the patterns of fixations made by subjects as they viewed normal and negative faces in both the learning and test phase of their study.
They found that negation significantly decreased recognition accuracy, with the number of false positive reports increasing in particular. The pattern of fixations also differed between the positive and negative images, with far more attention being paid to the internal features of the face in the positive than the negative condition. Luria & Strauss concluded that negation might be acting to distract subjects away from the details that are normally important in face recognition and encouraging them to focus on gross detail that is of little value in an identification task. It could be that negation encourages them to study these "low-value" features because of their unusual pigmentation in this condition. For example, Luria & Strauss comment that in the negative condition subjects made many more fixations to the cap badge (the faces were of service personnel all dressed in identical uniforms), a feature containing no useful information for identification, and they suggest that subjects may have been drawn to this "feature" by its unusual patterning in the negative condition.

The fact that, in the negative condition, there were more fixations on these unusually pigmented features could be seen as support for the argument put forward by Bruce & Langton (1994) that it is the disruption of pigmentation, and not shape-from-shading information, that gives rise to the negation effect.

3.4.3 Early visual processing and the negation effect

The work of Pearson and his colleagues provides some indirect evidence that the negation effect might be caused by the disruption of the shape-from-shading processes. For a number of years Pearson and his co-workers at the University of Essex have been developing image compression systems to allow the transmission of still and moving images of the human face and hands, down a conventional telephone line. The
The motivation behind this research was to allow the development of video phones for the deaf, and the approach adopted by Pearson was to try to extract the main "features" of the face and hands, and to send information about these only, thus reducing the transmission requirements.

Working from first principles and considering what is known about the shape information afforded by shadows, Pearson and his colleagues decided that what was required was an operator that detected "valleys" in the image - that is, narrow regions of low image intensity surrounded by brighter regions. It was discovered that such an operator detected many of the critical features, but missed others; some of which were picked up by the edge detector described by Marr & Hildreth (1980).

Pearson & Robinson (1985) describe the construction of an operator designed to be maximally sensitive to valleys in the image, but that also responds to edges. In practice, Pearson and colleagues found that the addition of a third component to the operator, a thresholding function that fills large areas of low luminance with black, improved the appearance of the output without increasing the data transmission requirements. The "valledge" operator (as this operator has since been termed) combines these three components of valley detector, edge detector and threshold function, and has been shown by Pearson, Hanna & Martinez (1990) to produce useful images of the human face under a variety of lighting conditions. Bruce, et al. (1992) have shown that the face images processed by this operator are easily and accurately recognised by human subjects, with images combining all three components of the operator being recognised almost as accurately as full grey scale images.
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The negation effect

Pearson, et al. (1990) noted how much more recognisable the "cartoons" (as they call the output of the valledge operator) were when displayed with the detected features marked in black on a white background than when displayed as white on black (i.e. in negative). They argued that this was because the operator was maximally responding to a feature composed of a dark region bounded by light, and so a black on white representation was more faithful to the original than was white on black. The white on black image suggests that ridges are located in the positions where the valleys and edges are to be found in the original image. Pearson (1992) noted that ridges are an example of a feature type that will not be detected by the valledge operator, and that luminance ridges and valleys are indicators of very different 3-D structures. Hence, replacing the valleys in the image description with ridges will be very disruptive to the construction of a 3-D representation of the face. Taking the photographic negative of the output of the valledge operator has exactly this effect and produces a surprisingly poor likeness of the human face.

Pearson, et al. (1990) argued that since the valledge operator produces such useful images at very low data rates, it is probable that the operator is producing an output similar to that produced by the early stages of the human visual system. In support of this they note that:

"the one-dimensional form of a valley detector is similar to the difference-of-gaussian weighting function for the retinal receptive field at ganglion-cell level, while the two-dimensional form is similar to the weighting function of a cell in the visual cortex, where orientation becomes important." (page 55).
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The negation effect

If we assume that the valledge operator is responding in a manner analogous to the early stages of the human visual system then we could get some impression of the output of the early visual system when a human subject studies one of these "cartoon" images, by feeding the output of the valledge operator (the cartoon) back through the operator. Pearson, et al. (1990) did exactly this and found that the black-on-white image was unchanged by this second pass through the operator (they coined the term *eigenimage* to describe the fact that a cartoon input image was unchanged by the operator), unlike the white-on-black cartoon which was greatly changed by the operator (the white-on-black cartoons were not eigenimages for this operator). They suggested that, if the valledge detector operates in a manner analogous to the early visual system, then this might explain why the white on black image is such an unsatisfactory facial representation.

Pearson, et al. (1990) also applied their valledge operator to photographic negatives of human faces. As they comment, this manipulation of the input image should have little effect on the output of an edge detector, such as the operator described by Marr & Hildreth (1980). However, the valledge operator is very disrupted by this negation of the input image, producing a very poor likeness in the output cartoon. Pearson, et al. (1990) state:

"If we again suppose that the output of the cartooning operator is similar to the output of the early stage of the human mechanism for recognising faces, then this output can be seen to be quite different for positive and negative images, with the positive input producing the recognisable cartoon." (page 58).
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The negation effect

If, as Pearson et al. suggest, the human face recognition system has its primary sensitivity to valleys, then negatives will be hard to recognise as the process of negation turns valleys into ridges and vice-versa. This, of course, is not an explanation of the negation effect, as saying that negation turns valleys into ridges is simply another way of describing the transformation. Rather, this is a more detailed account of the shape-from-shading explanation, since the detection of valleys and ridges, and the perception of form based on those valleys, relies on the fact that shape can be discerned from shading information.

Cavanagh & Leclerc (1989) have demonstrated that the visual system will readily interpret any region of an image as shadow so long as the shadow region is darker than the non-shadow region, and that there is a consistent contrast polarity along the shadow border. The output of Pearson's operator will clearly fit these requirements so long as the features are marked as black on white (and the thresholding operation is also included). Hence it seems likely that it is the computation of shape-from-shading that is being disrupted in the white on black version of Pearson's cartoons.

3.5 The negation effect: Some conclusions

Bruce & Langton's (1994) demonstration that the recognition of 3-D surface images is not disrupted by negation seems at first to be compelling evidence that the disruption of pigmentation cues to recognition is the most important cause of the negation effect. According to this data, the shape-from-shading cues are of some importance in a sex discrimination task, but of very little importance in an identification task. The fact that the negation effect was much larger for a recognition task (Bruce & Langton (1994), experiment 1) than for a sex discrimination task
(Bruce, et al. (1993), experiment 3), when both use real photographs, but disappears for a recognition task using scanned heads containing no pigmentation (Bruce & Langton (1994) experiments 2, 3 and 4), would seem to support Bruce & Langton's assertion that 3-D cues are of little significance in a recognition task. The danger is that these results might not generalise to real heads. Studies using photographs of real heads seem to suggest that shape-from-shading information is much more important than Bruce & Langton (1994) believe. In particular, the fact that positive, but not negative, thresholded images are very well recognised, strongly suggests that shape-from-shading information forms an important part of the facial representation, and that negation is acting to disrupt the encoding of this information.

The work of Pearson, et al. (1990) seems to provide further support for this position. Pearson’s cartoons are successful representations of the face because they describe the 3-D structure of the face as revealed by the pattern of shadows in the two-dimensional image. It is difficult to see why such minimalist representations could be recognised so successfully in positive, but so poorly in negative\(^\text{10}\), if shape-from-shading was not an important cue to recognition.

Finally Hayes (1988) has demonstrated that what is critical to recognition of the facial image is the inclusion of certain bands of spatial frequencies, and that the lower spatial frequencies are of the correct relative luminance values. These lower spatial frequencies will be heavily involved in the coding of the shadow information contained in the original image, and as Cavanagh & Leclerc (1989) have suggested,

\(^{10}\)It has not been formally demonstrated that the negatives of Pearson’s "cartoon" images are poorly recognised, but this is evident from inspection of the figures provided.
it seems likely that the critical factor is that the shadow regions must be darker than the non-shadow regions.

### 3.6 Negative-inverted faces

Regardless of exactly how the inversion or negation effects act to reduce recognition accuracy, a clear prediction of Valentine's (1991) model of the representation of faces, is that these two transformations should be additive in their effect. In this model, any transformation that affects the encoding of facial features acts to increase the area of uncertainty in the representational system and hence increase the chance of a false identification or classification. Thus each of these transformations will add its own noise to the stimulus encoding process. Regardless of whether negation acts by disrupting shape-from-shading processes or by changing the normal pigmentation of the face, a face that has been both negated and inverted should be even more difficult to recognise than a face that has been either negated or inverted. This additive interaction has recently been demonstrated by several authors, (Bruce, et al., 1993; Bruce & Langton, 1994; and Jeffreys, 1993\(^{11}\)).

In contrast, Diamond & Carey's (1986) explanation of the inversion effect gives rise to a different prediction: the addition of a further image transformation should not affect recognition, as the inverted face is recognised on the basis of first-order features, and hence in a non-face-like manner. Thus, the evidence of this additive effect of various combinations of these transformations is important to our understanding of the processes involved in face perception.

\(^{11}\)and earlier, by Kemp et al. (1990) in the paper that describes the first five experiments reported in this thesis.
Chapter 4

The face as a visual stimulus
4.1 The face as a visual stimulus

The majority of the studies considered so far have investigated the processes underlying face processing by studying the effect of various procedures on subjects’ recognition memory for faces. Typically subjects have been presented with a list of faces to learn, and have then been tested on their memory for these faces. It is perhaps not surprising that there has been a tendency to interpret the results of such studies in terms of the subjects’ memory for faces. Relatively few studies have considered the nature of the face as a visual stimulus. The perception of a face and its representation in memory are separate processes, and a face can only be represented in memory, once it has been perceptually encoded. The success or failure to recognise a face is not necessarily dependent on the accuracy of the memory processes involved. A face can only be recognised if it is first accurately perceived, and the probability of later recognition is at least as dependent on the perceptual as the memory systems.

It may be that phenomena such as the inversion effect, which many authors have assumed to reflect the operation of the representation of information in long-term memory (for example Valentine, 1988), are, in fact, the result of earlier occurring perceptual processes. When we test a subject’s ability to recognise a face we are observing a behaviour that is the end result of a number of interrelated processes, some of which are purely perceptual while others are memory based. We should not assume that any factor that affects the subject’s behaviour reflects the exclusive action of either representational or perceptual processes. In some instances perceptual effects could determine the outcome of an experiment before the information is ever represented in memory.
Thus, it could be that apparently face-specific effects such as negation and inversion are perceptual phenomena and not memory effects. However, we can only explain these face-specific effects as perceptual effects if we can argue that the face is treated as a special type of visual stimulus by the perceptual system. If this was the case then the face would need to be identified as a face before it was fully perceptually processed, and this identification would need to affect the course of the subsequent perceptual processing. Thus, we need to look for evidence of the high-level visual characteristics of a stimulus (such as its "faceness") affecting the accuracy of the perceptual processing of the image. The literature on the "object-superiority" and "face-superiority" effects seems to provide just such evidence.

4.2 The object-superiority effect

Weisstein & Harris (1974) first described what has become known as the object-superiority effect. They found that barely visible, and briefly flashed line segments were more accurately identified when they were part of an object-like pattern than when they were part of a pattern that appeared to be a random collection of lines.

This effect seems to be an instance of a class of similar effects. For example, it has been shown that letters are better recognised when they are part of a pronounceable than an unpronounceable word (the word-superiority effect; Reicher, 1969 and Wheeler, 1970), that an object is better recognised when it is part of an organised scene than when the scene has been jumbled (the scene-superiority effect; Biederman, 1972), that parts of a face are better identified when seen in the context of the whole face than when seen in the context of a scrambled face (the face-superiority effect; Homa, et al., 1976; Mermelstein, et al., 1979), and even that parts of chairs are better
recognised in the context of a whole chair than a jumbled chair (Davidoff & Donnelly, 1990). These effects seem to be closely related, and can collectively be termed "context effects" or "object-superiority effects". A somewhat different, but probably related effect has been reported by Wong & Weisstein (1982) who showed that line segments were more accurately identified when they were perceived as being part of a figure in the foreground of a scene than part of the background.

4.2.1 The determinants of the object-superiority effects

Attempts have been made to specify the characteristics of the context needed to give rise to this class of effects, and Lanze, Maguire & Naomi (1985) suggest that the evidence points to the involvement of three such factors: overall pattern connectedness, the perceived depth of the pattern, and the relevance of the target line to the overall pattern. Weisstein, Williams & Harris (1982) considered the relative importance of the first two of these factors and demonstrated that the perceived depth of the pattern is of particular significance. Lanze, Weisstein & Harris (1982) compared the importance of perceived depth and target line relevance, and found that perceived depth was the better predictor of the strength of the object-superiority effect. Lanze, et al. (1985) demonstrated that the patterns giving the highest level of accuracy were also ones in which the target line formed some new pattern element (such as a triangle) within the pattern. Lanze et al call these new features emergent features. They argued that the emergent features of the pattern and the perceived depth acted independently of each other in determining the accuracy with which the target line could be identified. This evidence of the importance of the perceived depth of the whole figure to the strength of the effect could help explain the figure-ground effect described by Wong & Weisstein (1982).
4.3 The face-superiority effect

The so-called face-superiority effect was first demonstrated by Homa, et al. (1976) and replicated by Van Santen & Jonides (1978). Both of these studies tested subjects' ability to recognise a single facial feature after it had been briefly presented in one of three conditions: on its own; together with other randomly arranged facial features; or in the context of a face pattern. It was found that performance was best for the isolated feature condition, but that performance in the face context condition was better than in the scrambled face condition. The term face-superiority effect describes this advantage for the recognition of (that is, the memory for) a feature presented in the context of a whole coherent face, relative to one that is presented in the context of a scrambled face. The scrambled face condition and the whole face condition differ only in the arrangement of the features relative to one another, and hence the difference in these two contexts is best described in terms of our prior knowledge of face-like stimuli. It appears that our knowledge of the significance of a visual stimulus is affecting the accuracy with which we can perceive that same stimulus. It is important to appreciate however, that Homa, et al. (1976) and Van Santen & Jonides (1978) actually demonstrated what might more accurately be termed a "non-face-inferiority effect" as the advantage for the face context was only demonstrated relative to the scrambled face. The face context was not demonstrated to advantage the processing of the components of the face relative to the isolated presentation of the features.

The face-superiority effect could have a considerable impact on our understanding of the processes involved in face perception and recognition, but it is important to note that, to date, this effect has not been shown to be face-specific. That is, no differences have been demonstrated between the face-superiority effect and the other context
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effects. Indeed, Davidoff & Donnelly (1990) demonstrated that the object-superiority effects produced by chairs and faces (compared to scrambled-chairs and scrambled-faces respectively) were comparable. Thus, the face-superiority effect is probably best considered as an example of a context effect until such a time that it can be shown to differ in some way from the other object-superiority effects.

4.3.1 The causes of the face-superiority effect

Davidoff (1986) showed that it was possible to produce a face-superiority effect when the features of the face were replaced by other object parts (see figure 4.1), and Davidoff & Donnelly (1990) suggested that this demonstrated the effect must be due to the accessing of a base-level description of the object (face) in long-term memory, and that this base level description must contain information concerning the spatial arrangement of the parts.

This type of explanation has received support from Gorea & Julesz (1990) who showed a face-superiority detection effect, whereby the detection of a face-like pattern of four line-elements somewhere in a square 10x10 array of such line-elements was superior to the detection of the same elements arranged to make a non-face-like pattern (see figure 4.2). As Gorea & Julesz point out, this is an important result, as in this instance the face pattern only exists through the arrangement of the very elements that are being detected, and the face cannot be perceived unless the elements have first been perceived. They argue that this suggests that there is an interaction between top-down and bottom-up processes at the very early stages of perception. An explanation of the effect, they argue, would require the integration of two sources of information. Firstly there is information about the orientation of line segments; this
is likely to occur early, probably in area VI (Hubel & Wiesel, 1968), and secondly there is information about the presence of a face-like pattern; this could be the output of the face detectors hypothesised by Perrett, Rolls & Caan (1982) to exist in the temporal cortex.

Gorea & Julesz, and Davidoff & Donnelly are both seeking to explain the face-superiority effect in terms of an interaction between a higher level system that detects the presence of a face-like pattern, and a lower level system responsible for the processing of the information describing the smaller elements of the pattern. The difference between these two explanations is that Gorea & Julesz call on our knowledge of the physiology of the visual system in their explanation, whereas Davidoff & Donnelly's explanation is at a rather more abstract level.

Figure 4.1 Examples of the stimuli used by Davidoff (1986)
Figure 4.2 Examples of stimuli used by Gorea & Julesz (1990). The target stimuli are made up of horizontal and vertical lines embedded among lines oriented at other angles. In parts (a) to (c) the background lines are angled at $45^\circ$ making the detection of the target stimuli easy. In part (d) the background lines are angled at $14^\circ$ and $76^\circ$ making the detection of the target much more difficult (it is in the middle-right of the image). In parts (a) and (d) the target is a face. In parts (b) and (c) the targets are a symmetrical non-face, and an asymmetrical non-face respectively.
4.4 The face-detection effect

There have been several demonstrations of a face-superiority effect for the detection of a feature. In a series of studies Purcell and his colleagues (e.g., Purcell, Stewart, Botwin & Kreigh, 1983; Purcell & Stewart, 1986; Purcell & Stewart, 1988) showed that the detection of a feature (both temporally and spatially) was affected by whether the feature was presented in the context of a face or a scrambled face. For example, Purcell & Stewart (1986) showed that subjects were able to identify the location of the normal face when presented for only 38 msec compared to 56 msec for the scrambled face. The importance of this result, which Purcell & Stewart call the face-detection effect, is that the subjects were not required to remember anything, they were simply required to detect the presence of the stimulus. This effect of context on the detection of a stimulus has also been demonstrated by Gorea & Julesz (1990).

This demonstration that perceptual accuracy is enhanced by the presence of a facial context could be critical to our discussion of the perception of faces. In particular this could provide a mechanism whereby the perception of an inverted (or negated) face is less accurate than an upright (or positive) face.

4.5 Face-superiority, face recognition and the inversion effect

As we saw in chapter 2, attempts to explain face recognition in terms of the encoding of second-order-relational features (e.g. Diamond & Carey, 1986) give rise to the

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12 As Purcell & Stewart (1988) point out, a wide range of terms is used to describe these effects. Purcell & Stewart introduce the new term face-detection effect to describe this purely perceptual phenomenon. In an attempt to aid clarity, I will use the phrase face-superiority effect as a general term to describe any advantage in the recognition or perception of faces. Similarly, I will use the phrase object-superiority effect to refer to such advantages in the perception or recognition of objects in general.
prediction that the isolated features of a face will not be as easily recognised as those same features when in the context of a face. This result has recently been demonstrated by Tanaka & Farah (1993). Tanaka & Farah found that subjects were better able to recognise a single facial feature when it was presented in the context of a coherent face pattern than when presented in the context of a scrambled face, or when presented in isolation. Furthermore, they found that this coherent-context advantage did not extend to drawings of houses, and hence they argued this seemed to be a face-specific effect.

Clearly Tanaka & Farah’s results could be interpreted as an instance of a face-superiority effect, but Tanaka & Farah were aware of this possibility and concluded that this was not the case. They gave four reasons for this conclusion. Firstly, Tanaka & Farah stated that the face-superiority effect is thought to be a reflection of processes underlying the perceptual encoding of a visual stimulus, whereas they interpreted their own result as reflecting the accessing of a stored representation of the face. However, as we have seen, both Davidoff & Donnelly (1990) and Gorea & Julesz (1990) have explained the face-superiority effect in terms of the accessing of higher level representations of the face.

Secondly Tanaka & Farah claimed that the face-superiority effect was only observed under conditions of threshold vision, and not at the longer exposure durations that they used. It is true that short exposure durations have normally been used, and that Purcell, et al. (1983) showed that the size of the face-superiority effect decreased with increasing exposure duration, but recently Davidoff & Donnelly (1990) demonstrated a face-superiority effect (and indeed a chair-superiority effect) for stimulus exposures of up to 2 seconds duration, and so this argument also seems to be flawed.
Thirdly, Tanaka & Farah claimed that in the object-superiority effects, the perception of the parts in the presence of the context is as good as, but not better than, recognition of the parts when presented in isolation. That is, the object-superiority effect is normally demonstrated as an advantage of the coherent context over the scrambled context, but not over the isolated feature condition (thus, as mentioned earlier it could be thought of as a "non-object inferiority effect"). Tanaka & Farah argued that, as they found the recognition of the parts in the context of the whole face was better than the recognition of features when presented in isolation, this could not be an instance of an object-superiority effect. This argument is undermined by the fact that there have been a few reports of genuine object-superiority effects. In these cases the coherent context has been shown to advantage processing relative to the isolated feature condition as well as to the jumbled context condition. For example, Williams & Weisstein (1978) reported that under some circumstances line segments can be better identified when they are part of a context than when presented in isolation.

Finally, Tanaka & Farah argued that they had shown an effect that was specific to faces (the advantage for the coherent context did not extend to images of houses), whereas the face-superiority effect seems to be an example of the general class of context effects, and hence they argued that the two effects were different.

Of these four arguments, only the last seems to stand up to scrutiny, and therefore, rather ironically, the only valid argument that Tanaka & Farah present to justify their conclusion that their result is not an instance of the face-superiority effect, is that their effect is specific to faces! If we accept this position then we have to conclude that there are at least two different processes at work here; firstly a general object-superiority effect that advantages the perception of the parts of a coherent object, and
secondly some other face specific process which advantages the perception of upright faces. Might it not be more parsimonious to consider these two as examples of the same effect?

It is important that we recognise just how similar the face-superiority effect is to some of the phenomena that have previously been thought to reflect the accessing of stored facial representations in memory. For example, the inversion effect is usually seen in this light. Valentine (1988) commented:

"Therefore, it is possible that the disproportionate effect of inversion only emerges when the task involves recognising a face as one stored in memory." (page 474).

In support of this statement Valentine noted that Valentine (1986) and Bruyer & Velge (1981) both failed to observe a disproportionate effect of inversion on a matching task. Valentine also commented that Shepherd (1981) claimed there was evidence that the race-effect was found in studies employing a recognition memory task but not in those using a matching task.

If a face-superiority effect could be demonstrated for upright, but not for inverted faces (or, if an advantage could be demonstrated for the upright over the inverted context), then it would be difficult not to see the inversion effect as an example of an object superiority effect. As we have seen, Tanaka & Farah (1993) demonstrated a phenomena very like this, but chose to interpret their observations in terms of a memory rather than a perceptual effect.
4.5.1 Comparing the face-superiority for upright and inverted images

Given the widespread interest in the effect of inversion on recognition memory for faces, it is perhaps surprising that there are relatively few published papers in which the face-superiority advantage for the normal face context has been compared to that for an inverted face. Most of the studies conducted have used either (or both) scrambled faces and isolated features, rather than inverted faces as the control stimulus. However, there are a few exceptions.

Endo (1982) showed that subjects were less able to detect changes to some facial features in inverted than in upright images, and Endo (1986) showed that this effect of orientation disappeared if the participants were required to view the face through a small "window" that prevented them from seeing all of the face at one time. Under these conditions of restricted viewing, accuracy declined for upright but not for inverted faces. This seems to suggest an advantage for the processing of the upright face over the inverted whole face and the isolated features of the face.

Gyoba, Arimura & Maruyama (1980) required subjects to identify which of five sets of eyebrows had just been presented to them as part of either a normal face, an inverted face or a scrambled face. The eyebrows were also presented on their own. Identification was found to be 10% more accurate when the eyebrows were presented in the face context than when presented on their own. Critically, the inverted faces and the scrambled faces did not enhance performance in the same way, with performance being the same in these conditions as in the isolated feature condition. In experiment 2 Gyoba et al. reduced the extent to which the context looked face-like by reducing the number of salient features, and it was found that the degree of facilitation provided by the upright facial context declined with the reduction in what they termed the
"face-likeness". Gyoba et al. sought to explain these results in terms of the activation of a face schema which was assumed to generate "contextual expectations, allocating attentional resources to the places where specific data are expected" (page 113).

Purcell & Stewart (1988) undertook a series of experiments in which subjects were required to detect the presentation of a face either temporally (i.e. was a face shown within a time period) or spatially (i.e. was the face shown on the left or right hand-side of the visual field). In experiment 1 subjects were presented with either an upright or an inverted line-drawing of a face. The target face was presented for 20 msec, and was followed by a visual mask presented for 100 msec. During practice trials, stimulus onset asynchrony (SOA) was adjusted until each subject could detect the presence of the face with 75% accuracy (averaged over both upright and inverted trials). Subjects were told that, regardless of what they had thought they had seen, they were to indicate whether the stimulus appeared on the left or right hand side of the screen. Subjects detected the presence of the upright face on 76% of the trials, but the inverted face on only 69% of the trials.

In experiment 2 Purcell & Stewart (1988) varied the stimulus onset asynchrony and found that subjects could accurately detect the presence of a face at shorter SOA values than an inverted face. In experiment 3 a similar result emerged despite the fact that the subjects were shown the face (either upright or inverted) they were to detect immediately before each trial. Thus the result observed in experiment 2 cannot be due to a reluctance among the subjects to report the presence of a face that appears to be inverted, but rather must be due to the subjects adopting a set which "must be regarded as a more or less permanent characteristic of the subjects normal processing of visual information" (page 359).
In experiment 4 Purcell & Stewart (1988) compared the detection of normal, inverted and rearranged (scrambled) faces. They found that upright faces were detected at an average SOA of 34.75 msec, inverted faces at 47.5 msec, and rearranged faces at 53.79 msec. Thus it appears that faces are advantaged relative to both inverted and scrambled faces, and that scrambled faces are significantly disadvantaged relative to inverted faces. In experiment 5 it was demonstrated that the advantage for the normal (upright) over the rearranged face was consistent in both a detection task (was the face presented?) and a classification task (was the face normal or rearranged?). Importantly, it was also shown that more time was required for classification than detection, and thus at detection threshold subjects were not aware whether or not the face was normal. Thus the advantage for the normal face emerged without any conscious awareness of the type of stimulus being presented.

Purcell & Stewart (1988) concluded:

"What is counterintuitive about our results is that the processes underlying detection are influenced by the information contained in the arrangement of the pattern's individual components. It is as though the visual system, at some level, is able to determine where or when an interesting or familiar stimulus was presented. However, access to the information regarding the identity of that stimulus is not possible without further exposure to it." (page 363).

Purcell & Stewart argued that these results demonstrated that faces were "simply seen better than are rearranged faces". They also pointed out that their results undermined the explanation for the face-superiority effect offered by Mermelstein, et al. (1979) who suggested that both upright and inverted faces were seen equally accurately, but
that a semantic code is more easily generated for an upright face than an inverted face.

Thus, these two studies provide some evidence that the face-superiority advantage is stronger for the upright than the inverted face. Critically for the argument being developed in this thesis, Purcell & Stewart (1988) has also shown that the basis of this effect seems to be perceptual in origin rather than as the result of the memorial encoding of the stimulus. However, a critical limitation of these studies is that they have only demonstrated this advantage for the upright over the inverted face under very limited conditions. In particular, it is not at all clear that such an effect would emerge under unlimited exposure durations. Furthermore, the demonstration of an advantage for the detection of an upright over an inverted face, does not necessarily explain the superior recognition of the upright face. The fact that an upright face can be detected a few msec earlier than an inverted face does not explain why, under unlimited exposure durations, subjects are so less accurate in recognising inverted than upright faces.

4.5.2 Contrary evidence

The evidence reviewed above suggests that it might be possible to formulate a purely perceptual explanation of the inversion effect. However, there is also some contradictory evidence.

In the facial composite effect discussed in chapter 2 (Young, et al., 1987), the complete and upright facial context seems to be disadvantaging the recognition of the parts of the face, and Hole (1994) demonstrated that this effect was not limited to a recognition task but was also present in a matching task. Endo, Masame & Maruyama
(1989) used the composites technique to demonstrate, what they termed, an interference effect exerted by the facial context over the recognition of the facial parts, and Endo, Masame & Maruyama (1990) showed that this interference effect disappeared with stimulus inversion.

Thus, although Purcell & Stewart (1988), Gyoba, et al. (1980), Tanaka & Farah (1993) and Endo (1986) provide some evidence of a face-superiority effect which is reduced by stimulus inversion, Young, et al. (1987), Hole (1994), and Endo, et al. (1990) seem to indicate that the reverse can also be true - that the facial context reduces the accuracy with which the parts can be recognised and that inversion abolishes this interference effect.

4.6 A new explanation of the inversion effect

There is some reason to suppose that the strength of the context-superiority effects differs for different classes of object, and that, in the case of the face at least, it may also vary with the orientation of the object. Thus, the disproportionately large effect of orientation on the recognition memory for faces could be an instance of an object-superiority effect in which the context is most effective when upright. Davidoff & Donnelly (1990) would presumably explain such an effect in terms of inversion acting to reduce the tendency to access the base level representation of the object (the face) and hence reduce the accuracy with which the perceptual encoding of the object can take place.

This description of the inversion effect has some resonances with that put forward by Goldstein & Chance (1980), and is not incompatible with Valentine’s model.
Valentine, 1991). The major differences between this face-superiority description and the explanations reviewed earlier is that the face-superiority explanation places the locus of the effect at the stage of the early perceptual encoding of the face rather than at the point of the representation of the encoded face in memory, and that it describes a processing advantage for the upright face rather than a disadvantage for an inverted face.

This perceptual explanation of the inversion effect could also accommodate other transformations, such as negation, which might act to reduce the match between the image and the high-level representation of the object. This explanation could even account for the race effect, if we were to assume that the significance of the facial context is learned through repeated exposure with the faces in our immediate environment. Thus, like that proposed by Valentine, this model predicts that although negation and inversion (and other transformations) might act via different mechanisms, their effect will be very similar.

This explanation makes some specific predictions. In particular it predicts that inversion will affect the accuracy with which a subject can perceive a facial feature when the feature is in the context of the whole face. If it could be shown that subjects were less sensitive to the exact form of a facial feature in an inverted than in an upright face, and that this effect of inversion was not present (to the same degree at least) for non-facial stimuli, then we would have some powerful evidence that the inversion effect might have its origins in the perceptual processing of the face rather than the representation of the face in memory. Furthermore, if this could be demonstrated then we would have to see the face as a rather special type of context,
and would have to accept that even very low-level perceptual processes can be under
the influence of much higher-level pattern recognition processes.

\textbf{4.7 In search of a paradigm}

A paradigm is required that will enable us to investigate the perceptual processes
underlying face recognition by examining the sensitivity to relevant aspects of a facial
image without requiring subjects to remember the face. The studies of the face-
superiority effect discussed above are interesting, but are of limited value for two
important reasons. Firstly the face-superiority effect has not been shown to be face-
specific, and secondly, the effect has normally been demonstrated as an advantage of
the identification or detection of the whole face over the scrambled face. This second
factor particularly limits our ability to draw conclusions about the processes
underlying person identification.

The type of approach adopted in the face-superiority studies needs to be extended to
cover the identification of features relevant to individuation. Tanaka & Farah (1993)
and Rhodes, et al. (1993) have both, in rather different ways come quite close to this
point. Tanaka & Farah reported what was probably a face-superiority effect with faces
but not with houses, hence demonstrating an apparently face-specific effect. However,
the stimuli used by Tanaka & Farah lacked realism (they were produced using the
"Mac-a-Mug" computer package) and the aspects of the face manipulated (replaced)
were isolated features, such as noses and mouths, rather than the more relational
features that seem to be important for recognition. Rhodes et al used scanned images
of real faces and hence the images are slightly more realistic, and some of the
transformations applied by Rhodes et al were of a more relational quality. However,
one problem with the manipulations used in this study was that it was not always possible to determine which change was being detected by the subject. Rhodes et al, also compared the sensitivity to these feature changes in the upright and inverted conditions; what they failed to do was to compare the sensitivity to such changes in face and non-face stimuli. Rhodes et al, like Tanaka & Farah, may have been observing some form of face-specific, face-superiority effect, but we can not be sure that this is the case.

In order to test the hypothesis, that the inversion effect is an example of a "true face-superiority effect"\(^3\), an experiment that combines certain aspects of these two studies is required. A procedure is needed that would allow one to determine the sensitivity to feature changes while placing no memory load on the subject. Further, the number of feature changes employed should be limited so that it is possible to determine which changes are being detected by the subjects, and the sensitivity to these changes should be assessed in upright and inverted, face and non-face images.

Finally, in chapter 2 I observed that Valentine's model of the mental representation of faces (Valentine, 1991), unlike that of Diamond & Carey (1986), predicts that the effects of inversion and negation should be independent and additive in their disruptive effect on face perception. It would also be useful therefore to assess the effect of this image manipulation on the perceptual sensitivity to the image.

\(^3\)Henceforth I shall use this phrase "true face-superiority effect" to describe a face-specific advantage for the perceptual processing of the parts of face pattern in the presence of the whole, coherent and normally oriented, context.
Chapter 4  The face as a visual stimulus

The experiments reported in the following chapters were all designed to meet these requirements for a procedure that allows the assessment of subjects’ perceptual sensitivity to upright and inverted face and non-face images.
Chapter 5

Experiment 1:

Sensitivity to feature displacement in normal, negative and inverted faces
5.1 Introduction

In chapter 4 I argued that it was possible that the inversion and negation effects were examples of a face-superiority effect whereby the context of the upright positive face facilitates more accurate perceptual processing of the features making up that context. I argued that to test this explanation a procedure was required which allowed us to determine the accuracy with which the features of face and non-face patterns were perceived when presented upright and inverted. Furthermore, it is essential that this procedure assesses only perceptual accuracy and does not require subjects to remember the face.

Haig (1984) described an interesting technique for investigating the perception of faces that seems to potentially meet this list of requirements.

5.1.1 Sensitivity to the displacement of facial features

Haig (1984) noted that Mathews (1978) had shown that the recognition of a face was not only dependent on the incorporation of the correct features (i.e. nose, mouth etc), but also that these features were located in their appropriate positions. This type of positional description of the features is, of course, what has more recently been termed the configurational aspects of the face. Haig reasoned that in order to determine the importance of these types of locational features we needed to move the features in real faces. He developed a computer system that, through the use of histogram-stretching, contrast-matching and feature-displacement routines allowed areas of an image digitized to 128x128 pixels (with 8 bits of grey level information), to be moved without causing noticeable boundaries to develop around the displaced image segment.
Using this technique Haig prepared transformed versions of 5 different faces. The transformations employed were: eyes displaced vertically (eyes up/eyes down); eyes displaced horizontally (eyes narrow/eyes wide); nose displaced vertically (nose up/nose down); mouth displaced vertically (mouth up/mouth down); Mouth stretched (mouth wide/mouth narrow); mirror transformation (normal image/mirror image); all internal features displaced vertically (face up/face down); and a global stretch of the image (head narrow/head wide). With the exception of the eyes narrow/eyes wide transformation (in which the position of each eye was moved either inwards or outwards by 1 or 2 pixels), and the head narrow/head wide transformation (in which the head was narrowed or widened by either 5% or 10%), all other transformations involved the movement of between 3 pixels upwards (or outwards) and three pixels downwards (or inwards) in one pixel steps. This gave a total of 38 transformed images and the 1 original, resulting in a set of 39 images for each of the 5 faces used.

The subjects were required to study the original face presented for 50 seconds on a computer monitor. After this "familiarisation" period one of the 39 images was chosen at random and presented for 1 second on the screen. The subject had to then make a decision as to whether the image was the "original" or the "modified" form of the face. After the decision had been made the original was again displayed (at a different location to avoid template matching) for a further 7 seconds before the next trial. In this way the subjects were reminded of the appearance of the original face before each trial.

Haig commented that the pattern of sensitivities seemed to be similar for each of the five faces (2 of which were female, and at least one of which was familiar) and for each of the five observers. Greatest sensitivity was to the mouth-up transformation,
with observers noticing an average of less than 1.2 pixels movement in this direction (in a 128 pixel wide image where the inter-pupil distance is 30 pixels). This represents a sensitivity of almost 1 minute of visual angle - close to the visual acuity limit (Graham, 1965). Interestingly the sensitivity to mouth-down displacements was significantly less at an average of 1.4 pixels. Haig commented that this result, taken together with the difference in sensitivity between the nose up and the nose down conditions, might suggest that some form of "ratio-metric" effect was in operation, with the upper lip depth, or area being computed. This use of ratio-metric measures of the face could also explain the lower sensitivity to outward than inward movements of the eyes.

Similarly the sensitivity for vertical movement of the eyes was very great, but the sensitivity for vertical movements of the whole face was much less. From the rather complex pattern of results Haig concluded that "open areas of the face are significant features in their own right".

This procedure is an interesting one. Haig has demonstrated that we differ in our sensitivity to the displacement of certain features compared to others, and has provided evidence that certain ratio-metric comparisons are being encoded when a face is perceived.

Hosie, Ellis & Haig (1988) used the technique pioneered by Haig (1984) to investigate the effect of feature displacement on the perception of well-known faces. Hosie et al. reasoned that there was considerable evidence of different mechanisms being involved in the processing of familiar and novel faces, with the recognition of familiar faces being more dependent on internal features whereas novel faces were better recognized
from external features (e.g., Ellis, Shepherd & Davies, 1979; Young, et al., 1985). They therefore used Haig's technique with familiar faces to allow a comparison of the pattern of sensitivities obtained with familiar and unfamiliar faces. One important modification to the procedure adopted was that Hosie et al. used a perceptual judgement task where the subjects could simultaneously compare the altered and the original image. In this task subjects were asked to compare the two images (the original and a modified image) and were asked to rate the similarity of the pair on a 100 point scale.

The results showed a very high level of agreement for the two famous faces used, with the correlation of the ratings being significant for the eye and mouth displacements. A multi-dimensional scaling procedure was applied to the data, and the best solution was a two dimensional space where the dimensions seemed to correspond to the positions of the eyes and mouth. In the case of one of the famous faces, the pattern that emerged was particularly clear, with the inward/upward and up/down movements of the eyes clearly separating out in the two dimensional space plotted.

One of the major differences between the data reported by Haig (1984) and that of Hosie et al., was that Haig found that subjects were much more sensitive to inward displacements of the eyes than outward. Hosie et al. found that both these changes resulted in subjects reporting large differences in appearance. They explained this difference by the fact that they used famous faces, but given that at least one of the faces used by Haig was also known to the subjects (Haig's own face), it seems at least as likely that this difference is a consequence of the changes in both the task-demands and the dependent variables being employed; Haig measured the sensitivity to change, whereas Hosie et al. recorded subjects' impression of the difference in appearance.
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Experiment 1: Normal, negative & inverted faces

caused by the change. Furthermore, Haig's subjects had to remember the normal appearance of the face, while the subjects in the Hosie et al. study could directly compare the normal and transformed image.

Hosie, et al. (1988) also argued that as the horizontal and vertical displacements of the eyes seemed to separate out in their two dimensional solution to the multi-dimensional scaling analysis, then it was likely that "subjects were responding to the change in facial configuration, and not to the displacement of the feature itself" (page 473). Thus, Hosie et al. agreed with Haig that the sensitivity to feature displacement observed was the result of face-specific processing of the image.

5.1.2 A new technique

The feature displacement technique employed by Haig (1984) and Hosie et al. (1988) is clearly a useful one, and the ability to manipulate the location of a single feature answers the earlier criticism made of the procedure adopted by Rhodes, et al. (1993). In fact, Rhodes et al. did employ one feature displacement manipulation in that they varied the position of the eyes. They found that sensitivity to this manipulation was lower when the face was inverted than when upright, however the procedure adopted did not allow for this effect of inversion to be quantified precisely.

The technique employed by Hosie et al. is preferable to that used by Haig in that Hosie's subjects did not have to remember the original face. Haig was not measuring the perceptual sensitivity to feature displacement, but rather the sensitivity of a subject's memory for such changes. To obtain a pure measure of perceptual sensitivity it is necessary to avoid placing any memory load on the subject (as does the face-
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detection paradigm of Purcell & Stewart, 1986). On the other hand, the similarity
judgement employed as the dependent variable by Hosie et al. seems inferior to the
psychophysical measure of sensitivity used by Haig. What is required is a combination
of these two procedures whereby the subject always has the original stimulus for
comparison, and simply has to say whether the target stimulus has been modified or
not, hence allowing the estimation of the subject’s sensitivity to displacements of the
features.

Haig and Hosie et al. agree that subjects are particularly sensitive to vertical
displacement of the eyes, so it would be appropriate to measure sensitivity to this
displacement in normal and inverted faces and non-faces. There is some disagreement
about the relative sensitivity to horizontal displacements, but given that Haig seems
to provide some evidence that the distance of the eyes is computed as a ratio-metric
estimate (what Diamond & Carey, 1986, would call a second-order relational feature),
then this would make another suitable transformation.

This first experiment was designed to meet these specifications. Sensitivity was
measured to vertical and horizontal displacements of the eyes in normal, inverted and
negative images of the face.

5.1.3 Some hypotheses

The following hypotheses were offered:

\[ H_1 \text{ Subjects will be more sensitive to changes in the position of the eyes in an upright face than in an inverted face.} \]
Subjects will be more sensitive to changes in the position of the eyes in a normal than a negative image of a face.

These effects will emerge in a procedure that only requires the subject to make simple perceptual judgements and does not require the subject to represent the face in long-term memory or to compare the image to a representation already held in memory.

5.2 Method

5.2.1 Subjects

Twenty-nine medical students participated in the study. None was familiar with the individual whose face was shown in the stimuli, and all were naive to the hypotheses.

5.2.2 Preparation of the stimuli

The images used as stimuli in the study were all modifications of a single image showing the face of a member of staff in the Psychology Department at University College. The original image was prepared by sitting the model in front of a matt-black background. A video-camera was positioned in front of the model, with illumination provided by a single incandescent 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. This image was then captured and digitised to a resolution of 256 x 256 pixels with 8 bits of grey level information using a Pluto frame store under the control of a Corvus microcomputer. The image was then saved to disc and transferred to a Vax mini-computer where specially written software was used to threshold the image. The thresholding operation resulted in all grey levels above a criterion point
being set to white and all grey values below this same value being set to black. The
criterion point was adjusted until inspection of the resulting image showed that the
main features (the two eyes, the face surround and the mouth/nose) were clearly
separated and appeared as black features on a white background. The resulting image
was 70% black and 30% white.

The image coordinates of the features visible in the image (right eye, left eye, nose,
mouth, chin, facial surround) were then calculated, and specially written software was
used to "cut-out" each of these features which were stored as separate image files. A
novel image could then be prepared by "pasting" these features back into an image at
locations which could be determined to an accuracy of 1 pixel in the original 256 x
256 pixel image.

Photographic negatives of the image (henceforth referred to as negatives) were
prepared by substituting black pixels for white and vice versa. Inverted images were
produced by a simple rotation of 180°. The original image (full grey scale), the
unmodified thresholded image, and its negative and inverted transformations are
illustrated in figure 5.1.

The images were printed by a laser printer at a resolution of 300 dots per inch directly
onto acetate sheets suitable for use on an overhead projector.
Figure 5.1 The images used in experiment 1: Part (a) illustrates the original, 256 grey level, image which was thresholded to form the unmodified "normal" image illustrated in part (b). Part (c) illustrates the negative, and part (d) the inverted versions of the unmodified image.
5.2.3 Design

Each trial involved the projection of an overhead acetate slide. Each acetate contained three images. The top image was centred on the sheet and always depicted the face with its features in their original location. Two other images were presented below this image, one of which was identical to the top image (and hence also had the features in their original positions) and the other of which showed the face with the features in a changed location. The two lower images were deliberately slightly misaligned, with the left image lower on the acetate than the right to prevent direct comparisons of the vertical locations of the features by horizontal scanning across the slide.

In every trial the three images on the acetate were all of the same type, either normal, negative or inverted. Figure 5.2 depicts a typical acetate sheet prepared for trial.

Each subject completed a total of 120 trials. On each of these trials the eyes of the modified image (either the left or right hand image in the lower half of the acetate) were moved. This movement was horizontal in half and vertical in the other half of the trials. That is the eyes were either moved up/down or in/out. The two eyes were always displaced by the same distance. The sign of the direction also took two values, either positive or negative. A positive displacement was an outward movement for the horizontal displacements and upward for vertical displacements. A negative displacement resulted in movements in the opposite direction. The eyes were displaced by either 1, 2, 4, 6, or 8 pixels from their original location in a direction defined by the combination of the sign and direction factors for that trial.

Stimuli were of three types: Normal, Negative or Inverted. On any trial all three images were always of the same type, that is, both the top image and the lower two
images were, say, negative. The modified version of the image appeared in the left-
and right-hand locations equally frequently. Hence there were five factors involved in
the design:

Direction of displacement - 2 levels; horizontal and vertical
Sign of displacement - 2 levels; positive and negative
Size of displacement - 5 levels; 1, 2, 4, 6, or 8 pixels
Type of image - 3 levels; normal, negative, and inverted
Side of acetate - 2 levels; left- or right-hand side

Each of these factors was within-subjects, and the study employed a fully factorial
2x2x5x3x2 design (i.e. each image modification for each image type occurred once
on the left and once on the right hand side of the acetate slide), giving a total of 120
trials (120 acetate slides). These trials were presented in the same random order to all
subjects.

There were two dependent variables; the subjects’ accuracy at identifying which of the
two lower images had been modified, and their reported confidence in their decision.

5.2.4 Procedure

Subjects were tested in three groups of approximately ten, and all sat at about the
same distance from a projection screen in a dimly lit room. Subjects were told that
they would be shown a series of overhead slides depicting three images of the same
face. It was explained that in one of the lower pair of images the location of the eyes
had been changed slightly, either upwards, downwards, inwards or outwards. Each of
these directions of displacement was illustrated in a series of 10 demonstration slides that included examples of the normal, negative and inverted trials.

Subjects were told that their task was to identify which of the lower two images had *not* been modified in one of these ways, and hence was the same as the top image. It was stressed to the subjects that the features in this top image were always in their original location and hence was always available for comparison. Subjects were told that their task was identical for the three image types and that they should record their response for each trial in the answer booklet provided. Subjects indicated both their decision as to which of the lower two images was unaltered, and their confidence in that decision, by marking their response on a six-point scale of the following form:

| CERTAINLY | PROBABLY | POSSIBLY | POSSIBLY | PROBABLY | CERTAINLY |
| LEFT      | LEFT     | LEFT     | RIGHT    | RIGHT    | RIGHT     |

An example of a response booklet similar to the one used in this study is provided in Appendix 1.

Before the experimental trials began the subjects completed ten practice trials. The practice trials were selected from the experimental trials and included examples of each of the image types and each of the displacement directions/signs. Subjects recorded their responses to these practice trials to ensure that they understood how to use the response scale. On completion of these practice trials and after ensuring that all subjects understood the instructions, the experimental trials commenced.

Each slide was shown for about five seconds with a five second inter-stimuli interval during which the subjects recorded their response in their answer booklets. Subjects
were encouraged to inform the experimenter if they fell behind and were asked to ensure that they provided an answer for each trial, guessing if necessary.

A typical experimental session lasted about 30 minutes. After completion of all 120 trials, subjects were debriefed and thanked for their participation.

5.2.4.1 The dimensions of the images: The projector was set up so that the 256 pixel wide images subtended a visual angle of about 1.7 degrees, and a 1 pixel displacement was therefore equivalent to a displacement of 24 sec arc of visual angle. The centre of the upper image was 2.75 degrees above the centre line of the lower images, which were vertically displaced relative to each other by 0.65 degrees. The centres of the lower two images were separated horizontally by 2.35 degrees. In the unmodified image the centres of the eyes were 56 pixels apart (0.37 degrees), and hence a 1 pixel displacement inwards of each eye resulted in a 3.57% change in the relative location of the eyes. Likewise the centres of the eyes were 51 pixels (0.34 degrees) above the centre of the pixels making up the "nose", and hence a 1 pixel movement downwards of the eyes changes the relative vertical distance between eyes and nose by 1.96%
Figure 5.2  An example of a negative trial from experiment 1. The eyes in the right-hand image have been displaced upwards by 6 pixels.
5.3 Results

The responses recorded by the 29 subjects were analysed in two separate ways. Firstly the answer given by each subject to each trial was classified as either correct or incorrect. Secondly the answer given was used to compute a score combining both accuracy and confidence. Henceforth these two dependent variables will be referred to as the percentage correct (or accuracy) score and the certainty score. The analysis of these two dependent variables gave a very similar pattern of results and so, for the sake of simplicity, only the analysis of the % Correct Score will be reported.

Overall 72.6% of the judgements were correct (50% represents chance level performance). The data were further analysed by a three way, 3x2x2, within-subjects analysis of variance, with the factors included in the analysis being stimulus type (3 levels) direction of displacement (2 levels) and sign of displacement (2 levels). The side of the slide on which the modified image occurred was not included in the analysis as a preliminary analysis had shown the absence of any effects for this factor.

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14The analysis reported here is that published in Kemp et al., 1990. For all subsequent experiments the data has been reanalysed and details of both the accuracy and certainty data are reported. Unfortunately this was not possible in the case of experiment 1 as, due to the failure of a computer backup tape, the raw data is no longer available.

15The size of the displacement was not included as a factor in the analysis as this is unnecessary. A main effect of such a factor would simply indicate that larger displacements were more easily detected, and an interaction between this and another factor (Direction for example) would simply tell us that some directions of displacement are more difficult to detect than others and so require a larger displacement to be introduced before they can be reliably detected. As there were equal numbers of 1, 2, 4, 6 and 8 pixel displacement trials, any effect of the size of displacement factor will be automatically reflected in the overall percentage correct score. Hence the inclusion of this factor would not provide any additional information.
The main effect of image type was significant, \( F_{2,56} = 5.86; p < 0.01 \), with the detection of feature displacement being most accurate for normal images, and less accurate for inverted and negative images. A *posteriori* analysis showed no significant difference in performance between negative and inverted images. This result is illustrated in figure 5.3.

The main effect of direction of displacement was also significant \( F_{1,28} = 150.82; p < 0.001 \), with horizontal displacements being more accurately identified than vertical displacements (86.0% and 59.1% correct overall respectively). There was also a significant interaction between direction of displacement and sign of displacement, \( F_{1,28} = 6.39; p < 0.05 \). Inspection of the means suggests that this interaction is due to subjects more accurately recognising a negative (inwards) displacement of the eyes than a positive (outwards) displacement of the eyes in the case of horizontal displacements, whereas no such effect of the sign of the displacement exists in the case of vertical displacements.

Two other interactions were significant. The two-way interaction between type of image and direction of displacement was significant \( F_{1,56} = 3.34; p < 0.05 \), which indicated that the differences in performance between the image types were greater for vertical than for horizontal displacements. Finally, the three-way interaction between image type, direction of displacement and sign of displacement was also significant \( F_{2,56} = 3.79; p < 0.05 \), which is not readily interpretable.
Figure 5.3  Experiment 1: The effect of image type on the sensitivity to feature displacement in normal, negative and inverted faces (part a) and for inwards, outwards, upwards and downwards displacements (part b).
5.4 Discussion

Before considering the significant effect of stimuli type it is worth spending some time comparing the performance of the subjects in the normal face trials in this experiment with the performance reported by Haig (1984). Haig found that subjects were approximately equally sensitive to upwards and downwards displacements of the eyes, and that subjects were more sensitive to inwards than outwards displacements. The subjects in the present study demonstrated the same pattern of results (see figure 5.3). Haig required the subjects to decide whether a face was the original or the modified form of the image, essentially a similar task to that employed in the present study. However, Haig’s procedure required subjects to compare the stimuli to their memory of the original, unmodified face, whereas the procedure adopted in the present study did not require any comparison to a stored representation of the face as the subjects always had an image of the unmodified face available for inspection. In this sense the task demands were largely perceptual and did not rely on the subjects’ memory for the unfamiliar face.

The other major difference between Haig’s study and the present study was that Haig used full eight-bit grey level images (256 grey levels) while the present study utilised very simple one-bit, black and white representations. Given these differences in both the stimuli and the task demands it is perhaps surprising that the two studies have produced broadly comparable results.

Haig (1984) argued that the pattern of differential sensitivity to the various types of displacement provided evidence that the images were being processed specifically as faces. Differences in sensitivity, for example to inward and outward displacements of the eyes, are not easy to explain in terms of the physical characteristics of the stimuli;
however, once the "faceness" of the stimuli is considered, the results make more sense. Haig argued that the particular sensitivity to inward displacements of the eyes (a sensitivity close to the visual acuity of the human visual system) was perhaps best explained as reflecting a sensitivity to eye convergence; a sensitivity relied upon in face to face social contact. Similarly Haig suggested that the relative insensitivity to manipulations that altered the width of the mouth was explainable by the fact that the mouth width will appear to change during speech production.

Thus Haig's data can be seen as providing some evidence that these stimuli are being seen as faces and are being processed accordingly. The results from the normal trials in the present study provide further support for the position that the stimuli are being processed as faces. This view is reinforced when the effect of the image type is considered.

5.4.2 The effect of inversion and negation on the detection of feature displacement

The subjects in this experiment were more accurate at detecting which of three similar patterns had been modified when those patterns were presented in one orientation than when rotated though 180 degrees. Similarly, the subjects found it easier to tell which pattern had been modified when the luminance profile of all three images was in one configuration than when it was reversed. The results obtained are really rather surprising when expressed in this way. Why should subjects be better able to make simple perceptual judgments about the relative spatial location of two image components when the context of those components is in a certain orientation?
Similarly, why should subjects be less able to make these judgements when the luminance profile of the simple black and white pattern is reversed? I wish to argue that the only way to make sense of these results is to think of the social significance of the pattern; its "faceness".

5.4.3 A "true" face-superiority effect?

In chapter 4 I described the face-superiority effect whereby a subject's ability to recognise a briefly presented facial feature was significantly improved when the feature occurred in the context of the whole, coherent, face (e.g. Homa, et al., 1976; Van Santen & Jonides, 1978). I argued that the term face-superiority was perhaps misleading, as the advantage conferred by the context of the face had not been demonstrated to be any different from that inferred by any other coherent image (for example a chair; see Davidoff & Donnelly, 1990). I argued that the appropriate experiments had not been conducted, and that phenomena such as the inversion and negation effects might be accounted for by a "true" face-superiority effect. That is, the upright positive facial image might provide a context that allows more accurate visual processing of the image components that make up that context than does any other context.

In a sense, negation and inversion provide the perfect test of the existence of such a true face-superiority effect as neither of these reversible transformations results in a change to any global image statistic. If such a manipulation alters the ability to make basic perceptual judgements about a facial image or its components, and if the same manipulations do not affect a non-facial image in the same way, then it would appear that we have evidence of a true face-superiority effect.
The fact that the participants in this study were less able to detect small displacements of the eyes in inverted or negated images than in normal images, seems to satisfy the first of these two criteria. The three images that made up any trial were always of the same type, and thus in the case of the inverted trials, subjects were only having to make simple perceptual comparisons between a pair of inverted images: never was a comparison between image types required. The same was true of the negative trials, and so the procedure removed any requirement for subjects to remember the face, or to attempt to reverse the image manipulation by, for example, attempting to rotate the image mentally. These are both task demands imposed by the paradigm normally adopted to demonstrate the inversion and negation effects. For this reason, explanations of these effects frequently assume that errors of recognition are, for example, due to errors introduced by the process of mental rotation (c.f. Valentine & Bruce, 1988) or the need to compare the face to other faces stored in long-term memory (Valentine, 1988). The procedure adopted here clearly demonstrates that these effects could be explained by much lower-level perceptual phenomena, and that it need not even be necessary to involve memory encoding processes in an explanation of the effect. Valentine (1988) suggested that the disproportional effect of inversion on face recognition only emerged when the experimental procedure involved recognising a face as one stored in memory, and noted that previous attempts to demonstrate an inversion effect using a matching task had failed. The results of this study clearly demonstrate an inversion effect in a matching task that has no memory component. However, this study has not demonstrated a disproportional effect, as only face stimuli have been employed.

It is important to recognise that the face-superiority hypothesis is not a precise explanation of the causes of the negation and inversion effects. In some senses it is
little more than an alternative description of these effects. However, its importance lies in the fact that such a description explicitly locates the causes of these effects at the stage of the early visual processing of the stimulus. The results of this experiment provide some evidence that it might be possible to explain the negation and inversion effects in terms of just such early visual processing of the stimulus.

This argument might be interpreted as supporting the existence of a specific "face detector" process and/or mechanism (see Bruce & Young, 1986). However, this can equally be couched in terms of subjects' differential expertise in perceiving very face-like and less face-like stimuli. Either of these explanations offers the possibility that the detection of a face-like pattern can focus and refine the very perceptual processes that resulted in the original perception. The "knowledge" of the existence of a face within the visual field could usefully adjust the detailed processing of the scene. For example, it might be possible to locate the features within a face more accurately given a detailed knowledge of factors such as the 3-D structure of the face/skull. Given that so much of the face shape is very tightly constrained, it is easy to see how a knowledge of the way in which faces vary might assist in their accurate perception (and hence their individuation).

It is because the appearance of the human face is so tightly constrained that Diamond & Carey (1986) argue that faces can only be disambiguated on the basis of second-order relational features. An interesting distinction emerges between Diamond & Carey's description of the inversion effect and that offered above. Diamond & Carey

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14It is interesting to note that within the field of machine vision there is considerable interest in procedures designed to locate a face within a field of view so that the processing of the image can be focused towards that area of the scene.
see the constrained form of the human face as a problem for the perceptual system that can only be overcome by a reliance on second-order relational features identified through experience with the class of stimuli. In contrast, the explanation offered above sees the constrained form of the human face as inferring a perceptual advantage by providing a wealth of implicit knowledge about the structure of the face that is used by the visual system to refine the perceptual processes.

If we are to argue that these results can be described in terms of the operation of true face-superiority effect then we need to satisfy the second of the criteria posed above. That is, we need to demonstrate that the effects of inversion and negation upon subjects' sensitivity to small displacements of the features do not apply equally well to non-face stimuli. The conventional inversion effect (i.e. the reduced recognition memory for inverted faces) has been widely studied, precisely because it has been shown especially to affect face recognition. The perceptual inversion effect demonstrated in this study has not, as yet, been shown to be specific to faces, or even to affect faces more than other stimuli. Until this can be demonstrated we can not be sure that we have not simply stumbled upon a more general effect that reflects some basic perceptual process common to the perception of all coherent patterns which have a "normal" orientation and contrast polarity. That is we need to be sure that we have located a face-superiority effect and not another, rather unusual, object-superiority effect. This will be the focus of experiment 3, but before undertaking that investigation it is necessary to consider what else we can learn from the negation and inversion manipulations of face-like stimuli.
5.4.4 Alternative explanations

In chapter 2 I reviewed the existing explanations of the inversion effect and identified two of these as being particularly worthy of further investigation. These are the second-order relational feature theory proposed by Diamond & Carey (1986), and the face-space model proposed by Valentine (1991). These explanations will now be reconsidered in light of the data from the current study.

5.4.4.1 The second-order relational feature model: As was pointed out in chapter two, a central tenet of Diamond & Carey’s explanation of the inversion effect is that the encoding of second-order relational features is more disrupted by inversion than is the encoding of first-order relational features. Tanaka & Farah (1991) and Rhodes, et al. (1993) both attempted direct tests of this aspect of the explanation, but neither were able to offer conclusive evidence either for or against. One particular problem identified with this explanation was the difficulty in classifying features as either first- or second-order. At first sight it would appear that the precise location of the eyes within the face is a prime example of a second-order relational feature, and so we might expect Diamond & Carey to predict that subjects would be less sensitive to changes in the location of the eyes in an inverted than upright face; precisely the result we have just observed. Diamond & Carey offer no comment on the negation effect, and so the fact that negation and inversion led to very similar outcomes neither supports or undermines their position. There is, however one problem with this interpretation. If this difference in sensitivity between upright and inverted trials had not been apparent it would have been possible to argue that the subjects were not relying on the perception of the second-order relational features when undertaking the task. This is precisely the argument that Rhodes, et al. (1993) employed to help explain some of their data. In this case it would be relatively easy to argue that the
Chapter 5  Experiment 1: Normal, negative & inverted faces

area of the face between the eyes forms a first-order relational feature. The subjects could have made use of this first-order feature when tackling the task and hence been immune to the effects of inversion. This is clearly a nonsense; if any result can explained as being either in support of, or contrary to, the model then the model has no worth. Until we can pre-define features as either first- or second-order then there is nothing to be gained from pursuing this explanation of the inversion effect. The advantage of the new explanation that I am offering is that it is not necessary to attempt to classify features as first- or second-order. All that is necessary is to argue that the whole face provides a context that focuses and guides the perceptual processes allowing any feature to be more accurately perceived.

5.4.4.2 Valentine’s face-space model: Valentine (1991) sought to explain the representation of faces in memory using an analogy to a multi-dimensional space within which the faces are located. This model has considerable utility in that it can explain much of the existing data (see for example, Valentine, 1991; Valentine & Endo, 1992) and it makes several predictions. One of these predictions would seem to be that even if the negation and inversion effects have different causes, they will act in the same way by increasing the error inherent in the encoding of the face.

Although it is not clear that this model would necessarily predict the result we have observed, there is no doubt that it is compatible with the fact that subjects are less sensitive to feature displacements in upright or inverted faces than normal faces. It could be argued that the effect of orientation on the detection of feature displacements is an example of the more error-prone encoding of some of the dimensions of the face space.
This is not really an explanation of the effects as Valentine does not seek to explain why the encoding is more error-prone. He prefers instead to concentrate on the consequences for the representational system of this error in encoding. It is not clear whether we should see the error-prone encoding as a result of, or as a cause of, the inversion and negation effects. That is, Valentine is not really specifying the causes of these effects, and for this reason I argued in chapter 2 that the Valentine and the Diamond & Carey explanations are not mutually exclusive.

The major difference between Valentine’s position and that offered here is that I am explicitly seeking to describe the less accurate perceptual encoding of the inverted or negated face as a cause of the inversion and negation effects.

5.4.5 Comparing inversion and negation

In this study I have demonstrated that inversion and negation decrease subjects' sensitivity to feature displacements by similar amounts. This is important because, as Valentine (1988) pointed out, these two effects have not previously been directly compared. It is also important to investigate how these two effects interact with each other. In chapter 3, I argued that the inversion and negation effects probably have different causes, and that it was important to investigate the way in which these two effects interact.

A logical extension of the Diamond & Carey (1986) explanation of the inversion effect is that, a face that is both negative and inverted should be no harder to

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17 Although this has since been done; see chapter 3.
recognise than an image that is only inverted. This is because Diamond & Carey argue that inversion prevents (or at least severely hinders) the encoding of second-order-relational cues; the cues that most easily allow individuation. A similar logic has also been applied to the interaction of race and inversion by Rhodes, et al. (1989) who predicted that inverted other-race faces will be no more difficult to recognise than inverted own-race faces. The logic of this prediction is that, if the own-race advantage results from expertise with that racial group allowing a more appropriate selection of features for encoding, then inversion, which acts by preventing the encoding of second-order relational features, will abolish this advantage. In other words, the inverted face is not processed as a face, and so no own-race advantage will apply. The same line of argument can be applied to the interaction between inversion and negation. Quite simply, if we assume that negation is a transformation that especially affects face-like stimuli, then inversion will render the stimuli non-face-like, and so the negation transformation will cause no additional decrement in performance. Thus Diamond & Carey would seem to predict that these two transformations will not be additive in their effect.

As discussed in chapter 3, Valentine's multidimensional face space model makes a different prediction concerning this interaction. Valentine explicitly states that all image transformations such as blurring, filtering, inversion and negation act by increasing the noise associated with the encoding processes, and so any combination of these manipulations will have an additive effect on recognition performance. That is, as the encoding of the dimensions of a face that is both inverted and negated will

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18 The race effect is seen as operating through a slightly different mechanism; see chapter 2.
be more error-prone than a face that has been transformed in just one of these ways, then the recognition performance with such faces will be very poor. It will be harder to recognise a face that is both inverted and negated than a face that is either just negated or just inverted.

By investigating the nature of the interaction between the inversion and negation effects we can begin to separate these two competing explanations of the inversion effect. Valentine's model predicts that the effects will be additive in their consequence on the detection of feature displacements, while Diamond & Carey's model predicts that the addition of the extra manipulation will not make the task any more difficult. The next experiment therefore includes a fourth type of stimuli; faces that are both negated and inverted.
Chapter 6

Experiment 2: Negative-inverted faces

Chapter 6

Experiment 2:

The interaction between inversion and negation
6.1 Introduction

In Experiment 1 it was demonstrated that sensitivity to small displacements of the eyes within a facial image decreased when the face was either inverted or negated. In the previous chapter I argued that it was important to study the nature of the interaction between these two transformations. The following study is therefore largely a replication of the previous one, but with the addition of an extra image type, one that is both negated and inverted.

Given the results of the first experiment, the following hypothesis was offered.

\( H_1 \) Subjects will be no less sensitive to small displacements of the eyes within a face that is both negated and inverted than within a face that is either negated or inverted. That is, the effects of negation and inversion will not be additive in their detrimental effect on the sensitivity to feature displacements.

In experiment 1 inversion and negation were found to approximately equally affect a subject's sensitivity to feature displacements, and so a prediction of a non-additive interaction means that we would expect the three image types, negative, inverted, and negative-inverted to be equivalent and all result in reduced sensitivity relative to the normal face trials.
Chapter 6  

Experiment 2: Negative-inverted faces

6.2 Method

6.2.1 Subjects

Twenty-three subjects participated. All were undergraduate students of Psychology at North East London Polytechnic. None of the subjects was familiar with the individual depicted in the images, and all had normal, or corrected to normal, vision. All were about 20 years of age.

6.2.2 Preparation of the stimuli

The images used in experiment 2 were identical to those prepared for experiment 1 except that a fourth type of image was prepared by both inverting and negating the face (henceforth referred to as negative-inverted). An example of a negative-inverted trial is depicted in figure 6.1.

6.2.3 Design

The design of this study was the same as used for experiment 1 except for two minor modifications. Firstly there were now four image types, normal, negative, inverted, and negative-inverted. Secondly only three levels of feature displacement were employed, with features being displaced by either 2, 4, or 6 pixels in this study. This modification was made to reduce the number of trials required in light of the increase in the number of levels of the image-type factor. Experiment 1 had revealed that performance with a 1 pixel displacement was close to chance and with 8 pixels was close to 100%, and it was therefore felt that little information was being gained by the inclusion of these two levels of the size factor, and they could be excluded from the study with very little effect on the power of the design.
Chapter 6 Experiment 2: Negative-inverted faces

As a result of these two changes, experiment two was a fully balanced 2x2x3x4x2 design. The factors of, Direction of displacement (2 levels), Sign of displacement (2 levels), Size of displacement (3 levels), Image type (4 levels), and Side of slide (2 levels), were all within-subjects, and thus the participants were all exposed to a total of 96 experimental trials.

6.2.4 Procedure

Subjects were tested in a single group, all experiencing the trials in the same random order and under the same viewing conditions. All subjects were seated a similar distance from the screen in a dimly lit room.

The instructions given to the subjects were identical to those used in experiment 1, except that subjects were told to identify the image which was different from the original, top image. This modification was made in light of comments made by the subjects in experiment 1 who had reported that it would be easier to look for the "odd-one-out" in the set of three images. As in experiment 1, subjects were shown a series of demonstration slides including examples of each type of image, and each direction and sign of displacement. All subjects then completed ten practice trials selected at random from the experimental trials before starting the run of 96 experimental trials. The experimental session lasted about 30 minutes. On completion subjects were debriefed and thanked for their participation.

6.2.4.1 The dimensions of the images: The projector was set up so that the 256 pixel wide images subtended a visual angle of about 2.4 degrees, and a 1 pixel displacement was therefore equivalent to a displacement of 34 sec arc of visual angle.
Figure 6.1 An example of a negative-inverted trial from experiment 2. The eyes in the right-hand image have been moved upwards by 6 pixels.
Chapter 6

Experiment 2: Negative-inverted faces

6.3 Results

Two dependent variables were derived from the raw data, the accuracy score (percentage of correct responses) and the certainty score. The certainty score was a combined measure of the subject's accuracy and confidence, and was calculated by allocating a score of 1 to a "certainly" response, 0.6 to a "probably" response, and 0.2 to a "possibly" response. These scores were then multiplied by +1 for a correct decision or -1 for an incorrect decision. Thus, for each trial a subject's certainty score could be -1, -0.6, -0.2, 0.2, 0.6 or 1.

Each of these dependent variables was subjected to analysis by a three-way, 2x2x4, repeated measures analysis of variance. The factors included in the analysis were:-

- Negation (positive or negative image)
- Orientation (upright or inverted orientation)
- Movement (displacement either inwards, outwards, upwards or downwards)

The factor entitled Movement was created by combining the two design factors Direction and Sign in order to simplify the analysis and the interpretation of the results.

6.3.1 Accuracy Data

The analysis of variance revealed a significant main effect of Negation ($F_{1,22}=10.83; p=0.003$) with feature displacement being less accurately detected in negative than positive images. Similarly, the main effect of Orientation was significant ($F_{1,22}=12.51; p=0.003$).
Experiment 2: Negative-inverted faces

$p=0.002$) demonstrating greater sensitivity to displacement in upright than inverted images. However, the interaction between these two factors was not significant ($F_{1,22}=0.97; p=0.335$) suggesting that the two effects are additive. See figure 6.2a.

The main effect of the Movement factor was also significant ($F_{3,66}=43.12; p<0.0005$), indicating that, overall, some directions of displacement were easier to detect than others. See figure 6.3a. Both the Negation by Movement, and the Orientation by Movement two-way interactions were non-significant ($F_{3,66}=1.99; p=0.124$, and $F_{3,66}=0.23; p=0.876$ respectively). The three-way Negation by Orientation by Movement interaction was also non-significant ($F_{3,66}=0.68; p=0.564$).

*A priori* analyses revealed no significant difference in the sensitivity to feature displacements in negative and inverted images ($F_{1,22}=0.246; p=0.625$), but a significantly greater sensitivity in the negative and the inverted images than in the doubly transformed, negative-inverted image ($F_{1,22}=5.266; p=0.032$).

6.3.2 Certainty data

The analysis of the certainty data revealed a very similar pattern of results to that described above, and so only differences between these two analyses are reported here. The main differences were that with the certainty data the interaction between Orientation and Negation just achieved significance ($F_{1,22}=4.53; p=0.045$), and that the interaction between Negation and Movement was significant ($F_{3,68}=4.47; p=0.006$). See figures 6.2b and 6.3b.
6.3.3 Sensitivity to different directions of displacement

Several *a priori* analyses were undertaken to compare the sensitivity to inwards and outwards, upwards and downwards, and horizontal and vertical displacements for each of the four types of image. The results of these analyses are summarised in table 6.1. As can be seen from the table, subjects were more sensitive to horizontal than vertical displacements in all image types. However, the relative sensitivity to inwards and outwards displacements varied with image type. Subjects were significantly more sensitive to inwards than outwards displacements in the negative and negative-inverted faces, but equally sensitive to these two displacements in normal and inverted images. Subjects were equally sensitive to upwards and downwards displacements for all image types. Analysis of the certainty data revealed an identical pattern of results. See figure 6.3 parts (a) and (b).
Table 6.1 Univariate $F$-tests with (1,22) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>$F=1.35; p=0.257$</td>
<td>$F=97.84; p&lt;0.0005$</td>
<td>$F=1.23; p=0.279$</td>
</tr>
<tr>
<td>Negative Faces</td>
<td>$F=11.78; p=0.002$</td>
<td>$F=50.32; p&lt;0.0005$</td>
<td>$F=0.617; p=0.441$</td>
</tr>
<tr>
<td>Inverted Faces</td>
<td>$F=0.24; p=0.628$</td>
<td>$F=85.27; p&lt;0.0005$</td>
<td>$F=0.50; p=0.486$</td>
</tr>
<tr>
<td>Neg-Inv Faces</td>
<td>$F=13.65; p=0.001$</td>
<td>$F=109.79; p&lt;0.0005$</td>
<td>$F=1.37; p=0.254$</td>
</tr>
</tbody>
</table>
Figure 6.2  Experiment 2: Sensitivity to feature displacement in normal, negative, inverted and negative-inverted faces as measured by accuracy (part a) and (certainty part b).
Figure 6.3  Experiment 2: Sensitivity to inwards, outwards, upwards and downwards feature displacements as measured by accuracy (part a) and certainty (part b)
6.4 Discussion

6.4.1 The interaction of the inversion and negation effects

It is clear that the hypothesis cannot be accepted. The absence of a significant interaction between inversion and negation (for the accuracy data) suggests that these effects are additive in their effect on the sensitivity to displacement (although not necessarily confidence about this decision). Inspection of figure 6.2a makes it clear that subjects found the trials in which they had to compare images which were both negated and inverted considerably more difficult than either the negative only, or inverted only, trials. This additive effect of the two transformations would seem to be contrary to the predictions based on Diamond & Carey (1986) as outlined in the previous chapter, but is entirely compatible with the Valentine (1991) model.

The fact that this interaction is just significant for the certainty data probably reflects the fact that the subjects cannot precisely introspect, or record, their own confidence about a decision. In this case, they might have been less accurate with the doubly-transformed images, but they were not always less confident in their decision. This could also reflect a floor effect. If subjects record very low confidence scores for the negative and inverted images then they are not able to record even lower confidence scores for the negative-inverted images.

6.4.2 Interpreting the additive effect

Within the framework of the "true" face-superiority effect this result suggests that, with the introduction of each image transformation that moves us away from the normal facial context, we are less able to make use of our knowledge of the highly constrained facial form to focus our perceptual processes. This does not mean that we
Chapter 6

Experiment 2: Negative-inverted faces

do not know that we are looking at an image of a face when that image is both negated and inverted. It cannot be claimed that merely because inverted faces are recognised as faces per se, their recognition as faces, as opposed to some other object, demonstrates that we have access to the full range of information that is available from the upright face. The perception of "faceness" (i.e. identifying a face as a face) is not necessarily the same process as distinguishing between faces, and need not rely on the same information. Hence, to demonstrate that we know a face is a face is not to demonstrate that we can engage the perceptual processes normally involved in the individuation of faces.

The face-superiority effect model suggests that, the more face-like an image is, the more that the perceptual processing of the form can be refined and focused through a knowledge of the structure of the face. Seeing a pattern as a face is clearly a precursor to recognising that face as belonging to a particular individual, but the fact that we can do the former does not prove that we can efficiently do the latter. The fact that we know that we are looking at an inverted and negated image of a face does not mean that we are able to overcome these transformations and recognise the individual depicted. The inversion and negation transformations can sufficiently disrupt the perceptual processes to prevent individuation without preventing us from identifying the image as that of a face.

6.4.3 Sensitivity to inward and outward displacements

It is of considerable interest that the differential sensitivity to inward and outward displacements of the eyes varies with image type. If we accept that the image type manipulation only makes sense in the context of "faceness", then this would seem to suggest that this difference in sensitivity between inward and outward displacements
is also genuinely a feature of faceness. Haig (1984) argued that this difference in
sensitivity was a function of the stimulus being a face (as opposed to some basic
perceptual function of the stimulus of the sort that I have argued could give rise to the
difference between horizontal and vertical displacements). At first sight it would
appear that this result confirms Haig’s position; however, the a priori tests (see also
figures 6.3a and b) revealed that inward displacements were only detected more easily
than outward displacements in images with negated luminance profiles - i.e. negative
and negative-inverted images. For the normal and inverted image types there was no
significant difference in sensitivity to these two types of displacement. This could
result from negation either enhancing the detection of inward displacements, or
disrupting the detection of outward displacements. Close inspection of both parts of
figure 6.3 would seem to suggest that the latter is the case: negation seems to be
differentially decreasing the sensitivity to outward displacements of the eyes. Why this
should be is far from clear. Haig (1984) reported that inward displacements were more
easily detected than outward displacements in all of the faces studied. As all of Haig’s
faces were presented in the normal orientation and luminance relationships we should
expect to find the same effect in our normal face trials. In fact the difference reported
by Haig has only emerged in faces which have been negated. We clearly need to
establish whether this unexpected effect of negation is specific to face stimuli or
whether it generalises to any similar geometric pattern.

6.4.4 The next experiment

I have previously suggested that in order to argue for the existence of a true face-
superiority effect it would be necessary to satisfy two criteria. The first of these
criteria (that sensitivity to changes in the features of a face would be increased when
the features were part of a whole and coherent facial context) was satisfied by the
results of experiment 1. The second criterion was that the manipulations used to reduce the facial context could be shown to have no effect on non-facial stimuli. Experiment 3 was designed to test this criterion and to investigate whether the effect of negation on the sensitivity to inwards and outwards feature displacements described above, would generalise to a non-face stimulus.
Chapter 7

Experiment 3:

Sensitivity to feature displacement in normal, negative and inverted dot patterns
7.1 Introduction

I have argued that the results of experiments 1 and 2 are best interpreted in light of subjects' implicit knowledge of faces. That is, I have argued that it is the "faceness" of the upright positive image that makes it a powerful context for the perception of small dimensional changes. However, this conclusion is not entirely justifiable, as I have not demonstrated that the effect of orientation and contrast polarity on the detection of dimensional changes in an image is face-specific.

In chapter four I argued that the so-called object-superiority and face-superiority effects might offer us a novel explanation of the inversion effect, one based on the description of the face as a visual object rather than as a pattern to be encoded in long term memory. However, I also pointed out that the face-superiority effect is probably not worthy of that name, as there has been no demonstration that the effect is in any way specific to a facial context. There are no differences, either qualitative or quantitative, between the face-superiority effect and the other object- and context-superiority effects. The explanation of the inversion effect offered in chapter four relies on the supposition that the face offers a special kind of context that allows very precise visual encoding of the perceptual characteristics of the pattern. Without this, and the related supposition that inversion and negation act to reduce the power of this special context, the fact of the face's special sensitivity to orientation can not be explained.

What is required then is a demonstration that the effects reported so far are face-specific. At the very least we need to show that the effects of negation and inversion reported for the face stimuli used in experiments 1 and 2 will be reduced for non-face stimuli. Experiment 3 is therefore largely a replication of experiment 2, but employing
non-face stimuli. The stimulus in this experiment has been broadly matched in terms of its physical characteristics, to the face used in the preceding experiments. Like the face used in the previous experiments, the normal and the modified versions of this stimulus can only be distinguished by reference to second-order relational features.

The use of this non-face stimulus also allows us to investigate further the differential sensitivity to inward and outward displacements of the eyes. If, as I have argued, this effect is related to the faceness of the stimuli then we should expect to find that subjects are equally sensitive to inward and outward displacements in a non-face image whether it is normal, negative or inverted.

In contrast, the greater sensitivity to horizontal than vertical displacements reported in the previous two experiments seems to be independent of image type (normal, negative or inverted) and so is probably not a consequence of the faceness of the stimuli. Rather, this differential sensitivity is more likely to be a reflection of the fact that a 1 pixel displacement in the horizontal direction results in a greater percentage change in the position of the eyes than a one pixel displacement in the vertical direction.

7.1.1 Some hypotheses

It is therefore possible to offer three hypotheses for this experiment:

\[ H_1 \] Subjects will be equally sensitive to feature displacements in normal, negative, inverted and negative-inverted non-facial images.
Chapter 7

Experiment 3: Dot patterns

H₂ Subjects will be equally sensitive to inward and outward displacements of the "eyes" for all four image types.

H₃ Subjects will be more sensitive to horizontal than vertical displacements of the eyes for all four image types.

7.2 Method

7.2.1 Subjects

Ten undergraduates studying Psychology at North East London Polytechnic participated in the study. All had normal, or corrected to normal, vision, and all were about 20 years of age. None of the subjects had participated in either of the previous experiments and all were naive to the hypothesis.

7.2.2 Preparation of the stimuli

The images used in experiment 3 were constructed using specially written software. An "original" image was produced "drawing" three identical black circles in a 256 x 256 pixel image file. The diameter of the circles was such that the total area of black pixels in the circle approximately matched the area of the eyes in the thresholded face image used in the previous two experiments. The three black circles were placed in the image frame at coordinates that matched those of the left eye, the right eye, and the mouth in the face image. Figure 7.1 illustrates the original dot-image constructed in this way.

This image was then manipulated in the same way as the thresholded face in the previous experiments, to produce normal, negative, inverted and negative-inverted
Chapter 7  

Experiment 3: Dot patterns

types. As in experiment 2, 96 experimental trial slides were constructed from this image by displacing the "eye-dots" either inwards, outwards, upwards or downwards, by one of three distances, and for four different image types. Figure 7.2 illustrates a typical experimental trial from this study.

7.2.3 Design & Procedure

The design of experiment 3 was identical to that used for experiment 2, the only modification being that the non-face, dot patterns were used as the stimuli.

The subjects were tested in a single group, and all saw the trials in the same random order. The subjects all sat a similar distance from the screen in a dimly lit room.

The instructions given to the subjects were identical to those in experiment two. As in experiments 1 & 2, subjects were shown a series of demonstration slides including examples of each type of image, and each direction and sign of displacement. All subjects then completed ten practice trials before undertaking the run of 96 experimental trials.

The experimental session lasted about 30 minutes. After completion of the trials subjects were debriefed and thanked for their participation.

7.2.3.1 The dimensions of the images: Experiments 2 and 3 were conducted in the same room with the projector and screen in the same positions, and the subjects seated a similar distance from the screen, so the dimensions of the projected image were broadly comparable to those in experiment 2.
Figure 7.1 The dot pattern used in experiment 3. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the image respectively.
Figure 7.2 An example of an inverted trial from experiment 3. The "eye-dots" in the left-hand image have been moved outwards by 4 pixels.
7.3 Results

As in the previous experiment, two separate three-way repeated measures analysis of variance were undertaken, the first analysing the accuracy data, and the second the certainty data.

7.3.1 Accuracy Data

Neither of the image transformations significantly affected the sensitivity to feature displacements, with both the main effects of Negation ($F_{1,9}=0.03; p=0.869$) and of Orientation ($F_{1,9}=0.12; p=0.739$) being non-significant; see figure 7.3a. The main effect of Movement was significant, however, indicating that some directions of displacement were more accurately detected than others ($F_{3,27}=6.25; p=0.002$); see figure 7.4a.

The two-way interaction between Orientation and Negation was also non-significant ($F_{1,9}=0.24; p=0.638$), as were the two-way interactions between Orientation and Movement ($F_{3,27}=1.2; p=0.329$), and between Negation and Movement ($F_{3,27}=0.74; p=0.536$). The three-way interaction between Orientation, Negation and Movement also failed to reach significance ($F_{3,27}=1.23; p=0.318$).

7.3.2 Certainty Data

Analysis of the certainty data revealed an identical pattern of results to that described above. See figures 7.3b and 7.4b.
7.3.3 The effect of direction of displacement

A series of *a priori* comparisons were conducted to compare sensitivity to various directions of displacement in each of the four image types. The results of these comparisons are summarised in table 7.1 below. As can be seen from this table, subjects were equally sensitive to inwards and outwards, and to upwards and downwards displacements of the "eye-dots" in all four image types. However, subjects were shown to be more sensitive to horizontal than vertical displacements for all four image types. Analysis of the certainty data revealed an identical pattern of results.

Table 7.1: Univariate F-tests with (1,10) degrees of freedom, comparing sensitivity to different directions of displacement. *F* ratios and *p* values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td><em>F</em>=0.0; <em>p</em>=1.0</td>
<td><em>F</em>=27.0; <em>p</em>=0.001</td>
<td><em>F</em>=0.0; <em>p</em>=1.0</td>
</tr>
<tr>
<td>Negative Faces</td>
<td><em>F</em>=0.192; <em>p</em>=0.671</td>
<td><em>F</em>=6.6; <em>p</em>=0.030</td>
<td><em>F</em>=0.545; <em>p</em>=0.479</td>
</tr>
<tr>
<td>Inverted Faces</td>
<td><em>F</em>=1.385; <em>p</em>=0.269</td>
<td><em>F</em>=5.260; <em>p</em>=0.048</td>
<td><em>F</em>=1.157; <em>p</em>=0.310</td>
</tr>
<tr>
<td>Neg-Inv Faces</td>
<td><em>F</em>=0.802; <em>p</em>=0.394</td>
<td><em>F</em>=22.22; <em>p</em>=0.001</td>
<td><em>F</em>=2.723; <em>p</em>=0.133</td>
</tr>
</tbody>
</table>
Figure 7.3  Experiment 3: Accuracy (part a) and certainty (part b) for the detection of "feature" displacements in normal, negative, inverted and negative-inverted dot patterns.
Figure 7.4  Experiment 3: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted dot patterns.
7.4 Discussion

7.4.1 The effects of Negation and Inversion

It is clear from the results described above and from inspection of Figures 7.3 and 7.4 that all three hypotheses can be accepted. Figure 7.3 demonstrates that subjects were equally sensitive to displacements (and equally certain about their decisions) with all four image types. That is, the inversion and negation transformations did not have any effect on the subjects' ability to detect small displacements of parts of the image. This is in contrast to the results from experiments 1 and 2 where both of these transformations significantly decreased the subjects' ability to detect feature displacements.

It would perhaps have been surprising if these transformations had been found to affect sensitivity of feature displacement in the non-face images used in this study. It is difficult to see why subjects should be less able to compare two images when both are made up of, say, small white circles on a black background than small black circles on a white background. However, it is no more obvious why this should be the case for face-stimuli. It seems that these transformations are significant for a face-like stimulus but of no consequence for a stimulus that is physically very similar, but non-face like. Inspection of Figure 7.1 demonstrates this effect. It is difficult to remember which of these patterns is the "normal" and which is the negative or inverted. Although clearly reminiscent of a face, the stimuli do not have a strong "natural" orientation or luminance profile.

Previously I argued that if we were to accept that the inversion and negation effects (as demonstrated using a recognition memory paradigm) were the result of a face-
superiority effect, then we needed to demonstrate two things. Firstly, that negation and inversion disrupt the ability to perceive small details of the face patterns, and secondly that these transformations do not have a similar effect on all patterns. Experiments 1 & 2 satisfied the first of the criteria, and Experiment 3 has satisfied the second. However, although I have shown that the effects of negation and inversion on the detection of feature displacement do not generalise to all non-face patterns, I have not shown that they do not occur for other objects. The pattern used in this experiment does not represent any known object. The lack of a negation or an inversion effect with this pattern might therefore reflect the loss of a general object-superiority effect, rather than a specific face-superiority effect.

7.4.2 Sensitivity to Inward and Outward displacements

The second hypothesis was also confirmed. Subjects were equally sensitive to inwards and outwards displacements of the "eye-dots" in each of the normal, negative, inverted and negative-inverted groups of trials. This is in contrast to the previous experiment where subjects were equally sensitive for normal and inverted faces, but were significantly more sensitive to inward than outward displacements in faces that had been negated (negative and negative-inverted). Thus it seems that a peculiar and unexpected effect of the negation transformation is to make outward displacements of the eyes less detectable than inward displacements, and that this effect is specific to face-like stimuli.

Why could this be? In chapter 3 I argued that the negation effect probably acted by disrupting the shape-from-shading processes that normally help the perceptual system to interpret the 3-D shape of the face. Perhaps this newly observed consequence of negation has the same origin. If we are unable to interpret the precise topography of
the eye region of the face then perhaps it will be harder to locate the eyes precisely on the complex 3-D surface of the face. Furthermore, perhaps outward movements of the eyes cause particular problems here, either because an increase in the distance between the eyes results in a greater expanse of curved surface emerging between the eyes, or because an outward movement of the eyes takes them into a region of the face that starts to fall away from the perpendicular to the observer’s line of sight. That is, as the eyes move outwards their position must be "mapped" on to the increasingly curved surface of the sides of the face. If this latter suggestion is true, then one might predict that the negation transformation would be more disruptive if the eyes were more widely set. That is, if we took as the starting point for the eyes, a position several pixels further apart than their original location, then we might expect negation to be particularly disruptive to the detection of outward feature displacement.

7.4.3 Sensitivity to Horizontal and Vertical displacements

The third hypothesis was based on the supposition that the differential sensitivity to horizontal and vertical displacements observed in the last two studies was a consequence of the low-level, physical properties of the stimulus rather than its "faceness"; a higher-order and abstract conceptual dimension of the stimulus. The reasoning here was that the differential sensitivity to horizontal and vertical displacements had been shown to hold for all image types (normal, negative and inverted) where as the inward/outward differential sensitivity had been shown to vary with these image transformations. If we accept that these image transformations only make sense in the context of "faceness" then anything that varies with these transformations must be seen as an aspect of faceness. Thus the inward/outward differential is a consequence of the face-like properties of the stimuli (the stimuli’s higher-order properties) but the horizontal/vertical differential is a consequence of the
lower-order features of the stimulus. The results from the present study support this view. While the differential sensitivity to horizontal and vertical displacements was also observed in a stimulus that shares many low-level characteristics with a face, the differential sensitivity to inward and outward displacements was not.

7.4.4 A face specific effect?

The results of this study confirm that the effect of negation and inversion on the detection of feature displacements found in experiment 1 and 2, do not generalise to any stimulus that is a geometric approximation of the face. However, I am still not in a position to argue that I have demonstrated a "true" face-superiority effect, as I have not demonstrated that these effects do not also occur for non-face objects.

The conventional negation and inversion effects (as demonstrated using a recognition memory paradigm) have been so widely studied because they seem to affect faces more than other objects (see however, Diamond & Carey, 1986). Although I have demonstrated that an object-superiority effect can account for the failure to recognise negated or inverted faces, I cannot yet be certain that it can account for the especial sensitivity of faces to these transformations. I have therefore demonstrated a face-superiority effect, but not a "true" face-superiority effect.

The "dots" that made up the stimuli used in this study were of approximately the same size as, and in a similar position to, the eyes of the original face. Had the negation and inversion effect reported in experiments 1 and 2 been due to some previously unknown but non-specific perceptual phenomenon that affects our ability to make simple distance estimates, then the same results would have emerged from experiment
3. In fact, there is not even a non-significant trend present in the data. There appears to be absolutely no evidence of any effect of negation or inversion on these stimuli.

Given that viewing conditions were not tightly controlled either within or between these three experiments it could be argued that this failure to observe negation and inversion effects was due to a lack of sensitivity in experiment 3. Several factors suggest that this is not the case. Although not tightly controlled, the viewing conditions between experiments 2 and 3 were very similar. It seems unlikely that any small changes to the viewing conditions could have abolished the large effects observed in experiment 2. It could also be argued that the low subject numbers in experiment 3 provide insufficient statistical power to allow the detection of the effects. This seems unlikely as there are not even trends present in the data (the normal patterns actually gave rise to the poorest mean performance). Finally, the presence of a significant difference in the ability to detect horizontal and vertical displacements demonstrates the power of the procedure.

7.4.5 Sensitivity to feature displacements in a non-face pattern

The use of a non-face pattern in this experiment allows a comparison to be made between the pattern of differential sensitivities to feature displacements in face and non-face stimuli.

Haig (1984) claimed that the difference in sensitivities to horizontal and vertical displacements of the eyes and the mouth reflected face-specific processing of the stimulus. Unlike Haig, Hosie, et al. (1988) found no difference in the sensitivity to inwards and outwards displacements of the eyes. They argued that this difference was a result of their use of familiar face. A difference in sensitivity to inward and outward
displacements was also observed in experiment 1, but I argued that this could be due
to the nature of the displacements adopted, and not a result of face-specific processing.

A comparison of the results from experiments 2 and 3 support this explanation, as in
both these studies there was a significant difference in sensitivity to horizontal and
vertical displacements despite that fact that only experiment 2 employed face-like
stimuli. This suggests that this differential sensitivity is a consequence of the fact that
a horizontal displacement of 1 pixel changes the distance between the eyes by 2
pixels\(^{20}\), while a vertical displacement of 1 pixel only changes the distance between
the eyes and any point of comparison by 1 pixel.

In the case of inwards and outwards displacements, however, a comparison between
experiments 2 and 3 reveals that subjects are more sensitive to inwards than outwards
displacements for face, but not non-face, stimuli. This seems to support the suggestion
made by Haig (1984) that the inwards/outwards differential sensitivity reflects some
knowledge of faces per se rather than some simple ratio-metric effect. Haig suggested
that we might be particularly sensitive to inward displacements because of the social
importance we attach to gaze direction. Inwardly displaced eyes could be interpreted
as reflecting converging angle of gaze, and the notion that we might have some
specific and biologically determined innate mechanism for the detection of eye gaze
has recently been put by Baron-Cohen (1993).

\(^{20}\)Because both eyes are always displaced equally.
7.4.6 The concept of "faceness"

As at least one sort of non-face stimulus has been shown to be immune to these perceptual inversion and negation effects, an interesting possibility arises; these effects could be used to titrate "faceness". It should be possible to discover what aspects of a face are important in generating these effects, and this procedure could afford a novel insight into what makes a face a face. This knowledge might also help us to understand the perceptual origins of the effects by identifying what aspects of the face are necessary and/or sufficient to give rise to these effects. This in turn, might help resolve the question of whether the negation and inversion effects observed in experiments 1 and 2 are truly face-specific. The following experiments are designed with this aim in mind.
Chapter 8

Experiment 4:
Sensitivity to feature displacement in a pattern containing only the internal facial features
8.1 Introduction

The results of experiment 3 suggest that the effects of negation and inversion on the sensitivity to feature displacements may be face-specific effects. But how face-like does a stimulus have to be to give rise to the effects observed in experiments 1 and 2, and what parts of the face stimuli used in those experiments were essential for the emergence of the effects? Experiment 4 was designed in an attempt to address these questions. If the three dots used in experiment 3 were not sufficient to give rise to negation and inversion effects, then would just the three features that the dots represented be sufficient? Experiment 4 was very similar to experiment 2 except that the stimuli used consisted of the internal features of the original face, but without the surround of the face/head outline.

8.2 Method

8.2.1 Subjects

Twelve medical students from St Mary's Hospital Medical School participated in the study. All had normal, or corrected to normal, vision, and all were naive to the hypothesis. None had participated in any of the previous experiments.

8.2.2 Preparation of the stimuli

The images used in Experiment 4 were all modified forms of an image constructed by removing the facial surround from the original thresholded image of the face used in experiments 1 and 2. The resulting image consisted only of the two eyes and the nose/mouth features (see figure 8.1).
Chapter 8  Experiment 4: Internal features of the face

This image was then manipulated in the same way as the thresholded face in the first two experiments, to produce normal, negative, inverted and negative-inverted images. As in experiments 2 and 3, the overhead projector slides for 96 experimental trials were constructed from this image by displacing the eyes either in, out, up or down, horizontally or vertically, and by one of three distances, for the four different image types. Figure 8.2 illustrates a typical experimental trial from this study.

8.2.3 Design & Procedure

The design of experiment 4 was identical to that used for experiments 2 and 3. The subjects were tested in a single group, and all undertook the 96 experimental trials in the same random order. All the subjects were seated approximately the same distance from a projection screen in a dimly lit room.

The instructions given to the subjects were identical to those in experiment two. The subjects were shown a series of demonstration slides including examples of each type of image, and each direction of displacement. All the subjects then completed ten practice trials before undertaking the run of 96 experimental trials.

The experimental session lasted about 30 minutes. After completion of the trials subjects were debriefed and thanked for their participation.
Figure 8.1 The four types of stimulus used in experiment 4. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the image respectively.
Figure 8.2 An example of a negative-inverted trial from experiment 4. The eyes in the right-hand image have been displaced inwards by 6 pixels.
8.3 Results

As in the previous experiments, the accuracy and the certainty data were analysed separately. Both analyses involved a three-way, within subjects, analysis of variance.

8.3.1 Accuracy Data

Subjects detected feature displacement equally accurately in upright and inverted stimuli (i.e. the main effect of Orientation was not significant; $F_{1,11}=1.94; p=0.191$), and in positive and negative stimuli (i.e. the main effect of Negation was not significant; $F_{1,11}=1.16; p=0.305$). The interaction between these two factors was also not significant (Orientation by Negation; $F_{1,11}=0.06; p=0.815$). See figure 8.3a.

As in the previous experiments the main effect of Movement was significant ($F_{3,33}=42.79; p<0.0005$) indicating that displacements were more accurately detected when in some directions than others (see figure 8.4a). The Orientation by Movement interaction was not significant ($F_{3,33}=0.6; p=0.617$), but the Negation by Movement interaction was significant ($F_{3,33}=4.98; p=0.006$). The three-way interaction between Orientation, Negation and Movement was not significant ($F_{3,33}=2.57; p=0.071$).

8.3.2 Certainty Data

Analysis of the certainty data revealed an identical pattern of results to that described above. See figures 8.3b and 8.4b.
8.3.3 The effect of direction of displacement

A series of *a priori* tests were conducted on the accuracy data to compare the sensitivity to the different directions of displacement in the four image types. The results of these tests are summarised in table 8.1. As can be seen from this table, subjects were, once again, more sensitive to horizontal than vertical displacements for all image types. Subjects were also more sensitive to downwards than upwards displacements for all image types, and were more sensitive to inwards than outwards displacements in the negative and negative-inverted image types, but equally sensitive to these two directions of displacement for the normal and inverted image types.

Analysis of the certainty data revealed an identical pattern of results.

Table 8.1 Univariate *F*-tests with (1, 11) degrees of freedom, comparing sensitivity to different directions of displacement. *F* ratios and *p* values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>F=2.54; <em>p</em>=0.139</td>
<td>F=31.43; <em>p</em>&lt;0.0005</td>
<td>F=9.78; <em>p</em>=0.010</td>
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<tr>
<td>Negative Faces</td>
<td>F=12.69; <em>p</em>=0.004</td>
<td>F=39.60; <em>p</em>&lt;0.0005</td>
<td>F=18.41; <em>p</em>=0.001</td>
</tr>
<tr>
<td>Inverted Faces</td>
<td>F=0.61; <em>p</em>=0.809</td>
<td>F=9.10; <em>p</em>=0.012</td>
<td>F=6.81; <em>p</em>=0.024</td>
</tr>
<tr>
<td>Neg-Inv Faces</td>
<td>F=22.40; <em>p</em>=0.001</td>
<td>F=205.61; <em>p</em>&lt;0.0005</td>
<td>F=11.80; <em>p</em>=0.006</td>
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</tbody>
</table>
Figure 8.3  Experiment 4: Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal, negative, inverted and negative-inverted patterns of internal features.
Figure 8.4  Experiment 4: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted patterns of internal facial features.
8.4 Discussion

8.4.1 The effects of Inversion and Negation

The absence of a main effect of either negation or inversion might initially lead to the conclusion that the internal features on their own are not sufficient to give rise to these two effects, and thus it could be argued that these features on their own do not provide a strong enough context to allow more accurate perceptual processing of the image components. However, some caution should be exercised here, as inspection of figure 8.3a clearly reveals that a trend is present in the data, and consideration of the pattern of relative sensitivities to the various directions of displacements suggests that the stimuli used in this study might have been treated as face-like by at least some parts of the cognitive system.

8.4.2 The effect of Direction of Displacement

The analysis of the effect of direction of displacement revealed a pattern of results very similar to that obtained from experiment 2. The subjects in this experiment, and in experiment 2, were more sensitive to inward than outward displacements of the eyes, but only in the case of negative or negative-inverted stimuli types. As in the case of experiment 2, it appears that an effect of negation has been to make small outward displacements particularly difficult to detect. Earlier I argued that as the negation transformation only really made sense in terms of the higher order characteristics of the stimuli, such as its "faceness", then the emergence of a pattern of differential sensitivities to different directions of displacements which varies with the negation transformation, suggests that the stimuli are being seen (and presumably processed)
as face-like. In this sense then, there is some evidence that the patterns used in this experiment were being seen as face-like.

A further complication here is that in this experiment the difference in sensitivity to upward and downward displacements emerged as significant for all image types. In all the previous experiments subjects have performed better with downwards than upwards displacements. The difference between this experiment and the previous three is that in this case the difference is significant. This appears to be due to a very poor performance on the upward displacement trials. Inspection of figure 8.4a and 8.4b reveals that subjects were performing, on average, worse than would be expected by chance alone on these trials. Table 8.2, below, compares the subjects’ performance for the upwards and downwards trials in a little more detail. It is clear from this table that the dramatic difference in performance is not simply due to a few subjects performing very badly. Indeed, 66% of the subjects identified the modified image in less than 50% of the upwards displacement trials, and all but one of the subjects performed worse on the upwards than downwards displacement trials. By comparison, in the downwards displacement trials, none of the subjects failed to identify the modified image in less than 50% of the trials. It is as if displacing the eyes upwards made the face look more like the original than did the unmodified face. I can offer no explanation for this result. It cannot be that the removal of the facial surround has deprived the participants of a fixed reference point against which to make judgements, as in experiment 3 the stimulus was also devoid of such a reference point yet the there were no significant differences in sensitivity to upward and downward displacements. However, a simple chi-square analysis revealed that the proportion of subjects who correctly identified the upwards displacements on less than 50% of occasions was not
significantly more than would be expected by chance \((\text{chi}=1.33; \; d.f.=1; \; p=0.248)\) so we should be cautious about reading too much into this result\(^2\).

![Table 8.2](image)

<table>
<thead>
<tr>
<th></th>
<th>% of correct trials</th>
<th>% of subjects scoring more than x% correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Upwards Displacements</td>
<td>4.17</td>
<td>62.5</td>
</tr>
<tr>
<td>Downwards Displacements</td>
<td>54.17</td>
<td>87.5</td>
</tr>
</tbody>
</table>

Table 8.2 A detailed comparison of the performance in the upward and downward displacements trials.

8.4.3 Necessary and sufficient features of the face

The fact that, on their own, the internal features of the face were not sufficient to give rise to the inversion and negation effects, would seem to suggest that the external features (the face/head outline) are necessary for the emergence of these effects. But would the external features, on their own, be sufficient? This question was examined in the next experiment.

\(^2\)It is interesting to note that had a more conventional psychophysical procedure been adopted (such as an adaptive probit procedure) this unexpected pattern of results would not have been observed. Using such a procedure it would have appeared that subjects were simply very insensitive to upwards displacements. The less conventional methodology adopted in these studies reveals a more interesting picture; subjects seem to be detecting even quite small displacements but are then tending to consider that the displaced image is more like the original than is the unmodified image.
Chapter 9

Experiment 5:

Sensitivity to feature displacement in faces in which the internal features have been replaced by dots
9.1 Introduction

The results of experiment 4 seemed to indicate that, on their own, the internal features of the face were not sufficient to give rise to a negation or inversion effect. This suggests that the external features are necessary for the emergence of these effects. Experiment 5 was therefore designed to investigate whether a pattern which combined the external features of the face with the three dots used in experiment 3 would be sufficiently face-like to restore the negation and inversion effects observed in experiments 1 and 2.

9.2 Method

9.2.1 Subjects

Eleven staff and postgraduate students of the Department of Psychology at University College London participated in the experiment. All had normal, or corrected to normal vision and all were naive to the hypothesis. None had participated in any of the previous experiments.

9.2.2 Preparation of the stimuli

The stimuli were all modified forms of an image created by taking the unmodified, thresholded face image used in experiments 1 and 2, and replacing the internal features (eyes, nose and mouth) with the three dots used in experiment 3. As in experiment 3 these dots occupied the same positions in the image as the eyes and nose of the original face. Using the software developed for the previous experiments the "eye-dots" of this image were then displaced and negative and inverted forms
produced. As in the previous studies the stimuli were printed directly onto acetate sheets suitable for projection by an overhead projector. Figure 9.1 illustrates the normal, negative, inverted and negative-inverted image types used in this experiment.

9.2.3 Design & Procedure

The design and procedure of experiment 5 were identical, to those used in experiments 2, 3 and 4. All the subjects saw the 96 experimental trials in the same random order. Figure 9.2 illustrates a typical experimental trial from this study.
Figure 9.1  The four types of stimulus used in experiment 5. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the image respectively.
Figure 9.2  An example of an inverted trial from experiment 5. The eye-dots in the left-hand image have been displaced upwards by 6 pixels.
9.3 Results

As in the previous experiments, two separate analyses were undertaken, both employing a three-way, repeated measures analysis of variance.

9.3.1 Accuracy Data

The main effect of Orientation was not significant ($F_{1,10}=0.12; p=0.740$); subjects were equally sensitive to displacement of the eye-dots in upright and inverted stimuli. The main effect of Negation was, however, significant ($F_{1,10}=11.36; p=0.007$) with subject being more sensitive to displacement of the eye-dots in positive than negative images. The interaction between Orientation and Negation was not significant ($F_{1,10}=0.40; p=0.754$). See figure 9.3a.

As in the previous experiments, the main effect of Movement was significant ($F_{1,10}=36.19; p<0.0005$) indicating a greater sensitivity to displacements in some directions than others. The two-way interaction between Orientation and Movement was not significant ($F_{1,10}=0.40; p=0.754$), but that between Negation and Movement was ($F_{1,10}=6.32; p=0.002$); see figure 9.4a. The three-way interaction between Orientation, Negation and Movement was not significant ($F_{1,10}=0.88; p=0.462$).

9.3.2 Certainty Data

Analysis of the certainty data revealed an identical pattern of results to that described above. See figures 9.3b and 9.4b.
9.3.3 The effect of direction of displacement

A series of *a priori* comparisons were performed on the accuracy data to compare sensitivity to the various different directions of displacement for each of the image types. The results of these comparisons are summarised in table 9.1. Inspection of this table reveals that subjects were equally sensitive to inward and outward displacements of the eye-dots in normal images, but were more sensitive to inward than outward displacements in negative, inverted and negative-inverted images. Subjects exhibited greater sensitivity to downwards than upward displacements in all four image types, and as in all the previous experiments, were significantly more sensitive to horizontal than vertical displacements in all image types. See figure 9.4a. An identical pattern of results emerged from the analysis of the certainty data; see figure 9.4b.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
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</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>F=0.88; p=0.371</td>
<td>F=34.00; p&lt;0.0005</td>
<td>F=14.69; p=0.003</td>
</tr>
<tr>
<td>Negative Faces</td>
<td>F=9.80; p=0.011</td>
<td>F=8.03; p=0.018</td>
<td>F=29.16; p&lt;0.0005</td>
</tr>
<tr>
<td>Inverted Faces</td>
<td>F=11.27; p=0.007</td>
<td>F=42.19; p&lt;0.0005</td>
<td>F=29.16; p&lt;0.0005</td>
</tr>
<tr>
<td>Neg-Inv Faces</td>
<td>F=11.56; p=0.007</td>
<td>F=11.49; p=0.007</td>
<td>F=41.23; p&lt;0.0005</td>
</tr>
</tbody>
</table>

Table 9.1 Univariate F-tests with (1,10) degrees of freedom, comparing sensitivity to different directions of displacement. F ratios and p values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and certainty data.
Figure 9.3  Experiment 5: Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal, negative, inverted and negative-inverted patterns.
Figure 9.4  Experiment 5: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted patterns.
9.4 Discussion

9.4.1 The facial surround - a sufficient characteristic?
The discovery of a significant effect of negation upon the detection of 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 negation effect observed in experiments 1 and 2. However, the total absence of an effect of inversion is very surprising, since, as far as can be determined from the literature, this is the first demonstration of a stimulus which is affected by one transformation but not the other. It would seem that the face surround is both necessary (given the absence of the effect in experiments 3 and 4), and sufficient (given its re-emergence in this experiment), to give rise to the negation effect. The inversion effect, however, has only been demonstrated in a stimulus that contains both the internal and the external features of the face. These results therefore reinforce the view that the negation and inversion effects are independent of one another and have different causes.

9.4.2 Inversion and Negation: independent effects?
The possibility of a dissociation between the negation and the inversion effects provides the best evidence of their independence. It is important to note that, although the evidence of an additive effect demonstrated in experiment 2 suggests that these two effects are independent of one another, it does not prove this to be the case. In a footnote to their main text, Bruce & Langton (1994) point out that we should not seek to argue that two processes are independent on the basis of additivity of accuracy scores:
"This is because if each independent process has a certain probability of success (or failure) the combined probability of success (or failure) should be the product of multiplying, rather than adding, the independent probabilities."\(^{22}\) Bruce & Langton (1994)

Following the logic of this argument, the participants in experiment 2 should have made correct decisions for just over 55% of the negated-inverted stimuli (where 50% represents chance level performance). The observed level of performance was much higher than this, suggesting that the two processes are not totally independent of each other. I would dispute this conclusion for a number of reasons.

It is central to the argument that I am developing here, that knowledge of the structure of the face results in a refining and focusing of the visual processes involved in face perception. Thus negation and inversion are not seen as two processes that each have an associated probability of failure: rather, each is seen as reducing the probability of success down toward some base level that is achievable without this prior knowledge of the structure of faces. In other words, within the face-superiority effect framework, the level of performance can not fall below that achievable for a non-face stimulus; negative and/or inverted faces are disadvantaged only relative to normal faces, not relative to normal non-face objects. If performance with non-face stimuli is higher than the level predicted by the multiplication of the probabilities of success with the negative and inverted stimuli, then actual performance with the doubly transformed image will not fall below the higher of these two levels.

\(^{22}\)Bruce & Langton attribute this observation to a personal communication by Bundesen
Chapter 9

Experiment 5: face outline & dots

The fact that the level of performance achieved with the negative-inverted stimulus in experiment 2 was so much higher than might have been predicted on the basis of the observation quoted above, is thus not contradictory with the view that the effects are independent. It seems perfectly possible that the level of performance observed (approximately 70%) would be achievable with a non-face stimulus under the same viewing conditions, and the fact that the non-face stimuli used in experiment 3 resulted in a performance level of approximately 65% seems to support this view (caution must be exercised when making comparisons such as this, as viewing conditions varied between these studies).

It is evidence of double dissociation, and not arguments about absolute performance levels, that provide the most compelling evidence of the independence of the negation and inversion effects. The stimuli used in this study were prone to the negation effect but not the inversion effect, and so Kemp, et al. (1990) suggested that if a stimulus could be identified that gave rise to the orientation effect but not the negation effect, then this would be very strong evidence for the independence of these two effects. As discussed in chapter 4, Bruce & Langton (1994) suggested that one of their stimuli might provide such an example. The recognition of scanned head volumes that were devoid of pigmentation were found to be sensitive to inversion but not negation. Thus it would appear that there is evidence of double dissociation, and very good reason to believe that the inversion and negation effects are independent of each other.

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9.4.3 The causes of the Negation effect

The discovery that the face surround is so important to the emergence of a negation effect should help us to identify the causes of the effect. In chapter 4 I discussed the two most likely causes, the disruption of the shape-from-shading processes and the change in apparent pigmentation. It is difficult to reconcile the pigmentation explanation with the results of the studies in this series (it is not clear why a change in pigmentation should affect the ability to locate the features on the face), and the results from this latest experiment do not help this explanation. The face images used in these studies are very simple, and with only the facial surround present, very little apparent pigmentation is discernable. Bruce & Langton (1994) describe the changes to the apparent colouration of the eye, caused by negating the image, as an example of the pigmentation changes they believe to be so important. However, in this experiment I have shown that replacing the eyes with plain circles does not eliminate the negation effect, and the previous experiment demonstrated that a stimulus containing the original eyes (in which the relative pigmentation of the iris and the pupil is evident) need not be sensitive to negation. These observations would seem to present some difficulties for the pigmentation explanation.

It is very much easier to explain these results within the alternative, shape-from-shading explanation. The facial surround (at least in the case of the stimuli used here) is very important in providing shape-from-shading cues. Inspection of Figure 9.1 reveals how the face surround is made up of shadows caused by the facial surface falling away from the plane perpendicular to the line of sight of the camera and light source. Figure 8.1 appears very flat in comparison to figure 9.1 which seems to protrude from the page (although, I would suggest that figure 9.1 seems have less "depth" around the eyes and nose region which has the appearance of being flattened).
Thus the apparent depth of the image seems to correlate with the emergence of the negation effect, and these (admittedly rather subjective) observations seem to support the suggestion that it is the disruption of the shape-from-shading processes that result in the poorer performance with the negative image.

9.4.4 The effect of direction of displacement

In this study and in each of the preceding four, the difference in sensitivity to horizontal and vertical displacements was significant for all image types. This reinforces the view that this difference in sensitivity is a consequence of the lower-level, physical characteristics of the stimuli that have been employed. However, it has been suggested that a differential sensitivity to inward and outward displacements is a consequence of the "faceness" of the stimuli being employed. With the stimuli used in this study, participants were more sensitive to inward than outward displacements of the eyes in images that had been negated; a result previously observed with face-like stimuli. In the current study, however, the difference in sensitivity to inward and outward displacements was also significant for inverted stimuli. This is a surprising result in light of the lack of any main effect of orientation in this study, and casts some doubt on the interpretation of the pattern of differential sensitivities.

In the last experiment subjects were found to be significantly more sensitive to downwards than upwards displacements; a result that has been replicated in the current study. Once again, this seems to be a consequence of the subjects' remarkably poor performance on the upward displacement trials. A detailed comparison of the performance on the upward and downward trials is presented in table 9.2. A Comparison of tables 8.2 and 9.2 reveals that the absolute levels of performance and

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the range of scores in these two studies was very similar. However, as in the case of
the previous experiment a simple chi-square analysis revealed that the proportion of
subjects who correctly identified the upwards displacements on less than 50% of
occasions was not significantly less than would be expected by chance alone
\( (Chi=0.818; d.f.=1; p=0.366) \). It is very difficult to see what characteristic of the two
very different stimuli used in these studies might give rise to this peculiar tendency
for subjects to believe that a stimulus in which the features have been displaced
upwards is more like the original than is the unmodified image. Once again, the very
complex pattern of differential sensitivities emerging from this study must cast serious
doubt on the explanations previously offered.

<table>
<thead>
<tr>
<th>% of correct trials</th>
<th>% of subjects scoring more than x% correct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;=50%</td>
</tr>
<tr>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>Upwards Displacements</td>
<td>20.8</td>
</tr>
<tr>
<td>Downwards Displacements</td>
<td>70.8</td>
</tr>
</tbody>
</table>

Table 9.2 A detailed comparison of the performance on the upward and downward
displacements trials.

9.4.5 The next experiment

I have demonstrated that the facial surround seems to be a necessary characteristic of
a stimulus that is sensitive to negation and inversion. However, it is possible that
inversion and negation effects did not emerge with the dot stimuli used in experiment
3 (dots with no surround) simply because the task was more difficult. Both of the
stimuli that have been found to be immune to negation (experiments 3 and 4) have
been devoid of any surround. The lack of a surround might be depriving the subjects of a fixed point of reference against which to measure the position of the internal features. The importance of the face surround might lie, not only in its higher-order characteristics - its faceness, but also in the fact that its presence makes the task easier by providing a point of reference when deciding if the features have been displaced. The next experiment was designed to test this possibility.
Chapter 10

Experiment 6:
Sensitivity to feature displacement: the role
of the facial surround
10.1 Introduction

The results of the previous experiments suggest that the facial surround plays an important role in the emergence of the negation effect. However, it is possible that the surround is simply acting as a reference point, making it easier to judge accurately the location of the internal features. Experiment 6 was designed to determine whether the importance of the face surround lay in this low-level physical property, or in its significance as a facial feature. A new set of stimuli was constructed for this experiment, in which the face surround was replaced by a geometric shape which, although retaining some of the physical characteristics of the face outline and serving as a fixed reference point, remained non face-like.

10.2 Method

10.2.1 Subjects

Fourteen undergraduates studying psychology at the Polytechnic of Central London participated in the experiment. All had normal vision and all were naive to the hypothesis of the study. None had participated in any of the previous experiments.

10.2.2 Preparation of the stimuli

The original image from which all the stimuli used in the experiment were derived, was created using specially written software. The outline of the head used in experiments 1 and 2 was measured, and the dimensions of an ellipse that would approximately match the outline were calculated. The face and head outline of the original image were then removed and replaced by the ellipse which was located so
as to match the position of the head as closely as possible. This composite of an ellipse that matched the head outline and the internal features of the face used in experiments 1 and 2 formed the normal, unmodified image for this experiment. All the experimental stimuli were produced by modifying this image.

Inverted, negative and negative-inverted versions were produced by rotating the image and/or by reversing the contrast of the image. As in the previous studies the stimuli were printed directly onto acetate sheets suitable for use on an overhead projector. Figure 10.1 illustrates examples of normal, negative, inverted and negative-inverted stimuli used in the experiment. Figure 10.2 illustrates a typical experimental trial.

10.2.3 Design & Procedure

The design and procedure of experiment 6 were identical to those of experiments 2, 3, 4 and 5, with the 96 experimental trials being preceded by demonstration and practice trials. All participants experienced the trials in the same random order.
Chapter 10 Experiment 6: Features in an ellipse

Figure 10.1 The four types of stimulus used in experiment 6. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the image respectively.
Figure 10.2 An example of a negative trial from experiment 6. The eye-dots in the left-hand image have been displaced inwards by 2 pixels.
10.3 Results

As in the previous experiments, two separate analyses were undertaken, both involving a 2x2x4, repeated measures analysis of variance (Orientation by Negation by Movement).

10.3.1 Accuracy Data

Neither Orientation nor Negation significantly affected the accuracy with which feature displacements were detected ($F_{1,13}=3.37; p=0.089$; and $F_{1,13}=0.02; p=0.881$ respectively), but the interaction between these two factors was significant ($F_{1,13}=7.17; p=0.019$). See figure 10.3a. As in all previous experiments, the main effect of Movement was significant ($F_{3,39}=16.24; p<0.0005$) indicating that some directions of displacement were more easily detected than others, but the 2 two-way interactions involving the movement factor were not significant ($F_{3,39}=1.87; p=0.151$ and $F_{3,39}=0.89; p=0.456$ for Orientation by Movement and Negation by Movement respectively). The three-way interaction (Negation by Orientation by Movement) was not significant ($F_{3,39}=0.37; p=0.778$).

Post-hoc comparisons\textsuperscript{24} of the performance on the normal, negative, inverted and negative-inverted trials revealed that subjects were significantly less accurate at detecting feature displacements in the inverted trials than in the normal trials. All other comparisons were non-significant.

\textsuperscript{24}Using Dunnett's test as recommended by Howell (1992).
10.3.2 Certainty Data

Analysis of the certainty data revealed a very similar pattern of results to that reported above, the only difference being that when considering the certainty data the main effect of Orientation was significant ($F_{1,13}=5.36; p=0.038$). As with the accuracy data, post-hoc analysis of the certainty scores revealed lower scores on the inverted trials than on the normal trials. No other comparisons were significant. See figures 10.3b and 10.4b.

10.3.3 The effect of direction of displacement

A series of planned comparisons was undertaken on the accuracy data and revealed that for all four image types subjects were more sensitive to horizontal than vertical displacements. Subjects were equally sensitive to upwards and downwards displacements for all image types, and were equally sensitive to inwards and outwards displacements for normal, negative and inverted trials, but were more sensitive to inwards than outwards displacements in negative-inverted images. Analysis of the certainty data revealed an identical pattern of results. These comparisons are summarised in table 10.1.
Table 10.1  Univariate $F$-tests with (1,13) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant with the accuracy data. Analysis of the certainty data revealed an identical pattern of results.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out?</th>
<th>Horiz&gt;Vertical?</th>
<th>Down&gt;Up?</th>
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</thead>
<tbody>
<tr>
<td>Normal Ellipses</td>
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<td>$F=18.18; p=0.001$</td>
<td>$F=0.154; p=0.701$</td>
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<td>Negative Ellipses</td>
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<tr>
<td>Inverted Ellipses</td>
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<td>$F=17.80; p=0.001$</td>
<td>$F=0.00; p=1.00$</td>
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<tr>
<td>Neg-Inv Ellipses</td>
<td>$F=12.34; p=0.004$</td>
<td>$F=13.54; p=0.003$</td>
<td>$F=0.33; p=0.578$</td>
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</tbody>
</table>
Figure 10.3  Experiment 6: Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal, negative, inverted and negative-inverted features-in-an-ellipse patterns.
Figure 10.4  Experiment 6: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted features-in-an-ellipse patterns.
10.4 Discussion

The features-in-an-ellipse stimuli used in this experiment were expected to result in a pattern of sensitivity similar to that found in either experiment 3 (dots) or 2 (thresholded face). The previous experiments have suggested that the face outline must be present if the image is to give rise to negation and inversion effects. However, it is possible that the importance of the face surround lay not in its significance as a facial feature, but in that it provided a fixed point of reference against which the location of the eyes could be assessed. If it was this low-level physical characteristic of the face surround that was important, then the elliptical surround used in this study should act as an adequate replacement and the negation and inversion effects observed in experiment 2 should reemerge. If however, the importance of the facial surround lay in its "faceness" then the ellipse should not be an adequate replacement, and this image should be immune to the effect of negation and inversion (as in experiment 3).

The absence of a significant main effect of either Negation or Orientation on the accuracy of feature displacement detection suggests that the role of the face surround was not met by the ellipse. However, post-hoc comparisons of the performance with the normal and the inverted images revealed a significant difference. Thus, although the main effect of Orientation was not significant (i.e. the normal and the negative images were not significantly more accurately perceived than the inverted and negative-inverted images) the normal image was perceived significantly more accurately than the inverted image. Inspection of figure 10.3 suggests that the main effect of Orientation failed to reach significance because the performance with the negative-inverted images was better than with the inverted images. This pattern of performance also resulted in the significant Orientation by Negation interaction. Thus,
although there was no significant main effect of Orientation with this stimulus, there is evidence that subjects were affected by image orientation (but only for positive images). This position is reinforced by the fact that the main effect of Orientation was significant with the certainty data.

Given this unexpected pattern of results it was decided to replicate this experiment before considering the results in any more detail. For this reason, the following experiment (experiment 7) is a replication of experiment 6.
Chapter 11

Experiment 7:

A replication of experiment 6
Chapter 11

11.1 Introduction

This experiment was designed as a replication of experiment 6.

11.2 Method

11.2.1 Subjects

Thirteen psychology undergraduates from the University of Westminster participated in the experiment. All were naive to the hypotheses and none had participated in any of the previous experiments.

11.2.2 Preparation of the stimuli

The stimuli prepared for the previous experiment (experiment 6) were used in this study.

11.2.3 Design & Procedure

The design and procedure of experiment 7 were identical to those of experiment 6 except that the 96 experimental stimuli were presented in a different random order. The overhead projector and the lighting were adjusted so that the viewing conditions were similar to those of the previous experiment.

11.3 Results

As in the previous experiments, two separate analyses were undertaken, both involving a 2x2x3 (Orientation by Negation by Movement) repeated measures analysis of variance.
11.3.1 Accuracy Data

The main effects of Orientation and Negation were both non-significant ($F_{1,12}=0.22; p=0.644$ and $F_{1,12}=0.88; p=0.367$ respectively), but as in previous experiments the main effect of Movement was significant ($F_{3,36}=31.0; p<0.0005$). In contrast to the previous experiment, the interaction between Orientation and Negation was not significant ($F_{1,12}=0.07; p=0.792$). All other interactions were non-significant (for Orientation by Movement $F_{3,36}=0.27; p=0.847$, for Negation by Movement $F_{3,36}=2.73; p=0.058$, and for Orientation by Negation by Movement $F_{3,36}=2.03; p=0.128$). See figures 11.1a and 11.2a.

Post hoc comparisons (Dunnett's test) failed to reveal any significant differences in performance with the four image types.

11.3.2 Certainty Data

Analysis of the certainty data revealed a very similar pattern of results to that described above, the only difference being that with the certainty data the interaction between Orientation and Negation was significant ($F_{1,12}=4.83; p=0.048$). The only other significant effect was the main effect of Movement. See figures 11.1b and 11.2b.

Post hoc comparisons (Dunnett's test) of the certainty scores for the normal and inverted images revealed a marginally significant difference with subjects scoring higher on the normal than the inverted trials.
11.3.3 The effect of direction of displacement

Planned comparisons were undertaken to compare the accuracy with which various different directions of displacement were detected. The results of these comparisons are summarised in table 11.1.

As can be seen from table 11.1 (considering both certainty and accuracy) subjects were more sensitive to horizontal than vertical displacements in all image types, and were more sensitive to inwards than outwards displacements in negative-inverted images, but equally sensitive to these displacements in normal, negative and inverted images. Subjects were equally sensitive to inwards and outwards displacements in normal and negative-inverted images, but more sensitive to downwards than upwards displacements in negative and in inverted images.

As in experiments 4 and 5, the difference in the accuracy with which upwards and downwards displacements were detected seems to have been largely due to the very poor performance in the upwards displacement trials. In this experiment only 5 of the 13 subjects correctly detected the upwards displacements in more than 50% of the trials. However, this level of performance was not as poor as that observed in experiments 4 and 5, and, as in those cases, a simple chi-square analysis revealed that the proportion of subjects who correctly identified the upwards displacements on more than 50% of occasions was not significantly less than would be expected by chance alone ($Chi^2=0.692; d.f.=1; p=0.405$).
Table 11.1 Univariate $F$-tests with (1,12) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and certainty data. See footnotes for differences between accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out?</th>
<th>Horiz&gt;Vertical?</th>
<th>Down&gt;Up?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Ellipses</td>
<td>$F=2.51; p=0.139$</td>
<td>$F=151.7; p&lt;0.0005$</td>
<td>$F=3.698; p=0.079^{25}$</td>
</tr>
<tr>
<td>Negative Ellipses</td>
<td>$F=4.42; p=0.057^{26}$</td>
<td>$F=25.97; p&lt;0.0005$</td>
<td>$F=11.15; p=0.006$</td>
</tr>
<tr>
<td>Inverted Ellipses</td>
<td>$F=1.09; p=0.32$</td>
<td>$F=49.7; p&lt;0.0005$</td>
<td>$F=6.26; p=0.028$</td>
</tr>
<tr>
<td>Neg-Inv Ellipses</td>
<td>$F=4.90; p=0.047$</td>
<td>$F=48.39; p&lt;0.0005$</td>
<td>$F=6.255; p=0.028^{27}$</td>
</tr>
</tbody>
</table>

$^{25}$Significant with the certainty data ($F_{1,12}=5.527; p=0.037$).

$^{26}$Significant with the certainty data ($F_{1,12}=7.59; p=0.017$).

$^{27}$Not significant with the certainty data ($F_{1,12}=4.47; p=0.056$).
Figure 11.1  Experiment 7: Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal, negative, inverted and negative-inverted patterns.
Figure 11.2  Experiment 7: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted patterns.
11.4 Discussion

11.4.1 Comparing experiments 6 and 7

Comparing figures 10.3 and 11.1, it seems that the effect of orientation detected in experiment 6 has not been replicated in experiment 7. The accuracy with which feature displacements were detected in negative, inverted, and negative-inverted images was very similar for these two experiments, but with the normal images, subjects were slightly less sensitive in experiment 7 than experiment 6. It appears to be this failure to replicate the superior performance with the normal image that has resulted in the non-significant effect of orientation with both the accuracy and certainty data in experiment 7. However, it should be noted that the performance on the normal trials in experiments 6 and 7 (74.4% and 71.8% correct respectively) differs by only 2.6%. Given that there is a total of 24 trials involving normal images, this difference in performance represents an average of less than 1 (0.62) more trial(s) correct in experiment 6 than 7. Furthermore, given that some of the trials are very much easier than others (for example the 4 and 6 pixel inward and outward displacement trials) it is clear that the subjects in these two experiments actually performed at very similar levels despite different (though similar) viewing conditions.

Given this failure to replicate the partial evidence of an inversion effect, it is difficult to know how to summarise the current position. Even though the inversion effect is not significant the mean accuracy is lower with the inverted than the other image types, and a post-hoc comparison revealed a marginally significant difference in the case of the certainty data. It seems then, that this features-in-an-ellipse image is not giving rise to a negation effect, but may be just capable of supporting an inversion effect.
If we accept this position, then a second question arises; why are subjects not also less sensitive to feature displacements in the negative-inverted image than the normal image? It appears that the marginal effect of image inversion is eliminated by additionally negating the image. Why should negation protect the subjects from the effect of image inversion?

11.4.2 The perception of negative and inverted patterns

The lack of any effect of negation for the features-in-an-ellipse pattern is consistent with the notion that the negation effect is largely a consequence of the loss of shape-from-shading cues, and that the face surround gives particularly important cues to the 3-D structure of the face. Since it is assumed that shape-from-shading cues are useful to subjects undertaking these feature displacement tasks, this explanation seems to suggest that there will be no effect of negation because the performance with the normal ellipse stimulus will be as poor as with the negative ellipse stimulus. When a stimulus does not contain a real face surround this useful shape-from-shading information is never available, and so negation cannot impair performance relative to the positive condition.

This explanation for the lack of the negation effect therefore predicts that subjects will be more sensitive to feature displacement in real faces than either negated faces or faces impoverished in shape-from-shading cues, such as the features-in-an ellipse stimuli used in this experiment. However, there is an alternative explanation equally capable of accounting for these effects and which makes a very different prediction.
Tanaka & Farah (1993) pointed out that the object-superiority effect is normally demonstrated as an advantage for the coherent context over the scrambled context, but not over the isolated feature condition. For example, the perception of the features of a face might be demonstrated to be more accurate when they are presented as part of a coherent face context than when part of a scrambled face context, but the isolated feature condition normally gives rise to a level of performance similar to the coherent context condition. Thus it would be legitimate to rename the object-superiority effect the "non object-inferiority effect".

Perhaps the non-face stimulus used in experiment 3 is like the isolated feature stimulus in a standard demonstration of the object-superiority effect. If this were the case then we would expect the performance with the positive-upright face (the coherent context) to be as good as, but not better than, performance with the non-face stimulus. In this scenario the effect of negation and inversion is to disadvantage the perceptual processing of the transformed face (the scrambled context) relative to both the normal face and the non-face pattern.

This non-object-inferiority explanation leads to the prediction that subjects will be equally sensitive to feature displacement in face and non-face stimuli and that only in transformed face stimuli (negated or inverted faces) will sensitivity be reduced. This explanation has an additional advantage in that it can account for the way in which negation of the features-in-an-ellipse stimulus seems to eliminate the effect of inversion. If the scrambled-context is disruptive to the perception of the image components, then perhaps the observer can be released from these negative effects by further distorting the context. If the context could be disrupted to such an extent that it stopped looking like a scrambled-context then perhaps performance would return to
the isolated-feature levels. Put in rather more conventional terms, this argument suggests that there is a cost involved in the inappropriate use of face-specific processing strategies, and that negation and inversion render these strategies inappropriate while leaving the stimulus sufficiently face-like to engage them. If the image is transformed to the extent that it no longer inappropriately engages these face-specific processes, then the perceptual system should be released from the cost involved in their use. The destruction (or gross distortion) of the facial context should therefore return performance to the level achieved with both faces and non-faces.

It could be that the inverted features-in-an-ellipse image is face-like enough to engage face-specific processes inappropriately, resulting in reduced sensitivity to feature displacement. However, additionally negating the inverted image might make the pattern sufficiently non-face-like so that these inappropriate processes are not engaged. In this explanation, negating the inverted stimulus is seen as releasing the viewer from the costs involved in trying inappropriately to perceive the image as a face, in much the same way as a change to the typeface in which words are printed can release a subject from pro-active interference in a memory experiment (see for example Wickens, 1970 and Cermak, Bulters & Mareines, 1974).

11.4.3 The object-superiority and non-object-inferiority explanations

A comparison of the sensitivity to feature displacement in experiment 3 (three-dots), the current experiment and experiments 1 and 2 (faces), offers no support for the non-object-inferiority explanation. The data suggest that subjects were considerably less sensitive to feature displacements in experiment 3 (non-faces) than in experiments 1 and 2, and that the level of sensitivity in the current experiment was close to that
achieved in experiment 3. However, we cannot be confident about this observation as viewing conditions were not controlled between these experiments.

Another potential flaw in this line of argument is that there have been some reports of object-superiority effects where features were identified more accurately when they were part of a context than when presented in isolation (e.g., Williams & Weisstein, 1978). Thus, the object superiority-effect does not always present as a non-object-inferiority effect, and even if one wishes to argue that the negation and inversion effects are examples of the object-superiority effect it is not necessary to argue that isolated features will be perceived as accurately as non-face patterns.

It is critical that these two differing explanations of the inversion and negation effect are tested by directly comparing sensitivity to feature displacement in face and non-face stimuli. The next experiment was designed to allow such a comparison.
Chapter 12

Experiment 8:
Comparing the sensitivity to feature displacements
in normal faces and ellipse patterns
12.1 Introduction

Two competing explanations have emerged from the discussion of the preceding experiments. In the first of these (the true face-superiority explanation) the facial context is seen as enhancing the processing of the image relative to a non-face or transformed face. In the second explanation (the non-object-inferiority explanation) transformation of the face (for example by either negation or inversion) is seen as resulting in a processing deficit relative to either the face or the non-face. These two explanations can only be tested by an experimental design that allows the direct comparison of sensitivity to feature displacements in faces and non-face images.

The approach adopted in this experiment was to include a block of normal face trials against which to compare performance with the various forms of the experimental stimulus. This block of face trials faces could either be randomly distributed amongst the other 96 trials, or presented as a separate block of trials. The second of these two options was chosen for this experiment in an attempt to minimise any possible influence that knowledge of the significance of the patterns might have on the results. The participants in the previous studies were not told that the experiments were designed to investigate the perception of faces, and in the case of experiment 3 at least this might not have been obvious. Knowing that the study concerns face perception might increase the likelihood that the stimuli are processed as faces. It therefore seems more appropriate to require the subjects to complete all the non face trials before starting the face trials.

As there is still some uncertainty as to whether the features-in-an-ellipse stimuli used in the last two experiments give rise to an inversion effect it was decided to introduce
Chapter 12

Experiment 8: Comparing faces and features-in-an-ellipse

this new methodology using these images. Furthermore, in the last chapter it was suggested that the better than expected performance with the negative-inverted stimuli could be explained within the context of the non-object-inferiority explanation of the negation and inversion effects. Examining the perception of these features-in-an-ellipse images also permits this explanation to be tested.

12.2 Method

12.2.1 Subjects

The fifteen participants were all undergraduate students of psychology at the University of Westminster. All were naive to the hypothesis and none had taken part in any of the previous experiments.

12.2.2 Preparation of the stimuli

The 120 stimuli used in the experiment comprised the 96 slides prepared for experiment 6 together with the 24 "normal" (i.e. upright-positive) face slides prepared for experiment 2.

12.2.3 Design

The design differed from the previous experiments in that the subjects were presented with two blocks of trials. The first block of trials was made up of the 96 slides prepared for experiment 6. The second block was made up of the 24 normal face slides taken from experiment 2. The order of the trials within each block was
randomised, with every subject receiving the same order of trials. All the subjects completed the features-in-an-ellipse trials before undertaking the face trials.

12.2.4 Procedure

The procedure for the first block of 96, features-in-an-ellipse trials was identical to that of experiments 6 and 7, with subjects being shown a series of demonstration slides and completing 10 practice trials before starting the experimental trials. On completion of these trials the participants were asked to turn over a page in their response booklets to reveal a new set of instructions. These instructions explained that they would now be asked to undertake the same task with images of a real face. It was explained that in each of the trials one of the lower two faces had been modified by moving the eyes either upwards, downwards, inwards or outwards, and that their task, as before, was to identify which of the lower two faces had been modified in one of these ways. Again it was stressed that the top image was always the original, unmodified version and so was available for comparison purposes. The participants were shown a series of demonstration slides and then completed 3 or 4 practice trials, before completing the 24 normal face trials. After completing the last face trial the participants were de-briefed and thanked for their participation.

12.3 Results

As in the previous studies the accuracy and certainty data were analysed separately.
12.3.1 Accuracy Data

The data were first submitted to a one-way repeated measures analysis of variance. The single factor, Type of stimulus, had five levels (normal faces, normal ellipse, negative ellipse, inverted ellipse and negative-inverted ellipse). This analysis revealed a significant main effect of Type of stimulus ($F_{4,55}=14.14; p<0.0005$) indicating that the overall accuracy with which subjects could detect feature displacements varied between the five image types; see figure 12.1a. A planned comparison (using contrast coefficients of $+4,-1,-1,-1,-1$) revealed that subjects were significantly more accurate with the normal face stimuli than with the other four types of stimuli collectively ($F_{1,14}=56.29; p<0.0005$).

The data from the normal face trials were then excluded and the ellipse data were submitted to the same three-way analysis of variance used in the previous experiments (Negation by Inversion by Movement). This analysis revealed a significant main effect of Orientation ($F_{1,14}=6.67; p=0.022$), but not of Negation ($F_{1,14}=0.73; p=0.408$). Once again, the main effect of Movement was significant ($F_{3,42}=45.22; p<0.0005$). Both the Orientation by Negation and the Orientation by Movement interactions were non-significant ($F_{1,14}=0.86; p=0.370$ and $F_{3,42}=2.39; p=0.083$ respectively), but the Negation by Movement interaction was significant ($F_{3,42}=2.99; p=0.042$). The three-way, Orientation by Negation by Movement interaction was not significant ($F_{3,42}=2.54; p=0.069$). See figure 12.2a.
12.3.2 Certainty Data

Analysis of the certainty data by one-way analysis of variance also revealed a significant effect of image type, and a planned comparison confirmed that as with the accuracy data, subjects scored higher with the face than the non-face stimuli.

A three-way, Orientation by Negation by Direction, analysis of the certainty data revealed an identical pattern of results to that reported above, with only the main effects of Orientation and Movement, and the Negation by Movement interaction reaching significance. See figures 12.1b and 12.2b.

12.3.3 The effect of direction of displacement

A series of planned comparisons were undertaken to compare the sensitivity to different directions of displacement for the 5 types of stimulus. The results are summarised in table 12.1 below. This table reveals that, for the faces and for all the types of ellipse stimuli, subjects were significantly more sensitive to horizontal than vertical displacements. Subjects were also more sensitive to downwards than upwards displacements for both the faces and for all types of ellipse; however only in the case of the negative ellipses and the negative-inverted ellipses were subjects more sensitive to inwards than outwards displacements. Analysis of the certainty data revealed a very similar pattern of results. See table 12.1.

As in the previous experiment the level of performance in the upward displacement trials with the ellipse stimuli was very poor. In this case less than 30% of the subjects correctly identified the upwards displacement trials on more than 50% of occasions.
A simple Chi-square revealed that this pattern of performance was not significantly different from what would be expected by chance ($\chi^2=3.267$; $d.f.=1$; $p=0.071$).

Table 12.1 Univariate $F$-tests with (1,14) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant for both accuracy and certainty data (see footnote).

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>$F=1.91$; $p=0.189^{28}$</td>
<td>$F=35.5$; $p&lt;0.0005$</td>
<td>$F=7.99$; $p=0.013$</td>
</tr>
<tr>
<td>Normal Ellipse</td>
<td>$F=0.38$; $p=0.550$</td>
<td>$F=29.44$; $p&lt;0.0005$</td>
<td>$F=20.8$; $p&lt;0.0005$</td>
</tr>
<tr>
<td>Negative Ellipse</td>
<td>$F=8.50$; $p=0.011$</td>
<td>$F=9.78$; $p&lt;0.007$</td>
<td>$F=17.5$; $p=0.001$</td>
</tr>
<tr>
<td>Inverted Ellipse</td>
<td>$F=0.88$; $p=0.364$</td>
<td>$F=31.79$; $p&lt;0.0005$</td>
<td>$F=5.24$; $p=0.038$</td>
</tr>
<tr>
<td>Neg-Inv Ellipse</td>
<td>$F=10.0$; $p&lt;0.007$</td>
<td>$F=97.7$; $p&lt;0.0005$</td>
<td>$F=24.1$; $p&lt;0.0005$</td>
</tr>
</tbody>
</table>

$^{28}$Significant with the certainty data ($F_{1,14}=5.05$; $p=0.041$).
Figure 12.1  Experiment 8: Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal, negative, inverted and negative-inverted ellipses and in normal faces.
Figure 12.2  Experiment 8: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal, negative, inverted and negative-inverted patterns, and in normal faces.
12.4 Discussion

12.4.1 Comparing performance with faces and ellipses

It is clear from figure 12.1 and from the analysis reported above, that the subjects were significantly more sensitive to displacements of the components of a face than a non-face pattern. On average the participants correctly detected a feature displacement in 84% of the face trials, but only 71% of the non-face trials. This is an important result. For the first time it is possible to directly compare levels of performance with face and non-face stimuli, and it is quite clear that the non-face, features-in-an-ellipse stimulus used in the previous two experiments is perceived significantly less accurately than the normal face image used in experiments 1 and 2.

This 13% difference in the sensitivity to faces and ellipse patterns seems to exceed slightly the performance decrement attributed to the effects of inversion and negation in experiment 2 (where performance on the normal face trials was very similar), and so it is probably the case that the normal ellipse is perceived somewhat less accurately than a negative or inverted face.

It is interesting to note how stable the performance has been with similar stimuli across experiments. The level of accuracy achieved with the normal face stimulus in this experiment was similar to that recorded in experiment 2, and only a few percentage points higher than experiment 1. This is despite variations in the viewing conditions between these studies. The levels of performance observed in experiments 6, 7 and 8 have also been very similar, with particularly close agreement between experiments 7 and 8 where the viewing conditions were most closely matched (these experiments were conducted in the same room). This would seem to suggest that small
changes to the viewing conditions are having relatively little effect on absolute performance levels, at least within the range of conditions experienced in this series of experiments.

12.4.2 The non-face stimuli

The pattern of results obtained with the features-in-an-ellipse pattern is similar to that observed in the previous two experiments. In this experiment this stimulus gave rise to a significant main effect of orientation with both the certainty and accuracy data. Given that there was also some evidence of an orientation effect in experiment 6 (and that the means were in the right direction in experiment 7), it now seems safe to conclude that the features-in-an-ellipse pattern gives rise to a small inversion effect.

As in experiments 6 and 7, there was no evidence of a negation effect for the features-in-an-ellipse stimulus, but once again, the negative-inverted stimulus was not perceived significantly less accurately than the normal stimulus. It appears that when the inverted image was additionally negated, the small inversion effect is eliminated rather than increased.
12.4.3 Explaining Inversion

The results of experiment 5 suggested that the facial surround was critical to the emergence of an inversion effect. The stimulus used in the last three experiments was designed to test whether the role of the face surround could be met by a simple geometric shape. The answer appears somewhat equivocal. The features-in-an-ellipse stimulus is just capable of sustaining an inversion effect, but given the level of performance with this image is so much lower than with the whole face, the ellipse could not be described as an adequate replacement for the real surround. Thus, the true role of the surround probably lies in its higher level significance (its "faceness") rather than its physical proximity to the displaced features.

It seems that for an image to give rise to an inversion effect it must include the internal features of the face together with some approximately face-shaped boundary. However, this combination of features is not perceived with the same level of accuracy as a thresholded image of face.

12.4.4 Negation

It has now been demonstrated on a total of three occasions that the features-in-an-ellipse pattern does not give rise to a decreased level of performance for the negative or the negative-inverted stimuli compared to the normal pattern. It seems that the conditions sufficient for the emergence of an orientation effect are not sufficient for the emergence of a negation effect. This could be seen as further evidence for the independent origins of these two effects.
In chapter 9 I argued that the most compelling evidence of the independence of the negation and inversion effects would be the discovery of two different stimuli, one which gave rise to only the inversion effect, and the other only the negation effect. The image used in experiment 5 (dots in a facial surround) gave rise to a negation effect but not an inversion effect. The image used in the last three experiments seems to give rise to a weak but replicable inversion effect and no negation effect. However, caution is needed in the interpretation of these results until it is possible to explain the lack of a performance decrement with the negative-inverted ellipse image.

12.4.5 Performance with the Negative-Inverted stimulus

As in experiments 6 and 7, the slight decrement in performance caused by rotating the image through 180 degrees seems to have been eliminated by additionally negating it. In the last chapter I sought to explain this phenomenon within the framework of what I called the non-object-inferiority explanation of the negation and inversion effects. Central to this explanation was the prediction that faces and non-faces would be perceived with equal accuracy, and that both would be more accurately perceived than transformed (negative or inverted) faces. The results of the current study seem to undermine this explanation, so some other explanation for the unexpectedly high level of performance with the negative-inverted image is required. What other explanations are available? If, as now appears to be the case, the face stimulus is more accurately perceived than the non-face stimulus, then the only explanation is that the negative-inverted, features-in-an-ellipse pattern is more face-like than the inverted features-in-an-ellipse pattern. Although this sounds rather unlikely, inspection of figure 12.3 suggests that this might be the case. Several subjects spontaneously reported that the negative-inverted figure used in this experiment could be seen as an upright
positive face. The stimulus is in some ways rather reminiscent of a reversible figure that can be viewed in either orientation, such as the Rex Whistler drawing reproduced by Johnston, et al. (1992) and included in this thesis as part of figure 12.3. In both the Whistler drawing and the features-in-an-ellipse image the reversibility relies on the fact that the mouth can also be seen as a forehead wrinkle and that the eyes, when in sufficient shadow, can be perceived as being upright in either orientation. It seems that this effect did not emerge in any of the previous experiments because the real face outline provided a strong cue to the correct orientation of the figure. The elliptical outline, on the other hand, is sufficiently symmetrical to ensure that it can be seen as a face in either orientation.

Figure 12.3 A comparison of the "reversibility" of the stimulus used in experiments 6, 7 & 8, and a drawing by Rex Whistler which, depending on orientation, shows either a scholar or a bruiser.
12.4.6 Direction of displacement

The relative sensitivity to the inwards, outwards, upwards and downwards displacements will be discussed fully in a later chapter, but it is interesting to note that subjects seem to have been more sensitive to the displacement of features in real faces than non-faces for all four directions of displacement (see figure 12.2). It is also interesting to note that in both the current experiment and experiment 7, the subjects tended to perceive ellipse images in which the eyes had been displaced slightly upwards as more like the original than the unmodified image (thus for all ellipse image types accuracy was less than 50% and certainty less than 0). This pattern of performance was also noted in experiments 4 and 5, and may be related to the fact that in all these cases the stimulus has consisted of either a partial face or a composite of facial and non-facial features. I would suggest that in all these cases the "eyes" appear to be unnaturally low within the image frame (or perhaps in the case of experiment 5 that the distance between the nose and the eyes appears too small). In fact the eyes appear halfway down the image frame in all unmodified stimuli, but the context of the real facial surround and real facial features seems to make the eyes of the thresholded face appear higher up the frame. It may be significant that one of the first lessons of portrait painting is that the eyes are lower down the head than is often realised (see for example, Brown, 1990).

12.4.7 The next experiment

The pattern of results emerging from the studies conducted so far offers some support for what I have called the true face-superiority explanation of the inversion and negation effects. It seems that subjects are more sensitive to feature displacements in
face than non-face patterns, and that this increased sensitivity for face patterns is not wholly attributable to the physical characteristics of the image, but rather to its higher level significance; its faceness.

It is, however, still possible to explain these results within the framework of the non-object-inferiority effect if we assume that the features-in-an-ellipse stimuli are seen as instances of a scrambled facial context. A critical, and as yet untested, prediction of the non-object-inferiority explanation is that subjects will be equally sensitive to feature displacement in a truly non-facial image (such as the three-dots pattern used in experiment 3) and a normal face. It is this prediction that allows us to determine whether perceptual processing is advantaged by the facial context (as specified by the true face-superiority explanation), or disadvantaged by a scrambled facial context (as specified by the non-object-inferiority explanation).

The next experiment was designed to test the validity of these two explanations.
Chapter 13

Experiment 9:

Face-superiority and non-object inferiority.

Comparing sensitivity to feature displacements

in normal faces and dot patterns
13.1 Introduction

It is important to establish whether subjects are less sensitive to feature displacements in a non-face pattern, such as the dot pattern used in experiment 3, than in a face image such as that used in experiments 1 and 2. The methodology introduced in the previous experiment provides a means of making this comparison by including a block of normal face trials along with the normal, negative, inverted and negative-inverted dot trials.

Rather than randomly distributing the face trials among the dot trials, it was decided to block the two types of trials together. If, as has been suggested in the previous chapters, the processing of face-like patterns involves the use of face-specific processes, then it may be possible to prime these processes, resulting in the more accurate perception of non-face patterns. This possibility was investigated by altering block order between two groups of subject who either completed the dot trials before undertaking the face trials or completed the face trials and then the dot trials.

It was hypothesised that:

$H_1$ There would be no effect of either inversion or negation on the sensitivity to feature displacement in non-face images.

$H_2$ Participants would show greater sensitivity to feature displacement in face than non-face images.

$H_3$ Subjects who completed the face trials before the non-face trials would be more sensitive to feature displacements in the non-face images than subjects who completed the face trials after the non-face trials.
13.2 Method

13.2.1 Subjects
A total of 61 students participated in the study. All were studying Psychology at the University of Westminster and were naive to the hypotheses. None had participated in any similar experiments. The 61 participants constituted two class groups of 38 and 23 students.

13.2.2 Preparation of the stimuli
The 120 stimuli used in the experiment comprised of the 96 "three-dots" slides prepared for experiment 3 together with the 24 normal-face slides prepared for experiment 2.

13.2.3 Design
The design of the experiment differed from that of the previous studies in that it incorporated a between-subjects factor; Order of blocks. Each of the two class groups of students participating in the study completed a total of 120 trials comprising a block of 96 dot trials and a block of 24 normal face trials. The 96 dot trials were those used in experiment 3 and incorporated normal, negative, inverted, and negative-inverted image types. The 24 normal face trials were a subset of the slides prepared for experiment 2, incorporating only the positive-upright trials.

The participants in Group 1 (N=38) completed the block of 24 normal face trials before commencing the block of 96 dot trials. Group 2 (N=23) completed the block
of 96 dot trials before starting the block of 24 normal face trials. The random order of presentation of the trials within each of the two blocks was the same for all participants.

13.2.4 Procedure

All participants were tested within two experimental sessions, one for each group. The two groups were tested in the same room and occupied a similar range of seats within the room. The location of the overhead projector and the lighting conditions were the same for the two sessions.

Participants in Group 1 were shown a series of demonstration slides illustrating examples of the normal face stimuli showing the four displacement directions and the three sizes of displacement. They then completed a total of 10 practice trials selected randomly from the 24 normal-face trials. The 24 experimental trials comprising the block of normal faces were then undertaken. Subjects were then asked to turn over the next page of their response booklet and read a further set of instructions. These instructions explained that in the second part of the experiment they would be asked to undertake a similar task but with dot patterns rather than faces, and that some of the patterns would have their contrast reversed (negated) and some inverted, but that the task was always the same irrespective of these changes. Examples of each of the types of dot stimuli were displayed illustrating examples of the various directions of displacement and sizes of displacement. The participants completed 10 practice trials drawn at random from the 96 dot pattern trials before undertaking the experimental trials. The procedure for Group 2 was identical to that for Group 1 except that the 96 dot pattern trials preceded the 24 normal face trials.
Chapter 13  Experiment 9: Comparing faces and dot patterns

After completing all 120 trials, all of the participants were asked to indicate whether they thought the dot trials or the face trials were the easiest, and which of the four types of dot trials was the easiest. An example of a response booklet similar to the one used in this study can be found in Appendix 1.

After writing their answers to these two questions all participants were thanked for their cooperation and fully de-briefed.

13.3 Results

13.3.1 Accuracy Data

The accuracy data were first submitted to a 5x2 mixed analysis of variance (Type of stimuli - faces, normal dots, negative dots, inverted dots, negative-inverted dots, by Group - faces first or dots first). In this analysis Type was a within-, and Group a between-subjects factor. The main effect of Type was significant ($F_{4,236}=21.77; p<0.0005$) indicating that accuracy varied with type of stimuli, but the main effect of Group was not significant ($F_{1,59}=0.73; p=0.397$) indicating that, overall, the performance of the two groups of subjects was not significantly different. The interaction between Type and Group was also not significant ($F_{4,236}=1.42; p=0.229$) indicating that the pattern of results across Types of stimuli was similar for the two groups of subjects. See figure 13.1

A planned comparisons (using contrast coefficients +4,-1,-1,-1,-1) revealed that feature displacements were significantly more accurately detected in faces than in the four types of dot pattern ($F_{1,59}=56.51; p<0.0005$).
The face trials were then excluded from the data set and the dot pattern data subjected to a 2x2x4x2 (Orientation by Negation by Movement by Group) mixed analysis of variance in which the factors Orientation, Negation and Movement were within-subjects and Group was between-subjects. As in the two way analysis of variance, the main effect of Group was not significant \((F_{1.59}=1.07; p=0.306)\). Neither the main effect of Orientation nor the main effect of Negation were significant \((F_{1.59}=0.31; p=0.582;\) and \(F_{1.59}=2.68; p=0.170\) respectively). As in all previous experiments the main effect of Movement was significant \((F_{3.77}=63.52; p<0.0005)\). None of the 3 two-way interactions involving the Group factor were significant (for Group by Orientation \(F_{1.59}=2.31; p=0.134\); for Group by Negation \(F_{1.59}=0.43; p=0.513\); for Group by Movement \(F_{3.77}=0.11; p=0.952\)).

The interactions between Orientation and Movement and between Negation and Movement were both non-significant \((F_{3.177}=0.36; p=0.785\) and \(F_{3.177}=1.98; p=0.118\) respectively), as was the interaction between Orientation and Negation \((F_{1.59}=0.26; p=0.61)\).

The three-way interactions, Group by Orientation by Movement, Group by Orientation by Negation, and Orientation by Negation by Movement, were all non-significant \((F_{3.177}=2.04; p=0.11; F_{1.59}=3.32; p=0.073;\) and \(F_{3.177}=1.78; p=0.153\) respectively). However, the Group by Negation by Movement interaction was significant \((F_{3.177}=2.89; p=0.037)\). Finally, the four-way interaction between Group, Orientation, Negation and Movement was not significant \((F_{3.177}=1.42; p=0.238)\).

Thus, the only significant effects were the main effect of Movement and the three-way interaction between Group, Negation and Movement. See figure 13.2a.
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Experiment 9: Comparing faces and dot patterns

13.3.2 Certainty Data

Analysis of the certainty data revealed a pattern of results almost identical to that described above, with the only noteworthy differences being that the three-way Group by Negation by Movement interaction was not significant with the certainty data \((F_{3,177}=2.63; p=0.051)\), and that the Group by Orientation by Negation interaction that had been only marginally non-significant in the analysis of the accuracy data was clearly non-significant for the certainty data \((F_{1,59}=0.14; p=0.712)\). See figures 13.1b and 13.2b.

Thus, only the main effect of Movement was significant with the certainty data.

13.3.3 The effect of direction of displacement

Apart from the three-way interaction between Group, Negation and Movement, which was significant for the accuracy data but not the certainty data, the Group factor was not shown to have any effect on the results and so subsequent analysis of the sensitivity to the different directions of displacement was undertaken on the total population of 61 subjects, ignoring the factor of Group.

\textit{A priori} tests to compare the sensitivity to different directions of displacement for the various types of stimuli are summarised in table 13.1 below. Once again, subjects were more sensitive to horizontal than vertical displacements for all image types. Subjects were also more sensitive to inward than outward displacements in normal faces, normal dots and negative-inverted dots, but not in negative or inverted dots.
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Experiment 9: Comparing faces and dot patterns

With the accuracy data subjects were more sensitive to downward than upward displacements only in the case of the negative and the negative-inverted dots, but with the certainty data the difference was also significant for all the dot patterns (but not the normal faces). These results will be discussed fully in a later chapter.

Table 13.1 Univariate F-tests with (1,60) degrees of freedom, comparing sensitivity to different directions of displacement. The F ratios and p values given are for the accuracy data. Shaded cells indicate differences significant for both the certainty and the accuracy data. See footnotes for differences between accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>Directions of displacement to be compared</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In&gt;Out</td>
<td>Horiz&gt;Vertical</td>
<td>Down&gt;Up</td>
<td></td>
</tr>
<tr>
<td>Normal Faces</td>
<td>$F=24.4; p&lt;0.0005$</td>
<td>$F=95.4; p&lt;0.0005$</td>
<td>$F=0.95; p=0.333$</td>
<td></td>
</tr>
<tr>
<td>Normal Dots</td>
<td>$F=26.3; p&lt;0.0005$</td>
<td>$F=42.2; p&lt;0.0005$</td>
<td>$F=0.56; p=0.456^{20}$</td>
<td></td>
</tr>
<tr>
<td>Negative Dots</td>
<td>$F=0.68; p=0.412$</td>
<td>$F=38.3; p&lt;0.0005$</td>
<td>$F=5.16; p=0.027$</td>
<td></td>
</tr>
<tr>
<td>Inverted Dots</td>
<td>$F=3.84; p=0.055$</td>
<td>$F=55.8; p&lt;0.0005$</td>
<td>$F=2.95; p=0.091^{20}$</td>
<td></td>
</tr>
<tr>
<td>Neg-Inv Dots</td>
<td>$F=16.43; p&lt;0.0005$</td>
<td>$F=55.81; p&lt;0.0005$</td>
<td>$F=12.75; p=0.001$</td>
<td></td>
</tr>
</tbody>
</table>

13.3.4 Subjective data

$^{20}$Significant with the certainty data ($F=4.19; p=0.045$).

$^{20}$Significant with the certainty data ($F=12.71; p=0.001$).
After the last trial the subjects were asked whether they felt that the dot trials or the face trials were the easiest, and whether they had thought of the dots as face-like when tackling these trials. Analysis of the responses revealed that overall 36% of the subjects reported that the face trials were the easiest while 18% felt that the dot trials were easiest (46% either did not know or felt they were equally difficult). Further analysis revealed that all of the subjects who felt that the face trials were easier than the dot trials had been in group 1, and hence had seen the faces first (all but 1 of the subjects from group 2 expressed no opinion).

Overall, approximately 20% of the subjects reported that they had thought of the dot patterns as face-like. Of these subjects, a slightly higher percentage had been in group 1 (faces first), but a Chi square (2x2) analysis revealed no significant association between these variables. Of the subjects who reported seeing the dots as faces, 83% also felt that the faces were easier than the dots. This compares to 68% of the subjects who did not report seeing the dots as faces but thought the face trials were easiest. Once again a Chi-Square revealed no significant association.

Although an inspection of the accuracy data revealed that those subjects who reported that the faces were easier than the dots were more sensitive to feature displacements in the face trials than were the remaining subjects, this difference was not significant ($t_{11.81}=1.61; p=0.134$). A second independent $t$-test revealed that the subjects who had reported seeing the dots as faces performed significantly more accurately on the face trials than did the remaining subjects (82.9% compared to 75.8%; $t_{56}=2.09; p=0.041$). However, these two groups of subjects did not perform significantly differently for any of the four types of dot trials.
Those subjects who did not think that the face trials were easier than the dot trials still performed significantly more accurately on the face trials than on the dot trials ($F_{138}=26.1; p<0.0005$). Finally, those subjects who reported that they thought of the dot patterns as faces were still significantly more accurate on the face trials than the dot trials ($F_{11}=25.05; p<0.0005$).
Figure 13.1  Experiment 9: Accuracy for the detection of feature displacements in normal faces and in normal, negative, inverted, and negative-inverted dot patterns. Part (a) illustrates the results from the faces first group, part (b) the dots first group.
Figure 13.2  Experiment 9: Accuracy for the detection of inwards, outwards, upwards and downwards displacements in normal faces and in normal, negative, inverted, and negative-inverted dot patterns. Parts (a) and (b) show the results of the faces first, dots first groups.
13.4 Discussion

13.4.1 Comparing dots and faces

It is clear from the results reported above and from inspection of Figure 13.1 that participants were able to detect the displacement of components of a face with greater accuracy than they were able to detect the displacement of components of dot patterns.

This experiment provided a critical test of the face-superiority explanation of the inversion and negation effect, and the data clearly support this explanation. Faces are more accurately perceived than either transformed faces (experiments 1 and 2), partial faces (experiment 3) or non-faces (experiment 4). This pattern of results cannot be explained by what I had termed the non-object-inferiority explanation. It can no longer be argued that the apparent advantage provided by the upright positive facial context is in fact a relative disadvantage provided by the inverted or negated context. It is clear that the coherent context results in an advantage relative to both the scrambled context condition (the negated or inverted condition) and the non-context condition (the non-face condition). It seems that inversion or negation of a face is not so much reducing the accuracy with which the face is perceived as removing the perceptual advantage inferred by the upright face. The perception of non-face patterns is not affected by negation or inversion because there is no meaningful context for these transformations to reduce.

This experiment has also provided evidence that performance is actually very stable within the range of viewing conditions experienced in the experiments reported here. The sensitivity to feature displacements in the block of normal faces in this
experiment was very similar to that from the previous experiment and from experiments 1 and 2 (in all cases between about 77% and 84% correct). Similarly, the sensitivity to feature displacement in the dot patterns used in this study is very similar to that from experiment 3 (in both cases a mean performance of about 65% correct). Thus sensitivity to feature displacements in the dot patterns seems to be about 10% lower than in the normal face stimuli. As noted in the previous chapter, this figure is very similar to the decline in performance attributed to inversion or negation in experiments 1 and 2.

13.4.2 Negation and Inversion in dot patterns

As in experiment 3, sensitivity to feature displacement in the dot patterns was not significantly affected by either inversion or negation. It appears that a non-face pattern, even one that is a geometric approximation of a face, will not give rise to these perceptual negation and inversion effects.

13.4.3 The effect of Block order

It is clear that the order in which participants experienced the two blocks of trials had no effect on sensitivity to feature displacement in either face or non-face stimuli. The only significant effect involving the Group factor was the three-way interaction between Group, Negation and Movement. Such an interaction suggests that the pattern of sensitivities for the four displacement directions for positive and negative trials, differs between the two groups. No explanation of this interaction is obvious, and the
fact that this interaction was not significant with the certainty data suggests that this result may represent a type I error, perhaps due to repeated significance testing.

This one result aside, no effect of group was observed, and it seems clear that suggesting that the dot patterns could be seen as faces does not affect the ability to detect displacements in the patterns. This suggests that any special processes that might be available when examining a face-like pattern and which might give rise to greater sensitivity to feature displacement with such stimuli cannot be primed by undertaking a similar task with face stimuli.

13.4.4 The effect of direction of displacement

It is possible to compare the relative sensitivity to the different directions of feature displacement for faces and dot patterns found in this experiment to those observed in experiments 2 and 3. Such comparisons reveal a rather confused picture which will be discussed in detail in chapter 18.

13.4.5 The subjective data

Several interesting results emerged from the analysis of the subjects' responses to the questions put to them at the end of the last trial. Firstly, it is interesting to note that all but one of the subjects who reported that the face trials were easier than the dot trials were in group 1. It seems that block order was more likely to affect the subjects' perceptions of the relative ease of the face and dot trials than any measure of actual performance.
Chapter 13  Experiment 9: Comparing faces and dot patterns

The second interesting result was that the subjects who had reported thinking of the dot patterns as being face-like were no more accurate on the dot trials than were those who had not (although strangely they were more accurate on the face trials). Assuming that the subjects were able to report their thought processes accurately, it appears that being aware that the dot patterns could be seen as faces does not increase the sensitivity to feature displacements in dot patterns. Furthermore, regardless of whether or not the subjects reported seeing the dots as face-like, they were still significantly more accurate in the face than the dot trials. This suggests that the processes that result in increased perceptual accuracy for face-like patterns are not influenced by the conscious knowledge that a pattern shares some physical attributes with a face.

Finally, it is interesting to note that even those subjects who did not feel that the face trials were easier than the dot trials were significantly more sensitive to feature displacements in the face trials than the dot trials.

13.4.6 The next experiment

The only combination of the real features, the dot-features, the real surround and the ellipse, that has not so far been investigated is dots-in-an-ellipse. For the sake of completeness it was decided to investigate the effects negation and inversion on this stimulus.
Chapter 14

Experiment 10:
Comparing the sensitivity to feature displacement in normal faces and dots-in-an-ellipse patterns
14.1 Introduction

Experiment 5 demonstrated that a pattern of three dots within a real facial surround is less accurately perceived when presented in negative than positive, and the results of experiments 6, 7 and 8 suggested that a composite image made up of the real facial features in an elliptical surround gives rise to a small inversion effect. An obvious question therefore is, would the three dots placed within an elliptical surround give rise to either an inversion or negation effect? Experiments 3, 4, 6, 7 and 8 suggest that a real facial surround is necessary for the emergence of a negation effect, and that the combination of real internal features, and either an elliptical or real facial surround, are necessary to give rise to an inversion effect. On the basis of these results it would be predicted that the combination of an elliptical surround and dots (dots-in-an-ellipse) would not be affected by either inversion or negation. Experiment 10 was designed to test this prediction.

14.2 Method

14.2.1 Subjects

A total of 24 students participated in the study. All were studying Psychology at the University of Westminster and all were naive to the hypothesis of the study. None had participated in any of the previous experiments.

14.2.2 Preparation of the stimuli

The 120 stimuli used in the experiment consisted of the 24 normal face stimuli prepared for experiment 2 plus an additional 96 new stimuli made up of the ellipse
figure used in experiments 6, 7 and 8, but with the features replaced by "dots" similar to those used in experiment 3. These new stimuli were produced by a specially written QBASIC programme that produced a text file containing PostScript commands. This file was printed to an HP LaserJet IIIP laser printer fitted with a PostScript programming language cartridge which interpreted the PostScript commands and directly controlled the laser printer. This enabled very high quality images to be printed directly to the laser printer. It is a feature of the PostScript language that an image can be described at any resolution; the image description is then mapped on to the printer hardware and printed at the highest possible resolution given the limitations of the hardware. In the case of the LaserJet IIIP this process results in an image resolution of 300 dots per inch.

The size of the ellipse and of the "feature-dots" was adjusted so that they matched those used in experiments 6-8 and 3 respectively, and these components were accurately located within an image whose size was equivalent to 256x256 pixels. The "eye-dots" were displaced upward, downward, inward and outward by distances equivalent to 2, 4, and 6 pixels. Negative and inverted trials were prepared by swapping the black and white components of the image and by rotating the image through 180 degrees respectively. Figure 14.1 illustrates examples of normal, negative, inverted and negative-inverted images prepared in this way. The stimuli for the 96 trials were printed directly on to acetate sheets suitable for use on an overhead projector. Figure 14.2 illustrates a typical experimental trial prepared in this way.

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31The size of a pixel was matched to the previous experiments, so the term pixel in the context of this experiment refers to a block of laser printer dots of a size equivalent to 1/256 of the image dimensions.
14.2.3 Design and Procedure

The design was identical to that of experiment 8. The order of the 96 ellipse trials and of the 24 normal face trials was randomised. All participants completed the block of ellipse trials before undertaking the block of face trials. All participants experienced the trials in the same order.

The procedure adopted was identical to that used with group 2 in experiment 9. All participants were tested in a single session and under conditions similar to the previous experiments. After completing the experimental trials, the participants were asked to indicate whether they thought the ellipse trials or the face trials were the easiest (or if there was no difference), whether they had tended to see the ellipse patterns as faces, and which of the four types of ellipse pattern had been the easiest (or if there was no difference). Participants were then fully de-briefed and thanked for their assistance.
Figure 14.1 The four types of dots-in-an-ellipse stimuli used in experiment 10. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the pattern respectively.
Figure 14.2  An example of a normal trial from experiment 10. The eye-dots in the left-hand image have been displaced downwards by 2 pixels.
14.3 Results

14.3.1 Accuracy Data

The accuracy data was initially submitted to a one-way analysis of variance where the single, within subjects factor, Type of stimulus, had five levels: normal faces, normal ellipse, negative ellipse, inverted ellipse and negative-inverted ellipse. This analysis revealed a significant main effect of Type of stimulus ($F_{4,92}=3.34; p=0.013$). A planned comparison was conducted to compare performance in the face trials to performance with the four types of ellipse pattern (i.e. using coefficients of $+4 -1 -1 -1 -1$). This revealed that the participants were more accurate at detecting feature displacements in normal faces than in the four types of ellipse pattern collectively ($F_{1,23}=8.91; p=0.007$). However a post-hoc comparison revealed that subjects were no more sensitive to feature displacement in the face trials than in the normal ellipse trials (using Dunnett’s procedure, as recommended by Howell, 1992).

The data from the face trials was then excluded and the remaining data submitted to a 2x2x4 within subjects analysis of variance (Negation by Orientation by Movement). This analysis revealed a significant main effect of Movement ($F_{3,69}=26.05; p<0.0005$) but no effect of either Orientation ($F_{1,23}=1.93; p=0.178$) or Negation ($F_{1,23}=0.21; p=0.654$). The two-way interaction between Orientation and Negation was also not significant ($F_{1,23}=2.60; p=0.120$). The two-way interaction between Negation and Movement was marginally non-significant ($F_{3,69}=2.69; p=0.053$), but that between Orientation and Movement was significant ($F_{3,69}=4.22; p=0.008$). The three-way interaction between Negation, Orientation and Movement was not significant ($F_{3,69}=2.49; p=0.067$).
14.3.2 Certainty Data

Analysis of the certainty data revealed a pattern of results identical to that reported above.

14.3.3 The effect of direction of displacement

A priori tests to compare the sensitivity to different directions of displacement for each of the five types of stimulus are summarised in table 14.1 below. Inspection of this table reveals that for both the normal face stimuli and all four types of ellipse stimuli, subjects were significantly more accurate at detecting horizontal than vertical displacements. The only other significant differences were that for negative ellipse stimuli, inverted ellipse stimuli (with the certainty data only) and negative-inverted ellipse stimuli, subjects more accurately detected upward than downward displacements.

14.3.4 Subjective data

The 22 participants who expressed an opinion were equally divided as to whether the face trials or the ellipse trials were the easiest. Similarly, exactly half of the 24 participants stated that they had tended to see the ellipse patterns as face-like, but there was no association between these two variables. One third of the participants reported that the four types of ellipse trial had been equally difficult. Of the remaining 16 participants, 6 thought the normal ellipse patterns easiest, 3 the negative dots
easiest, and 7 the negative-inverted patterns easiest. None of the participants thought
that the inverted patterns were easiest.

There were no significant associations between the responses made to these three
questions. For example, the participants who claimed to have seen the ellipses as faces
were equally divided as to whether the ellipse patterns or the faces were the easiest.

Those subjects who reported that the ellipse trials were easier than the face trials were
not significantly more accurate on the face trials than any of the four ellipse type
trials. These comparisons were significant with the data from the subjects who thought
that the face trials were the easiest (and also for the entire population). Those subjects
who reported that the negative-inverted ellipse patterns were the easiest had performed
significantly more accurately with these patterns than had the other subjects, and for
these subjects there was no significant difference between the performance on the face
trials and the negative-inverted ellipse trials (82.74% correct compared to 77.98% correct).

A comparison of the performance of those subjects who reported seeing the ellipse
patterns as face-like with those who did not, revealed no significant differences for
any of the stimulus types.
Table 14.1 Univariate F-tests with (1,23) degrees of freedom, comparing sensitivity to different directions of displacement. F ratios and p values are for accuracy data. Shaded cells indicate differences that are significant for both the accuracy and the certainty data. See footnotes for differences between accuracy and certainty data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>F=0.00; p=1.00</td>
<td>F=80.55; p&lt;0.0005</td>
<td>F=0.50; p=0.487</td>
</tr>
<tr>
<td>Normal Ellipse</td>
<td>F=0.329; p=0.083</td>
<td>F=40.85; p&lt;0.0005</td>
<td>F=0.008; p=0.93</td>
</tr>
<tr>
<td>Negative Ellipse</td>
<td>F=1.33; p=0.26</td>
<td>F=88.8; p&lt;0.0005</td>
<td>F=4.29; p=0.050</td>
</tr>
<tr>
<td>Inverted Ellipse</td>
<td>F=0.711; p=0.408</td>
<td>F=51.75; p&lt;0.0005</td>
<td>F=3.69; p&lt;0.067 (^\text{32})</td>
</tr>
<tr>
<td>Neg-Inv Ellipse</td>
<td>F=2.32; p&lt;0.141</td>
<td>F=43.94; p&lt;0.0005</td>
<td>F=12.79; p&lt;0.002</td>
</tr>
</tbody>
</table>

\(^{32}\text{Significant with the certainty data (F}_{1,23}=6.299; p=0.02)\).
Figure 14.3  Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal faces and in normal, negative, inverted and negative-inverted dots-in-an-ellipse patterns.

Error bars indicate 95% confidence intervals. N=24
Figure 14.4  Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal faces and in normal, negative, inverted and negative-inverted dots-in-an-ellipse patterns.
14.4 Discussion

14.4.1 Comparing faces and non-faces

The subjects were most sensitive to feature displacements in the normal face stimuli, and the level of performance with these images was comparable to, but slightly less than, that achieved in previous experiments (experiments 1, 2, 12 and 13). Accuracy during the face trials was significantly higher than in the non-face (ellipse) trials collectively, and there were no significant effects of either negation and inversion for the ellipse trials. This was the pattern of results predicted in the introduction to this study. However, the pattern of performance across the four types of dots-in-an-ellipse images (see figure 14.3) is somewhat reminiscent of that seen in experiments 10, 11 and 12. Although in this experiment the effects were not significant, there is clearly a tendency for the normal pattern to be perceived most accurately, and for the inverted patterns to be perceived least accurately. It is because of this trend that, although the faces were perceived more accurately than the ellipses overall, the performance on the normal ellipse trials was not significantly different from the face trials.

It appears that these dots-in-an-ellipse stimuli are not face-like enough to be sensitive to either negation or inversion (although trends are clearly present in the data), yet are sufficiently face like that when presented upright and positive they are perceived as accurately as a normal face.

The analysis of the subjective data reveals several interesting results. It seems that the subjects were able to introspect about their performance when answering these questions. When some of the subjects stated that the ellipse trials were the easier than
Chapter 14 Experiment 10: Faces and dots-in-an-ellipse patterns

the face trials they were reflecting on the fact that, unlike the other subjects, they were no more accurate on the face than the ellipse trials.

14.4.2 The effect of direction of displacement

It is possible to compare the sensitivity to the various different directions of feature displacement found in this study with those found in the previous experiments. These comparisons will be discussed in more detail in a later chapter (chapter 18).

14.4.3 The face surround and the inversion effect

The results of experiments 3,4,6,7 and 8 suggested that a real facial surround was necessary if a pattern was to be perceived more accurately when upright than when inverted. At first sight the results of this experiment seem to confirm this conclusion. However, the fact that there were trends in the data (especially the certainty data where the main effect of Orientation was only marginally non-significant) suggest that the ellipse was almost adequate to fulfil the role of the face surround.

It is therefore possible that it is not the face-like properties of the face-surround that make it so important, but rather some lower level physical property that might be met by the appropriate geometric shape. Close inspection of the real face surround reveals that it provides fixed points of reference against which the location of the eyes (or eye-dots) can be measured. These reference points are much closer to the eyes than are the edges of the ellipse used to replace it. The ellipse used in these studies was designed to match approximately the outline of the head, but the face-surround

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provides points of reference that make up the edges of the face rather than the head. It could be that the role of the face surround could be adequately met by a geometric form that matched the distance between the internal features and the closest fixed point of reference. That is, a surround that was matched to the face surround rather than the head surround, might give rise to an inversion effect. The next experiment was designed to investigate this possibility.
Chapter 15

Experiment 11:
Comparing the sensitivity to feature displacement
in normal faces and dots-in-a-rectangle patterns
15.1 Introduction

The most appropriate non-face stimuli against which to compare performance with face stimuli would include, not only dots of the same size and location as the internal features of the face, but also fixed reference points against which the location of the features could be compared. The ellipse surround used in the previous studies was designed to match the outside dimensions of the head of the original face image, but it is the edges of the face, not the head, that are closest to the eyes and therefore potentially the most useful reference points when calculating the location of the internal features. A more appropriate comparison stimuli would be one which had a boundary that was the same distance from the eye-dots as the nearest part of the face outline was from the eyes in the original face image. The stimuli used in this experiment were designed to meet this criterion.

15.2 Method

15.2.1 Subjects

A total of 21 students participated in the study. All were studying Psychology at the University of Westminster and were naive to the hypothesis of the study. None had participated in any of the previous experiments.

15.2.2 Preparation of the stimuli

The 120 stimuli used in the experiment consisted of the 24 normal face stimuli originally used in experiment 2, plus an additional 96 new stimuli prepared for this study.
The new stimuli were created using a modified version of the software written for the previous experiment which produced a text file to drive a PostScript laser printer.

The new stimuli were made up of the three dots used in the previous experiment surrounded by a rectangle. The dimensions of the rectangle were chosen to match those of the face outline. The left and right hand edges of the rectangle were matched up to the parts of the face outline closest to the eyes in the original face image. Similarly the top and bottom of the rectangle were matched to the top and bottom of the face outline. In this way the rectangle matched the parts of the original face outline closest to the internal features. This resulted in a rectangle of dimensions equivalent to 120 by 179 pixels. All of the 96 rectangle trials used in this experiment were produced by modifying this original image. The "eye-dots" were displaced upward, downward, inward and outward by distances equivalent to 2, 4, and 6 pixels. Negative and inverted trials were prepared by swapping the black and white components of the image and by rotating the image through 180 degrees respectively. Figure 15.1 illustrates examples of normal, negative, inverted and negative-inverted images prepared in this way. The stimuli for the 96 rectangle trials were printed directly on to acetate sheets suitable for use on an overhead projector. Figure 15.2 illustrates a typical experimental trial. (Note: The caption at the bottom of the slide was included to assist the experimenter - this portion of the slide was not projected.)

15.2.3 Design and Procedure

The design and procedure were identical to those of the previous experiment. The order of the slides in the block of 96 dots-in-a-rectangle trials, and the block of 24

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33 As in the previous experiment, the term pixel refers to a block of laser printer dots of a size equivalent to 1/256 of the image dimensions.
normal face trials, was randomised. All participants completed the block of rectangle trials before undertaking the block of face trials. All participants experienced the trials in the same order, and all participants were tested in a single session and under conditions similar to those of the previous experiments.

After completing the experimental trials, the participants were asked: (a) to indicate whether they thought the rectangle trials or the face trials were the easiest (or if there was no difference), (b) whether they had tended to see the rectangle patterns as faces, and (c) which of the four types of rectangle pattern had been the easiest (or if there was no difference). Participants were then fully de-briefed and thanked for their assistance.

Figure 15.1 The four types of dots-in-a-rectangle stimuli used in experiment 11. Parts (a) to (d) show the normal, negative, inverted and negative-inverted forms of the pattern respectively.
Figure 15.2  An example of a negative-inverted trial from experiment 11. The eye-dots in the right-hand image have been displaced inwards by 4 pixels.
15.3 Results

15.3.1 Accuracy Data

The accuracy data were initially submitted to a one-way analysis of variance. The single within subjects factor, Type of stimulus, had five levels (normal faces, normal rectangles, negative rectangles, inverted rectangles and negative-inverted rectangles). This analysis revealed a significant main effect of Type of stimulus ($F_{4,30}=10.15; p<0.0005$), and a planned comparison revealed that the participants were more accurate in detecting feature displacements in normal faces than in the four rectangle conditions ($F_{1,20}=32.12; p<0.0005$).

The data from the face trials were then excluded and the remaining data submitted to a 2x2x4 within subjects analysis of variance (Negation by Orientation by Movement). This analysis revealed significant main effects of Negation ($F_{1,20}=10.58; p=0.004$), and of Movement ($F_{3,60}=35.71; p<0.0005$), but no main effect of Orientation ($F_{1,20}=3.92; p=0.062$). The two-way interactions between Orientation and Negation ($F_{1,20}=0.92; p=0.348$), between Orientation and Movement, ($F_{3,60}=0.76; p=0.519$) and between Negation and Movement ($F_{3,60}=0.68; p=0.57$) were all non-significant, but the three-way interaction between Orientation, Negation and Movement was significant ($F_{3,60}=4.13; p=0.010$).

15.3.2 Certainty Data

Submitting the certainty data to the same one-way analysis of variance as described above also revealed a significant effect of type of stimulus and a significant difference
Chapter 15

Experiment 11: Faces and dots-in-a-rectangle patterns

in sensitivity to feature displacements in faces and the four rectangle types collectively.

The 2x2x4 analysis of variance of the certainty data from the four rectangle conditions revealed a slightly different pattern of results to that described above. In particular, both of the main effects of Orientation ($F_{1,20}=4.47; p=0.047$) and of Negation ($F_{1,20}=11.60; p=0.003$) were significant for the certainty data, as was the interaction between Orientation and Movement ($F_{3,60}=3.01; p=0.037$).

15.3.3 The effect of direction of displacement

A priori tests to compare the sensitivity to different directions of displacement for each of the five types of stimuli are summarised in Table 15.1 below. Inspection of this table reveals that for both normal face stimuli and all four types of rectangle stimuli, subjects were significantly more accurate at detecting horizontal than vertical displacements. For all stimulus types the sensitivity to downward displacements was greater than to upward displacements (with either the accuracy or the certainty data) and sensitivity to inwards displacements was greater than to outwards displacements for all but the normal rectangle patterns (again, with either the accuracy or the certainty data).

Once again, the significant difference in sensitivity to upwards and downwards displacements seems to be largely attributable to the very poor performance in the upwards displacement trials. In the case of the transformed rectangle stimuli the majority (60%) of the subjects correctly identified the upward displacements on less
than 50% of occasions. However, this pattern of performance was not significantly different from that expected by chance ($\text{chi}=1.19; d.f.=1; p=0.275$).

15.3.4 Subjective data

The 19 subjects who felt able to express an opinion were approximately equally divided as to whether the dots-in-a-rectangle or the face trials were the easiest. The majority of the subjects (61.9%) did not indicate that they had thought of the dots-in-a-rectangle pattern as face-like, and just under half (10) of the subjects reported that the normal rectangle trials were the easiest of the non-face trials. All other subjects expressing an opinion (4) thought that the negative trials were the easiest.

There was no association between these three variables, and post-hoc comparisons revealed no significant differences in performance between groups of subjects defined by the response given to these questions.
Table 15.1 Univariate $F$-tests with (1,20) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant with both the accuracy and the certainty data. Differences between these scores are described in the footnotes.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Faces</td>
<td>$F=5.38; p=0.031$</td>
<td>$F=86.78; p&lt;0.0005$</td>
<td>$F=5.49; p=0.030$</td>
</tr>
<tr>
<td>Normal Rectangles</td>
<td>$F=0.214; p=0.649$</td>
<td>$F=93.08; p&lt;0.0005$</td>
<td>$F=4.099; p=0.056^{34}$</td>
</tr>
<tr>
<td>Negative Rectangles</td>
<td>$F=6.51; p=0.019^{35}$</td>
<td>$F=36.99; p&lt;0.0005$</td>
<td>$F=30.8; p&lt;0.0005$</td>
</tr>
<tr>
<td>Inverted Rectangles</td>
<td>$F=4.630; p=0.044$</td>
<td>$F=44.99; p&lt;0.0005$</td>
<td>$F=14.52; p=0.001$</td>
</tr>
<tr>
<td>Neg-Inv Rectangles</td>
<td>$F=3.16; p=0.091^{36}$</td>
<td>$F=33.60; p&lt;0.0005$</td>
<td>$F=4.87; p&lt;0.039$</td>
</tr>
</tbody>
</table>

$^{34}$Significant with the certainty data ($F_{1,20}=11.77; p=0.003$).

$^{35}$Not significant with the certainty data ($F_{1,20}=3.97; p=0.060$).

$^{36}$Significant with the certainty data ($F_{1,20}=4.86; p=0.039$).
Figure 15.3  Accuracy (part a) and certainty (part b) for the detection of feature displacements in normal faces and in normal, negative, inverted and negative-inverted dots-in-a-rectangle patterns
Figure 15.4  Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in normal faces and in normal, negative, inverted and negative-inverted dots-in-a-rectangle patterns.
15.4 Discussion

15.4.1 Comparing faces and dots-in-rectangles

The normal face trials resulted in a level of performance that was significantly higher than that from the four types of dots-in-a-rectangle trials collectively. Furthermore, the performance on the normal face trials was significantly better than on the normal rectangle trials. This is an important result as it suggests that the superior performance obtained with the normal faces in the previous experiments was not simply a result of the presence of a fixed reference point (the sides of the face) in close proximity to the eyes. Had this difference not been significant then all the previous discussion of the high-level significance of the face as a stimuli would have been placed in doubt, as the superior performance with the face could have been explained as a consequence of a low-level physical characteristic of the stimulus. Even when fixed reference points are available close to the "eyes", subjects are still not as sensitive to displacement as in images of real faces. This is the best demonstration that faces are genuinely "special" stimuli as far as the visual system is concerned.

15.4.2 The negation and inversion effects

Although the effect of inversion was not significant with the accuracy data, there is a clear trend present in the data, and the effect was significant when the certainty data was analysed. Thus it seems that the stimuli generated for this study were just face-like enough to give rise to a marginal inversion effect. Given this result and that of the previous experiment, the earlier conclusion that the necessary conditions for the emergence of an inversion effect involved both the real facial features and a surround of some type, might have been incorrect. It would now appear that any combination
of feature like components and some form of surround is sufficient to give rise to this
effect; only in the case of experiment 5 has such a combination of components failed
to give rise to an inversion effect.

Although we can explain the presence of an inversion effect in the data from this
experiment, the emergence of a significant effect of negation is rather more puzzling.
It had seemed that a real facial surround was a necessary requirement for the negation
effect, and I had argued that this was because the facial surround provided information
about the three dimensional structure of the facial surface that was useful when
determining the location of the features, and that this information was lost when the
image was negated. However, the image used in this experiment contains no shadow
information, being entirely composed of geometric shapes. It seems that, in this case
at least, the negation effect could be due to the reversal of the normal contrast
between the features and the flesh tones. That is, the effect could be due to the
processes of negation rendering the "eyes" light relative to the "skin" colour.

In the normal face the features (or rather their shadows) are dark compared to the skin
coloration. Negation reverses these colour relationships as well as disrupting the
calculation of shape-from-shadow information, and it appears that in this experiment
the change in coloration has been sufficient to reduce performance. This is a very
surprising result as it is not clear why this effect did not emerge in experiments 6, 7
or 8.

This suggestion that the negation effect is caused by a change in the apparent
pigmentation of the face rather than by the loss of shape-from-shading cues was
discussed in chapter 3, and has recently received support from Bruce & Langton
Bruce & Langton failed to observe a negation effect using a traditional recognition memory paradigm with scanned head volumes devoid of any pigmentation. In light of the results reported above it does appear that this explanation requires more careful consideration. The next experiment was designed to test this explanation of the negation effect.
Chapter 16

Experiment 12:

The causes of the negation effect
16.1 Introduction

"Effects of negation may arise because of the reversal of pigmentation, or because of the difficulty provided for the derivation of 3D shape from shading, or both." (Bruce, 1994; page 10)

16.1.1 Two possible causes of the negation effect

The possible causes of the negation effect were considered in chapter 3, and two alternative explanations were identified; the shape-from-shading explanation and the pigmentation explanation. The results from the first 10 experiments reported in this thesis were largely compatible with the shape-from-shading explanation. This explanation also seemed better able to account for the reduced sensitivity to feature displacement in negative images. However, the emergence of a negation effect in experiment 11 is difficult to explain. The stimulus used in experiment 11 was a geometric figure that contained no shadow or shading information, and so it had been predicted that the perception of this stimulus would not be affected by negation. Given this unexpected observation of a negation effect in a stimulus containing no shadow information, it was decided that a more direct test of the shape-from-shading and pigmentation explanations was required.

16.1.1.1 The shape-from-shading explanation: This explanation relies on the fact that the visual system is known to estimate the 3-D structure of a surface on the basis of a number of sources of information, including the shading and shadow information
afforded by the luminance profile of the image (see Cavanagh & Leclerc (1989), Johnston & Passmore (1994a) and Johnston & Passmore (1994b) for a discussion of the shape-from-shading processes). Negating the image inverts the luminance profile and so will inevitably disrupt those processes that use the shading information to construct a 3-D representation of the face. Thus, if face recognition requires such a 3-D representation, then negation will result in slowed and less accurate recognition.

16.1.1.2 The pigmentation explanation: Bruce & Langton (1994) argued that the changes in the apparent pigmentation of the face caused by negation are responsible for the lower recognition accuracy. Bruce & Langton employed highly accurate representations of head volumes produced by scanning the head of a subject with a laser beam. The scanned heads were then represented on a computer screen and artificially "lit" by a notional light source with the resulting shadow and shading being calculated by the computer. These scanned heads were completely devoid of pigmentation, and so when Bruce & Langton (1994) found that subjects' recognition was not affected by negating the images, they concluded that the missing pigmentation information must be a vital factor in the negation effect. Negation causes, for example, fair hair to become dark, and the dark pupils of the eyes to become light, and Bruce & Langton suggested that it might be this type of false and misleading pigmentation that gives rise to the poor recognition performance.

"work in our laboratories suggests that the effect of pigmentation reversals may be more important than that of lighting for identification of faces ... In experiments in which subjects were required to identify faces shown as surface images lacking pigmentation ... performance
was disrupted by inversion but not significantly by negating the surface images."

(Bruce, 1994; pages 10-11).

Although it is clear that changing the pigmentation of a face might affect the accuracy with which it is recognised, it is far from clear why such a change should make it more difficult to detect small changes in the location of the features. It is easier to imagine that the precise calculation of the location of the features of the face might be dependent on the computation of the 3-D structure of the head, and thus the shape-from-shading explanation seems better able to explain the results reported in this thesis.

16.1.2 Distinguishing between pigmentation and shape-from-shading

One difficulty arises when trying to assess the role of pigmentation in the negation effect; it is not clear exactly what Bruce & Langton (1994) mean by this term. In a footnote to their main text Bruce & Langton discuss alternatives to this term, and it seems that they are attempting to describe the coloration of the surface of the face. Given that all research on negation has utilised monochrome images, and given that monochrome images represent only luminance information, then this term must be reflecting some aspect of the image encoded in the luminance profile.

This is important as the shape-from-shading information is also encoded in the luminance profile of the image. The crucial difference is that the shape-from-shading information is represented only in the luminance profile of an image. Cavanagh & Leclerc (1989) have demonstrated that the visual system is capable of correctly...
interpreting a scene provided the shadows are darker than the regions that cast them; the colour of the objects casting the shadows is of no importance in these calculations. This effect is neatly demonstrated by Livingstone (1988) who showed that when an artist is trying to represent a 3-D form, his or her choice of pigment should be determined more by its brightness than by its hue. Livingstone demonstrated that the skilled artist is able to give the impression of a coherent 3-D structure regardless of the hues s/he chooses to use in the image. So long as the relative luminance values are appropriate to the structure described, the image appears coherent (see figure 16.1).

The information relevant to the shape-from-shading process is thus coded exclusively in the luminance profile of the image, and shading and shadow are properties of the image. Pigmentation on the other hand is a property of the object, and the term refers to the optical properties of the object's surface. Thus these terms can be separated if we can find a way to manipulate the apparent optical properties of the object's surface without altering the shading and shadow information coded in the luminance profile of the image.
Figure 16.1 A self portrait by Matisse. Part (a) is reproduced in colour, part (b) in monochrome, part (c) in colour negative, and part (d) in monochrome negative. In part (a) the unusual pigmentation of the forehead region does not disrupt our perception of the face shape. The monochrome version (part b) reveals that the green patch on the forehead is actually a shadow for which the luminance is entirely appropriate for the 3-D structure being described. In the negative versions of the image the relative luminance of the shadow and high-light areas is inappropriate thus disrupting the shape-from-shading processes. (After Livingstone, 1988).
16.1.3 Monochrome images, scanned head volumes and colour images

As all previous studies of the negation effect (other than Bruce & Langton, 1994) have used conventional monochrome images, the role of the pigmentation and shading information have been confounded. In monochrome images only the brightness of an object is represented, and this can be affected by both the object’s pigmentation and the lighting conditions. Bruce & Langton were able to separate these two explanations because they were manipulating images devoid of all pigmentation. The scanned head volumes they employed, encoded only the shape, and not the optical properties, of the object’s surface. A potential problem with this approach however, is that the shape-from-shading information will only be encoded correctly and coherently if an accurate mathematical model is employed to artificially light the head volume. Bruce & Langton employ a relatively simple lighting model, and it is possible that it is the inadequacies of this model that gave rise to both the lack of a negation effect and the very poor level of recognition in the "normal" condition (see chapter 3 for a full discussion of this possibility).

A more satisfactory approach would be to employ full colour representations of natural faces. In a colour representation the hue and luminance of each part of the image are coded separately, and so could be manipulated separately.

16.1.4 The nature of full colour representations

What we normally refer to as the colour of an object has three distinct components, the brightness or luminance (essentially the amount of light reflected from the surface

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37 For example, it appears that the model employed makes no allowance for the illumination resulting from light reflected from other parts of the face.
of the object), the hue (the frequency of the light reflected from the surface of the object) and the chroma (the relative amount of hue).

In a monochrome image only the luminance profile of the object is represented, and thus two objects of equal luminance (two equiluminant objects) will appear identical. In a colour image both the luminance and the hue are represented, so the two equiluminant patches that appeared to be identical when photographed on monochrome film may appear very different from each other when photographed with colour film.

16.1.5 Monochrome and Colour Negatives

Because only the luminance profile is represented in a monochrome image, only this information is altered when a negative is created. In a colour representation the hue and luminance information are coded in separate and independent image channels. In a colour photographic negative both of these channels are reversed (see figure 16.1).

16.1.6 The representation of shape-from-shading and pigmentation in colour and monochrome images

As the shape-from-shading processes utilise only the luminance profile of an image, this computation will be identical for monochrome and colour representations of the same scene. The pigmentation of an object however, is a description of the visual properties of the object's surface, and as one such property is the frequency of the light reflected by the surface (the hue), the pigmentation is represented in both the luminance and the hue channels of a colour image.
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Experiment 12: The causes of the negation effect

Thus in a conventional monochrome image it would never be possible to manipulate separately the effects of pigmentation and shape-from-shading. However, in a full colour representation the addition of an independent channel of hue information allows us the possibility of changing the apparent pigmentation of a surface patch without affecting the luminance profile of the image.

If, as Bruce & Langton (1994) suggest, the negation effect is accounted for by the change in apparent pigmentation, then a facial image in which the luminance profile is unchanged while the hue values are inverted should be difficult to recognise as the pigmentation of the object will appear to have altered dramatically. If, on the other hand, the negation effect is caused by the loss of shape-from-shading cues, then such an image will be almost as recognisable as the original, unaltered image even though it looks very different.

Thus, the ability to alter the hue and luminance values independently of one another allows us to disentangle the two most widely accepted explanations of the negation effect. The use of full colour, rather than monochrome, images allow us to make just such image manipulations.

16.1.7 The effects of Colour Negation

It would appear that the negation effect has never been investigated using full colour images, but simple observation of negative colour film suggests that colour negation is at least as disruptive to recognition as monochrome negation (see figure 16.2). To date, all studies of the negation effect have explored monochrome negation and most
have employed monochrome film stock\textsuperscript{39}. This methodology has forced researchers to consider merely the effects of luminance reversal, and to ignore the effect of hue reversal.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{image16_2.png}
\caption{A famous face (John Major) presented in colour negative and monochrome negative}
\end{figure}

16.1.8 Naming the image manipulations

The independent manipulation of the hue and luminance channels of an image is illustrated in figure 16.3 where a representation of the colour wheel is presented in four different forms. Part (a) shows the normal full colour image and part d) shows this image in "normal colour negative" with both the hue and luminance relationships reversed (henceforth I shall refer to this manipulation as \textit{full negation}). Part b) of this

\textsuperscript{39}The one possible exception here is Phillips (1972) who made use of lith film. Lith film is like standard monochrome film in that it does not represent hue values, but unlike monochrome film it reduces the luminance information to 1 bit - that is all values are represented as either black or white with no intermediate greys. Most of the previous discussion holds true for this film type.
figure shows the effect of reversing the hue values without altering the luminance values of the image (henceforth I shall refer to this manipulation as *luminance negation*) and part c) shows the effect of reversing the luminance values (actually a 180 degree rotation of the colour wheel) without reversing the hue values (henceforth referred to as *hue negation*).

![Figure 16.3](image)

Figure 16.3 The four forms of colour negation applied to an illustration of the colour wheel. Part (a) illustrates the normal image, part (b) the hue-negative, part (c) the luminance-negative, and part (d) the full-negative version of the image. Note that hue-negation results in a rotation of the colour wheel by 180° but does not alter the relative luminance of the patches.
16.1.9 Comparing the manipulations

Figure 16.4 illustrates these four forms of colour representation when applied to the Matisse self portrait studied by Livingstone (1988). The reader is invited to inspect these four images carefully. I would suggest that the hue negative image appears to have normal "depth", and although not being quite as pleasing an image as the original, presents no problems of interpretation. This is because the brightness relationships in the image have not been changed, and hence the original shadow regions still remain darker than the objects casting those shadows. This is simply a different way of demonstrating the result shown by Cavanagh & Leclerc (1989) and Livingstone (1988); the hue of shadow regions is unimportant, and so long as the shadows remain darker then the objects casting them, the visual system will correctly interpret the 3-D structure of the scene.

By contrast, the full negative image and the brightness negative image look very different from the original, and I would suggest that the change in the luminance relationships has disrupted the calculation of the 3-D structure of the objects giving rise to their strange appearance.
Figure 16.4 The Matisse self-portrait prepared in the four forms of colour negation (parts (a) - (d) show the image in normal, hue-negative, luminance-negative and full-negative respectively). In parts (a) and (b) the luminance profile is as the artist intended, and the image looks relatively normal. In parts (c) and (d) the luminance profile has been reversed leading to a disruption of the shape-from-shading processes and give the image an unnatural appearance. (After Livingstone, 1988).
16.1.10 The predictions made by the two competing explanations

The pigmentation explanation of the negation effect would predict that both the hue-negative and the luminance-negative images of a face would be difficult to recognise as both these manipulations will give rise to changes in the image that can be interpreted as changes to the pigmentation of the face. The shape-from-shading explanation also predicts that the luminance-negative image will be difficult to recognise, but in contrast to the pigmentation explanation, this explanation predicts that the hue negated image will be almost as recognisable as the original\(^{39}\), as changes to the hues will not be seen as reflecting changes to the 3-D structure of the face and head.

If we assume that the sensitivity to feature displacement would be affected in the same way as recognition performance, then we could predict that subjects will be more sensitive to feature displacement in normal and hue-negative images than in luminance-negative or full-negative images.

16.1.11 Some hypotheses

These predictions need to be tested empirically. In the following experiment subjects' sensitivity to feature displacement is again assessed, but this time using full colour images which are presented in either normal, full-negative, luminance-negative or hue-negative image types. Given the previous discussion of the probable causes of the negation effect the hypotheses for this study were:

\(^{39}\)It is reasonable to assume that this manipulation will result in some small degradation of recognition performance since even very minor changes to the image have been shown to affect recognition accuracy- especially for unfamiliar faces.
H₁ Subjects will be less able to detect small feature displacements in full negative or luminance negative images than in normal or hue negative images.

H₂ There will be no difference between subjects' sensitivity to feature displacement in normal and hue negative images.

This experiment also has three other important objectives. Firstly, in all the previous studies the face employed was unfamiliar to the subjects (with the exception of experiment 5, where the subjects knew the individual depicted, but since in that experiment all the internal features of the face were replaced with dots it is unlikely that the subjects would have recognised the image). It was noted in chapter 4 that there is some evidence that sensitivity to the displacement of facial features might be different for familiar and unfamiliar faces (in particular there might be a difference in sensitivity to horizontal displacements of the eyes). In this experiment it was therefore decided to use a face that was familiar to the subjects.

Secondly, the preceding experiments all made use of very simplified images - images that were both monochrome and thresholded. Haig (1984) demonstrated similar sensitivities to feature displacement in upright faces using full grey scale images, but the inversion and negation effects shown in experiments 1 and 2 have never been demonstrated with any other images. It is therefore important to establish whether these effect will also occur with non-thresholded images. The requirement to use full colour images forced by the hypotheses means that we can investigate the effects of feature displacements in high quality colour images.

Finally, the decision to use a familiar face serves to satisfy a possible criticism of the studies undertaken so far. All of the studies undertaken so far have used the same
individual’s face (or a modified versions there of) and thus, to argue that these results are applicable to the perception of faces in general might be a little presumptuous! As this experiment uses a different face it will be possible to establish whether the effect of negation observed in experiments 1 and 2 was specific to the individual depicted in the original image, or whether it was a more general effect.

16.2 Method

16.2.1 Subjects

The 36 participants were all were students of psychology at the University of Westminster and hence were familiar with the individual whose face was used to construct the stimuli. All were naive of the hypotheses of the study and none had taken part in any of the previous experiments.

16.2.2 Preparation of the stimuli

The original image used in this study is shown in figure 16.5 part a). This image of a member of academic staff in the Division of Psychology at the University of Westminster, was captured using a Canon Ion RC-560 still video camera and then transferred to an Apple Centris microcomputer system. The image was manipulated using Adobe PhotoShop software.

The image was first converted into a 512x512 pixel RGB format image (i.e., each pixel contained 8 bits of information for each of the red, green and blue channels). Elliptical image regions centred around each eye were then copied and saved. These
image regions could then be written back to new locations in the original image
overwriting the original pixel values at that location. In order to ensure a smooth
boundary between the displaced feature region and the original flesh tones, a five pixel
wide smoothing function was applied around the edge of the elliptical region
containing the feature. This had the effect of calculating a weighted average of the old
and new pixel values at these locations, thus smoothing the transition between the
image segments.

Using this technique versions of the image were prepared in which both eyes were
displaced either upwards, downwards, inwards or outwards by either 1, 2, 3, 4, 5, 6,
7, 8, 10 or 12 pixels. This gave rise to a total of 40 new images in addition to the
original, unmodified image. Hue-negative, luminance-negative and full-negative
versions of each of these 41 images were then prepared.

The images were displayed on a standard 14-inch, 8-bit colour monitor, which was
capable of displaying over 16 million different colours, of which 256 could be
displayed at any one time. The PhotoShop software was set to optimise automatically
the choice of colour palette so as to provide the most accurate colour rendition for
each image displayed.

These images were then recorded onto film by photographing the monitor in a
darkened room using Kodak Ektachrome 100 ASA colour slide film in a Pentax ME-
Super SLR camera fitted with a standard (50mm) lens. The camera was positioned 0.7
meters from the screen and the exposure was set to 0.5 seconds at f8.0.
Two photographs were taken of each of the modified (feature displaced) images while three were taken of each of the unmodified images giving a total of \((40 \times 4 \times 2) + (1 \times 4 \times 3) = 332\) slides. The films were batch-processed by a professional laboratory and hand mounted into glassless slide mounts.

Inspection of the slides and informal piloting of the procedure seemed to indicate that, subjects who were familiar with the face depicted, were better able to detect small feature displacements than the subjects in the previous studies who were unfamiliar with the thresholded monochrome face. It was therefore decided to make use of only the 2, 4 and 6 pixel displacement sets of images in this study \(\text{(Note: The image used in the previous studies was only 256x256 pixels and hence a 2 pixel displacement in these new images is equivalent to a 1 pixel displacement in the old images).}\)

16.2.3 Design

As in the previous studies, each trial involved displaying three images of which the top and one of the lower images were identical and had their eyes in the original locations. The third image had been modified by having the eyes displaced. As in the previous studies the three images displayed within any one trial were always of the same image type (i.e. had the same luminance and hue levels).

As in previous studies the two eyes were both displaced either inwards, outwards, upwards or downwards (the Movement factor) and by either 2, 4 or 6 pixels (the Size factor). The three images making up a trial were all presented in either normal colour, full negative, luminance negative or hue negative, giving rise to two additional factors of Hue (normal or reversed) and Luminance (normal or reversed). Finally, as in the
previous studies, the modified image occurred once on the left hand side and once on the right hand side, give rise to the additional factor of Side.

Thus the study employed a fully factorial 3x4x2x2x2 design where the factors were:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of displacement</td>
<td>2, 4 or 6 pixels</td>
</tr>
<tr>
<td>Movement</td>
<td>Inwards, Outwards, Upwards or Downwards</td>
</tr>
<tr>
<td>Luminance</td>
<td>Normal or Reversed</td>
</tr>
<tr>
<td>Hue</td>
<td>Normal or Reversed</td>
</tr>
<tr>
<td>Side of image</td>
<td>Left- or Right-hand image modified</td>
</tr>
</tbody>
</table>

This resulted in a total of 96 trials.

16.2.4 Procedure

The major difference between this and the previous studies was that the use of colour required each image to be individually projected on 35mm photographic slides. The experiment was run by projecting sets of three slides simultaneously on to a white wall in a dimly lit room. The three Kodak Ektapro 5000 slide projectors used were under computer control via a specially written computer programme. This programme was written in QBASIC and ran on a 386 IBM compatible PC. The computer was modified to give it access to three serial ports and each of these was connected to the "P-Bus" port on one of the slide projectors. The programme controlled the projectors using Kodak's P-COM computer control protocol, giving access to any slide in the slide tray and allowing the internal shutter in the projectors to be opened or closed.
48 slides were loaded into each of two Kodak slide projector slide trays. These 48 slides constituted a set of the four image types (normal, luminance negated, hue negated and full negative) for each of the 3 feature displacements, in each of four directions. Four slides showing the original (features not displaced) face in each of the four colour types (normal, luminance negative, hue negative and full negative) were then loaded into the next 4 tray positions. These two slide trays were then loaded on to the projectors that projected the left- and right-hand images.

The third projector was aligned to display the top image and contained the four slides, showing the original face in each of the colour types, loaded into slide tray positions 1 to 4.

The computer programme controlled the entire experiment. Subjects were first given 8 demonstration trials, in the first four of which the largest displacements were demonstrated for, inwards, outwards, upwards and downwards displacements of the eyes, in the normal colour images. In the remaining four demonstration trials the other three colour types were each demonstrated at least once with a 6 pixel displacement. The exposure duration in these demonstration trials was under the control of the experimenter, and the computer randomly controlled whether the modified image was displayed by the left or the right projector.

The subjects were told that their task was to identify which of the two lower images had been modified by having the eyes moved either in, out up or down. They were told that the top image always had the eyes in the original location, and that they could use this knowledge together with their memory of the subjects normal facial appearance to assist them in the task. They were warned that on some of the trials the
three images would appear to be oddly coloured, but were told that despite this their
task always remained the same.

Following the 8 demonstration trials and after ensuring that all the subjects understood
the instructions, 10 randomly selected practice trials were given. Subjects were warned
that each trial would only be shown briefly. Subjects recorded their responses to these
practice trials and to the subsequent experimental trials in an answer booklet very
similar to that used in the previous studies (see appendix 1).

The 96 experimental trials were then commenced. The computer programme first
determined a random order for the 96 experimental trials, and then selected the
appropriate tray positions on the three projectors for the first trial. After allowing three
seconds for the trays to reach the desired positions, the internal shutters on all of the
projectors were opened simultaneously displaying the three images for that trial. These
images were displayed for 5 seconds before the shutters were closed and the computer
issued the appropriate commands to position the three slide trays ready for the next
trial. After allowing three seconds for the trays to reach the desired location the
shutters were again opened to start the next trial. Hence for each trial there was a
three second inter-stimuli-interval and a 5 second exposure duration.

The experimental session lasted slightly over 30 minutes, and on completion of the
last trial all participants were thanked and debriefed. All the participants were run in
a single session in a large lecture theatre and were seated at varying distances from
the projection screen. On average the visual angle subtended by the image was similar
to that in experiment 2. An example trial is illustrated in figure 16.6.
Figure 16.5  The original (unmodified) face used in experiment 12 illustrated in normal-colour (part a), hue-negative (part b), luminance-negative (part c), and full-negative (part d). In each of the four images the same two pixels have been enlarged to illustrate the effect of these transformations. The lines marked on part (a) show the original location of the pixels.
Figure 16.6  An example of a hue-negative trial from experiment 12. The eyes in the right-hand image have been displaced inwards by 6 pixels.
16.3 Results

16.3.1 Initial treatment of the data

Due to an error in the stacking of the slide trays it was not possible to analyse the data from the 2 pixel displacement trials. The following analysis is therefore based on the results from the 4 and 6 pixel trials only. The data from four subjects who correctly identified the modified image on less than 50% of the normal trials was also disregarded.

As in the previous experiments, the accuracy and the certainty data were analysed separately.

16.3.2 Accuracy data

Overall participants achieved a mean accuracy score of 69.6% correct. This data was submitted to a 2x2x4 (Luminance by Hue by Movement) within-subjects analysis of variance.

The main effect of Luminance was significant\(^{40}\) \((F_{1,31}=5.03; \, p=0.032)\), with participants being less sensitive to feature displacements in images with reversed luminance than normal luminance. In contrast, the main effect of Hue was not significant \((F_{1,31}=0.57; \, p=0.455)\), indicating that participants' sensitivity to feature displacement was not affected by negating the hue channel of the image. The

\(^{40}\)The only major difference between the analysis reported here and that involving all 36 subjects was that with all the subjects included, the main effect of luminance just failed to reach significance \((F_{1,35}=3.81; \, p=0.059)\).
interaction between these two factors was also not significant \( (F_{1,31}=0.01; p=0.917). \)

See Figure 16.7.

As in all previous studies, the main effect of Movement was significant indicating that some displacements were more easily detected than others \( (F_{1,31}=16.46; p=<0.001). \)

The two-way interaction between Hue and Movement was significant \( (F_{3,93}=6.38; p=0.001) \), but that between Luminance and Movement was not \( (F_{3,93}=1.44; p=0.235). \)

The three way interaction between Luminance, Hue and Movement was significant \( (F_{3,93}=3.06; p=0.032). \) See figure 16.8.

16.3.3 Analysis of the certainty data

An identical 2x2x4 analysis of variance was performed on the certainty data, and a very similar pattern of results emerged, the major difference being that the interaction between Hue and Movement that was significant with the accuracy data was non-significant with the certainty data \( (F_{3,93}=1.45; p=0.233). \)

16.3.4 The effect of direction of displacement

Sensitivity to the different directions of displacement was compared using a series of \textit{A priori} comparisons for each of the four image types. These comparisons are summarised in table 16.1. Inspection of this table reveals that although participants were more sensitive to horizontal than vertical displacements in normal images, this difference was not significant for the other three image types. Subjects were more sensitive to inwards than outwards displacements in hue-negated and full-negative
images, but not brightness-negative and normal images. The difference in sensitivity to upward and downward displacements was not significant for any of the four image types.

Analysis of the certainty data revealed a slightly different pattern of results. The difference in sensitivity to horizontal and vertical displacements was significant for the normal, hue-negative and full-negative image types, but not the brightness-negated images. Participants were more sensitive to inward than outward displacements, but equally sensitive to upward and downward image types for all four image types.
Table 16.1 Univariate $F$-tests with (1,31) degrees of freedom, comparing sensitivity to different directions of displacement. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate differences that are significant with the accuracy data. Where the significance differs with the certainty data this is indicated in the footnotes.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-colour</td>
<td>$F=1.93$; $p=0.174^{\dagger}$</td>
<td>$F=34.18$; $p&lt;0.0005$</td>
<td>$F=0.744$; $p=0.395$</td>
</tr>
<tr>
<td>Faces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hue-Negative</strong></td>
<td>$F=53.64$; $p&lt;0.0005$</td>
<td>$F=0.21$; $p=0.651^{\dagger\dagger}$</td>
<td>$F=1.98$; $p=0.169$</td>
</tr>
<tr>
<td>Faces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Luminance-</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>$F=3.58$; $p=0.068^{\ddagger}$</td>
<td>$F=0.95$; $p=0.336$</td>
<td>$F=1.14$; $p=0.294$</td>
</tr>
<tr>
<td>Faces</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Full-</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Negative</td>
<td>$F=37.48$; $p&lt;0.0005$</td>
<td>$F=3.21$; $p=0.083^{\dagger\dagger}$</td>
<td>$F=1.375$; $p=0.250$</td>
</tr>
<tr>
<td>Faces</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{\dagger}\)Significant with the certainty data ($F_{1,31}=7.62$; $p=0.010$).

\(^{\dagger\dagger}\)Significant with the certainty data ($F_{1,31}=9.03$; $p=0.005$)

\(^{\ddagger}\)Significant with the certainty data ($F_{1,31}=9.13$; $p=0.005$).

\(^{\dagger\dagger}\)Significant with the certainty data ($F_{1,31}=28.96$; $p<0.0005$).
Figure 16.7 Experiment 12: Accuracy (part a) and certainty (part b) for the detection of feature displacements in high quality, full-colour images of a familiar face presented in Normal-Colour, Hue-Negative, Luminance-Negative and Full-Negative.

Error bars indicate 95% confidence intervals. N=32
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Experiment 12: The causes of the negation effect

Figure 16.8  Experiment 12: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in Normal-Colour, Hue-Negative, Luminance-Negative and Full-Negative images of a familiar face.
16.4 Discussion

16.4.1 The Hypotheses

Earlier it was argued that if the negation effect acts by disrupting the encoding of the 3-D structure of the face from the shading and shadow information contained in the image, then negating just the luminance channel of a colour image should be as disruptive to performance as negating the entire image. The significant main effect of luminance negation means that we can accept the first hypotheses; participants found it more difficult to detect feature displacements in images in which the luminance channel had been negated.

The lack of a significant main effect of hue-negation allows us to accept the second hypothesis; participants were equally sensitive to feature displacements in normal and hue negated images.

16.4.2 Negation: Shape-from-shading or pigmentation?

I have argued that changing the hue channel of a colour image without changing the luminance channel has the effect of altering the apparent pigmentation of the face without altering the shape-from-shading information. This argument relies on the evidence (e.g., Cavanagh & Leclerc, 1989) that the visual system only considers the relative luminance of sections of an image, and not their hue, when trying to extract information about the 3-D structure of the object. Hence, even negating the hue channel by rotating the colour wheel through 180 degrees should have no effect on the perceived structure of the object, despite resulting in a very marked change to the
apparent pigmentation of the object. The hue-negated images look very bizarre, and in these images the flesh takes on a strange blue-green tone with the lips appearing particularly blue. If the standard negation effect (i.e., the negation effect demonstrated with monochrome images in a recognition memory paradigm) is caused by the apparent change to the pigmentation of the face resulting in poor subsequent recognition, then these hue negated images should surely also be problematic.

The fact that the hue negated images are so recognisable leads one to doubt the effect. There is a tendency to underestimate the effect of the hue-negation transformation, because the hue negative images look so ordinary. These images are very different from the original image, but we are relatively insensitive to the hue changes introduced by this manipulation. By comparison, the effect of luminance negation is dramatic. Both the luminance-negative and the full-negative images are difficult to recognise, and although the two images look very different due to the reversal of the hue channel information in the full-negative image, they appear to be equally recognisable. The current study has demonstrated that subjects are able to detect feature displacements in these two image types with a similar degree of accuracy.

In monochrome images negation results in a change to both the apparent pigmentation of the image and the perceived 3-D structure of the object. The use of colour images has allowed the separation of these two channels of information, and the fact that I have shown that performance in a feature displacement task is affected by luminance-negation, but not by hue-negation suggests that the negation effect, in the case of this task at least, can not be caused solely by a change in the apparent pigmentation of the face. A change in the luminance channel could be perceived as a change to the pigmentation of the face, but if this was the cause of the effect then surely the very
dramatic changes brought about by the hue-negation would also result in a decrease in performance. No such effect of hue-negation was identified and so the data are not fully compatible with the pigmentation explanation of the negation effect. The results are however compatible with the shape-from-shading explanation.

16.4.3 The role of 3-D information in face perception and recognition

Bruce & Langton (1994) found that negation did not significantly affect the recognition of images of faces that were devoid of pigmentation information. They therefore argued that pigmentation changes were the most likely cause of the negation effect in a recognition paradigm, and, more critically, that as the disruption to the shape-from-shading process caused by negation did not seem to interfere with recognition, then recognition can not be dependent on the formation of a detailed 3-D representation of the face. Thus Bruce & Langton (1994) argued that face recognition can be thought of, and presumably modelled as, a process that operates on flat, 2-D representation of faces:

"Our results thus provide rather little support for the use of shape from shading in providing information important for face identification."


This is a surprising conclusion, and as the authors recognise, one that is contrary to previous research by Bruce. For example, Bruce, et al. (1992) argued that the "mass" (dark) components of an image of a face were important for recognition as these components help preserve shape-from-shading information. Bruce & Langton (1994) reviewed this position and concluded that the importance of the "mass" component lies
in the fact that it reflects the relative pigmentation of parts of the face. I would dispute this conclusion. If the example images provided by Bruce, et al. (1992) are studied, it is clear the "mass" components are not reflecting relative pigmentation. With the possible exception of the hair, the large dark regions in the mass component reflect shadow and shading information. In the case of the hair there are often large dark regions reflecting the fact that the hair colour is darker than the flesh tones, but this information can not be critical to the negation effect as Bruce & Langton (1994) demonstrate the negation effect when the hair is covered (and the eyes are closed).

The results presented here suggest that, at least in the case of the feature displacement task, a knowledge of the 3-D structure of the face is beneficial; so why should there be such a discrepancy between these two studies? There seem to be two major differences between the studies that could account for this difference.

Firstly, the two studies employ different paradigms for measuring the effect of negation. Bruce & Langton (1994) use a variety of procedures, but all are versions of the basic identification task, where participants are required either to determine whether a face has been seen before or to identify a face. This task required the participants to compare the image to their memory for faces previously encountered. Any effect of the loss of shape-from-shading information would presumably reflect the fact that details of the 3-D structure of the face could not be represented in memory. In the experiment reported here, a feature displacement paradigm was employed resulting in task demands that are largely perceptual in nature and do not require the participant to represent the face in memory. In this paradigm an effect of the loss of shape-from-shading information would seem to reflect the fact that such information can be useful in the accurate location of the features on the complex and
folded surface of the face. Thus the different results from these studies could simply reflect the fact that different tasks demand the use of different sources of information; although information about the 3-D structure of a face might be useful in a feature displacement task this does not mean that such information is utilised in a face recognition task.

The second possibility is that the use of laser-scanned surface images, although technologically impressive, might give rise to results that can not be generalised to more normal representations of faces. Maybe we should be cautious before drawing conclusions about the role of shadows from images in which all the shadow information was derived from a simple computer model. There are no real shadows in the surface images used by Bruce & Langton (1994), only those provided by the lighting model applied by the computer system displaying the images. Thus we are as much testing the validity of the lighting model as testing the role of shadow in the recognition of these images. In chapter 3, I suggested that a particular weakness of the model used might be that it makes no allowance for reflection from the skin's surface. Another possibility is that the choice of location of the position for the notional light source might have acted to minimise the effect of negation⁴⁵. The heads were lit as if from the left side, but this results in negative images that are very like positive images lit from the right side; it is the use of top- or front- lighting that gives rise to dramatic changes in the pattern of shadows. Hence, either the lighting model used or the positioning of the notional light source could be having the effect of minimising the effect of negation.

⁴⁵I am grateful to Alan Johnston for this suggestion.
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Experiment 12: The causes of the negation effect

The first of these two possibilities can easily be tested by applying the image manipulation techniques developed for the current study, to a more conventional face recognition paradigm. This is the approach being adopted by the author in some research currently under way.

The second possibility, that the lighting model adopted by Bruce & Langton (1994) is somehow at fault, could also be examined. It would be relatively easy to change the location of the notional light source used to illuminate the surface images, and so see if a front-lit face surface image is more effected by negation than a side-lit image. The more general suggestion, that Bruce & Langton are in fact testing the validity of their computer lighting model, is rather more difficult to put to the test. If, as suggested by the experiment reported in this chapter, the negation effect is largely a consequence of the disruption to the shape-from-shading processes, then "painting" the surface of the images used by Bruce & Langton should have little effect on their recognition. If these surface images could be displayed on a colour monitor and a colour pattern mapped on the surface, then, as long as the shadows were accurately calculated and represented, this very dramatic change to the appearance of the face should have little effect on how recognisable the face is.

16.4.4 The direction of feature displacement

As in all previous studies, the main effect of movement was significant, but a major difference between this study and the others was that the difference in sensitivity to horizontal and vertical displacements was only significant for the normal image type. This may be due to a floor effect; it might be that the task was so difficult because
of the relatively small displacements introduced into the images, that the performance
with the horizontal displacement, non-normal trials was severely limited.

It is also interesting to note that participants detected inward and outward
displacements with equal accuracy for the normal image type, but were more certain
about their responses to inward than outward displacements. Haig (1984) found that
subjects were more sensitive to inward displacements of the eyes than outward
displacements, but Hosie, et al. (1988) reported equal sensitivity to these two
directions of displacement arguing that this difference in the pattern of results was
probably due to their use of famous, familiar, faces. The previous studies reported in
this thesis have used an unfamiliar face, and yet have failed to find a reliable
difference in sensitivity to inward and outward displacements for the normal image
type (though this difference frequently is significant for negative and inverted image
types). In the current study a familiar face was used and so Hosie, et al. (1988) would
predict that the difference in sensitivity to inward and outward displacements would
not be significant. In fact there was no significant difference in the accuracy with
which inward and outward displacements could be detected, but this difference was
significant when the participants' confidence in their response was also considered.
Hosie, et al. (1988) would therefore appear to be wrong; there is some evidence of a
significant difference for familiar faces, but I have often failed to observe this
difference for unfamiliar faces.

16.4.5 The negation effect with a familiar face

Previously the effect of negation on the detection of feature displacements had only
been demonstrated for an unfamiliar face. In this study all the subjects were familiar
with the face depicted in the stimuli and hence we can see that this effect generalises
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to familiar faces. Importantly we can also demonstrate that the effect shown in the previous studies was not specific to the one face used in all those experiments. Unfortunately, because the viewing conditions were not tightly controlled either within or between the studies presented in this thesis it is not possible to compare formally the size of the effect in this study with, say, that found in experiment 1 in order to investigate whether the switch to a colour image of a familiar face has modulated the strength of the effect. Informal observation of the two tasks would suggest that there is little, if any, difference in difficulty between the two stimuli types (after allowing for the difference in pixel size).

16.4.6 Conclusions

The results of this study suggest that the effect of image negation on the sensitivity to feature displacements in a facial image (as demonstrated in experiments 1 and 2) can not be accounted for solely by the change in apparent pigmentation introduced by this manipulation. Face recognition seems to rely on the accurate detection of very small variations in the configuration of the features, and so it is difficult to understand how an image transformation that has been shown to be so disruptive to the detection of feature displacements could fail to affect face recognition performance.

In this study I have also been able to demonstrate that the negation effect reported in experiments 1 and 2 generalises to a high quality image of a familiar face. The next experiment was designed to determine whether the inversion effect reported in experiments 1 and 2 would also generalise in the same way.
Chapter 17

Experiment 13:
Sensitivity to feature displacement in high quality colour images
17.1 Introduction

The results from experiment 12 demonstrated that the effect of image negation on the detection of feature displacements generalises to a familiar face and to full colour images. It now seems appropriate to investigate whether the effect of image inversion on the detection of feature displacements will also generalise to these high quality colour images of a familiar face.

The current study also provides a further opportunity to investigate the relative sensitivity to inward and outward displacements of the eyes in full colour images of a familiar face. Hosie, et al. (1988) suggested that the relative sensitivity to inward and outward displacements of the eyes was a function of the familiarity of the face. They suggested that subjects would be more sensitive to inward than outward displacements in an unfamiliar face (as observed by Haig, 1984) but equally sensitive to these two directions of displacements in a familiar face. The results of the previous study were rather equivocal in this respect. Although there was no difference in the accuracy with which displacements were detected, participants were more confident about their decisions with inward than outward displacements. The picture is even further complicated by the fact that the pattern of sensitivities previously reported by Haig (1984) with unfamiliar faces (greater sensitivity to inward than outward displacements) did emerge in the previous experiment, but in response to the negative forms of the image (in the case of the luminance-negative image this difference was only significant for the certainty data). This is a result that has also been observed in some of the earlier experiments in this series, and I have suggested that it might be a characteristic of face-like patterns that sensitivity to outward displacements is more affected by negation (and possibly inversion) than sensitivity to inward displacements.
Although inward displacements have given rise to slightly more correct detections for virtually every image type employed in this thesis, this difference is normally only large enough to reach significance when the image is either negated or inverted, or both.

It is therefore very difficult either to support or argue against the suggestion made by Hosie, et al. (1988) that participants are more sensitive to inward than outward displacements of the eyes for unfamiliar faces, but that this difference is not significant for familiar faces. The results reported in this thesis seem to suggest that there is a difference in sensitivity to inward and outward displacements of the eyes, and that this is probably a function of "faceness", but this difference tends to be small and normally not significant for either familiar or unfamiliar faces when presented in the "normal" image type (of course, it is only the normal image type that both Hosie, et al., 1988, and Haig, 1984, are referring to).

This experiment was therefore designed with two objectives in mind; to investigate whether or not the detection of feature displacement in full colour images would be affected by inversion, and to allow a further opportunity to investigate whether or not there was a difference in sensitivity to inward and outward displacements of the eyes in a normal colour image of a familiar face. Two hypotheses were offered:

\[ H_1 \] Participants will be less sensitive to feature displacements in inverted than upright, full-colour images of a familiar face.

\[ H_2 \] Participants will be more sensitive to inward than outward displacements of the eyes in normal, upright, full-colour images of a familiar face.
17.2 Method

17.2.1 Subjects

A total of 43 psychology students from the University of Westminster participated in the study. All were familiar with the individual whose face was used to construct the stimuli and all were naive to the hypotheses of the study. None had participated in the previous experiments.

17.2.2 Preparation of the stimuli

The stimuli used were a sub-set of those prepared for experiment 12. Three photographs were taken of each of the normal colour type images used in that experiment.

17.2.3 Design and Procedure

This study employed a fully factorial 5x4x2x2 design. The 5 within-subjects factors were:

- Size of displacement: 1, 2, 3, 4 or 6 pixels
- Movement: Inward, Outward, Upward or Downward displacements
- Orientation: Upright or Inverted
- Side: Left- or Right-hand image modified

This resulted in a total of 80 trials.

The procedure adopted was similar to that for experiment 12, with the same programme controlling the three slide projectors employed to project the images. The

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*This study was undertaken before the data from the previous experiment had been analysed, and so it was not appreciated that even the largest displacements used were likely to result in very difficult trials.*
20 different modified versions of the target face (5 Displacements x 4 Movements) were loaded into the first 20 slots of the slide trays used for the left- and right-hand projectors. The next 20 locations in these trays were then filled with a duplicate set of slides rotated through 180 degrees giving rise to an inverted image when projected. All three slide trays were also loaded with an upright and an inverted version of the unmodified image (with the eyes in their original location).

The instructions given to the participants were similar to those issued in experiment 12, except that participants were told that all three faces would either be upright or inverted. Participants were then given demonstration and practice trials in the same way as in experiment 12. Viewing conditions were similar to those used in experiment 12, and the same stimulus exposure durations and inter-stimulus intervals were employed. The experimental session lasted slightly under 30 minutes, and on completion of the last trial all participants were debriefed and thanked for their participation. Figure 17.1 illustrates a trial from this experiment.
Figure 17.1  An example of an inverted trial from experiment 13. The eyes in the left-hand image have been displaced downwards by 4 pixels.
17.3 Results

17.3.1 Accuracy data

The accuracy data were analysed by a 2x4 analysis of variance in which the Orientation (upright or inverted), and Movement (inwards, outwards, upwards or downwards displacement) factors were both within-subjects.

This analysis revealed a significant main effect of Orientation \( (F_{1,42}=7.52; \ p=0.009) \), with participants detecting feature displacements more accurately in the upright than the inverted trials. In contrast to all previous experiments, this analysis did not reveal a significant main effect of Movement \( (F_{3,126}=1.72; \ p=0.166) \). The Orientation by Movement interaction was not significant \( (F_{3,26}=0.55; \ p=0.651) \).

Inspection of the data suggested that the subjects had found the smallest displacements (1 and 2 pixels) more difficult than anticipated, and had performed little better than would be expected by chance on these trials (see figure 17.2). The above analysis was therefore repeated after excluding the 1 and 2 pixel displacement trials. This analysis also revealed a significant main effect of Orientation \( (F_{1,42}=7.44; \ p=0.009) \), but in this case the main effect of Movement \textit{was} significant \( (F_{3,126}=6.45; \ p<0.0005) \). The Orientation by Movement interaction was still not significant \( (F_{3,126}=1.44; \ p=0.234) \). See figures 17.3 and 17.4.

17.3.2 Certainty data

In the case of the certainty data, the initial 2x4 analysis of \textit{all} the trials (including the 1 and 2 pixel displacement trials) revealed a significant main effect of Orientation
(F_{1,42} = 11.30; p=0.002) and of Movement (F_{3,126} = 6.32; p<0.0005). The interaction between these factors was not significant (F_{3,126} = 0.93; p=0.428).

After excluding the 1 and 2 pixel trials the same analysis revealed an identical pattern of results; significant main effects of both Orientation and Movement but no interaction between these factors. See figures 17.3 and 17.4.

17.3.3 Sensitivity to different directions of displacements

Given the evidence that the 1 and 2 pixel trials were too difficult and were resulting in floor effects in the data, it was decided to compare sensitivity to different directions of displacement only for the 3, 4 and 6 pixel displacement trials.

Analysis of the accuracy data revealed that for both upright and inverted faces, participants were more sensitive to horizontal than vertical displacements, but that there was no difference in sensitivity to inwards and outwards displacements for either upright or inverted trials. Similarly, there was no difference in the sensitivity to upward and downward displacements in either upright or inverted images.

Analysis of the certainty data revealed a similar pattern of results, but with this data there was a significant difference in response to inward and outward displacements in the case of the inverted, but not the upright trials. See Table 17.1.
Table 17.1  Univariate $F$-tests with (1,42) degrees of freedom, comparing sensitivity to different directions of displacement. Only data from the 3, 4 and 6 pixel displacement trials are included. $F$ ratios and $p$ values are for the accuracy data. Shaded cells indicate comparisons that are significant with both the certainty and the accuracy data.

<table>
<thead>
<tr>
<th>Image type</th>
<th>In&gt;Out</th>
<th>Horiz&gt;Vertical</th>
<th>Down&gt;Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upright Faces</td>
<td>$F=0.10; p=0.749$</td>
<td>$F=7.46; p=0.009$</td>
<td>$F=0.27; p=0.607$</td>
</tr>
<tr>
<td>Inverted Faces</td>
<td>$F=2.02; p=0.163^{*}$</td>
<td>$F=11.82; p=0.001$</td>
<td>$F=2.16; p=0.150$</td>
</tr>
</tbody>
</table>

*Significant with the certainty data ($F_{1,42}=6.58; p=0.014$).
Figure 17.2  Experiment 13: Accuracy (part a) and certainty (part b) for the detection of 1, 2, 3, 4 and 6 pixel feature displacements in upright and inverted high quality, colour images of a familiar face.
Figure 17.3  Experiment 13: Accuracy (part a) and certainty (part b) for the detection of feature displacements in upright and inverted high quality colour images of a familiar face (includes data from 3, 4 and 6 pixel displacement trials only)
Figure 17.4 Experiment 13: Accuracy (part a) and certainty (part b) for the detection of inwards, outwards, upwards and downwards displacements in upright and inverted colour images of a familiar face (includes data from 3, 4 and 6 pixel displacement trials only).
17.4 Discussion

17.4.1 The effect of orientation
The results of this study clearly support the first hypothesis. The significant main effect of orientation demonstrates that participants more accurately detected small displacements of the eyes when the faces were upright than inverted. This is the same result as obtained in experiments 1 and 2, but in this case it has been demonstrated that the result generalises to high quality colour images of a familiar face.

17.4.2 Sensitivity to inward and outward displacements of the eyes
The second hypothesis concerned the sensitivity to inward and outward displacements of the eyes in a familiar face. The initial observation that subjects were equally sensitive to displacements in each of the four directions tested, seems to have been due to a floor effect introduced by the extreme difficulty of the 1 and 2 pixel displacement trials. Once these trials were excluded from the analysis the results from this study were comparable to previous experiment. As predicted by Hosie, et al. (1988) there was no difference in sensitivity to inward and outward displacements of the features in this familiar face. However, the earlier studies produced little evidence of a differential sensitivity to inwards and outwards displacements in normal, upright unfamiliar faces. It would therefore be unwise to conclude that the absence of a significant difference in sensitivity to inwards and outwards displacements in the current experiment was a function of the familiarity of the face used (as suggested by Hosie, et al., 1988). In this, and in the previous experiments, there was a greater difference in sensitivity to inwards and outwards displacements with inverted and/or
negated images than with the normal images (in this experiment this difference was significant with the certainty data).

It would appear that the differential sensitivity to inwards and outwards displacements is small in "normal" faces, and is not usually significant. However, inversion and/or negation seem particularly to affect the sensitivity to outward displacements (see figure 17.4), causing these displacements to be significantly less well detected than inwards displacements. Thus, the transformed, but not "normal", faces seem to demonstrate what Haig (1984) believed was the normal pattern of sensitivity to feature displacement in faces, while both unfamiliar and familiar "normal" faces demonstrate what Hosie, et al. (1988) thought was the pattern of sensitivity characteristic of familiar faces.

17.4.3 Task difficulty

Inspection of figures 17.2, 17.3 and 17.4 suggests that the overall level of accuracy achieved in this experiment was low compared to that of all the previous experiments. It would seem that the feature displacements introduced into these images (1, 2, 3, 4, or 6 pixels in a 512 pixel wide image) were rather too small, resulting in a very difficult task. It is clear from figure 17.2a that even for the easiest, upright 6 pixel trials, performance never reached the 75% level that would normally be taken as representing the psychophysical threshold for detection. However, it is interesting to note how smoothly accuracy increases with increased size of displacement, for both upright and inverted trials.
One unfortunate consequence of this unplanned level of task difficulty is that floor effects could be obscuring results in the data. In particular it is possible that some of the differences in sensitivity to the various directions of displacement might have been significant if the task had been easier. This limitation of the study further emphasises the difficulty in reaching appropriate conclusions regarding the pattern of differential sensitivities to different directions of displacement discussed above.

The overall level of performance has been very stable across all previous experiments despite the failure to control the viewing conditions, either within or between studies. The relatively poor level of performance in the current study is not really surprising. When viewing conditions are matched the largest displacement used in the current study (6/512 of the image width) is only marginally larger than the smallest displacement in the earlier studies (2/256 of image width).

17.4.4 Limitations and future directions

In experiments 1 and 2 both the negation and the inversion transformations were manipulated within the same experiment allowing the strength of these two effects to be compared. This has not been possible here because the introduction of colour images has meant that the negation transformation is now achieved by the manipulation of two independent factors, giving rise to the four types of colour negation that were studied in the previous experiment. To undertake an investigation similar to experiment 2 but using colour stimuli would require a minimum of 192 trials (2 orientations x 2 hues x 2 luminance x 4 directions of displacement x 3 sizes x 2 sides). It could also be argued that it would be useful to include monochrome positive and negative trials within such an experiment, and even that we should also include
Chapter 17  

Experiment 13: The inversion effect with high quality colour images

the geometric dot patterns used in experiment 3 as a base-line performance measure. The limiting factor here is the availability of participants who are prepared to undertake the massive number of trials required by such complex designs. In practice participants find it difficult to complete even the 96 trials required by experiment 2, and 192 trials would require an experiment lasting approximately an hour (without allowing for a rest period). It is unreasonable to require subjects to undertake such massive studies and so we are limited to comparing only restricted sets of these factors and cannot design fully factorial designs involving all the factors we would wish to include. It would be possible, if very time-consuming, to proceed by conducting a series of studies each of which investigated the interaction of smaller subsets of all the factors of interest. It might be better to accept that we have reached the natural limits of this particular experimental paradigm in investigating the roles of these various factors on the perception of faces. This does not mean that the feature displacement paradigm is of no further value. The strength of this paradigm is that it taps the participant’s perceptual abilities without reference to their recognition memory for the face. In the following chapters I will argue that this technique can now be applied to a variety of other areas of face-processing research. However, further investigation of the causes of the negation and the inversion effects will probably require modifications to be made to the current paradigm.

I would argue that the best way forward is to adopt a slightly more conventional psychophysical procedure to measure participants’ sensitivity to feature displacements (and other types of change). By employing adaptive techniques (such as that described by Lieberman & Pentland, 1982) it is possible to efficiently measure the threshold for detection of changes in the visual stimuli. Using this paradigm it would be possible to employ just a few participants who could conduct the many hundred trials required
over a period of days, resting as and when they liked. The careful control of the
viewing conditions required by such a procedure would allow us to compare the effect
of any number of manipulations or transformations on the detection of feature
displacements.

The adoption of this paradigm was considered at several stages during the conduct of
the research detailed in this thesis. The technology available has, however been the
limiting factor as until now there has been no easy and cost-effective way to display
the three 256 (minimum) pixel square images required, quickly enough to allow real
time computer control of the experiment. More recently this has become possible
using cheap and available computer technology, but perhaps the best way forward is
actually demonstrated by the computer control of three slide projectors achieved in the
last two experiments. These experiments were only made practicable by the advent of
Kodak's new generation of slide projector in which the slide advance mechanism is
under microprocessor control allowing true random access which can be achieved via
a controlling microcomputer. The advantage of this technology over current computer
displays is simple; a colour slide image contains many megabytes of information. The
microcomputer can be used to create any number of these images, but fast random
access to a large number of such files is not easy to achieve. Even with the advent of
modern high speed CD ROM drives, images of a quality comparable to that achieved
on slide film take some time to load. I would therefore argue that this line of research
should be continued by adopting an adaptive probit method to measure psychophysical
thresholds to displacements in normal, inverted and negated images of faces and non-
faces. This new approach is, however, beyond the scope of this thesis.
Chapter 18

A summary of the results from experiments 1 to 13.
Chapter 18

A Summary of the results

18.1 An overview

This chapter has two major sections. The first section consists of a table that summarises the main results from the 13 experiments reported in this thesis. The second part concerns the pattern of sensitivity to the different directions of displacement employed in these experiments, and considers whether any conclusions can be drawn from these data.
Table 18.1 A summary of the principal results of the 13 experiments reported in this thesis.

<table>
<thead>
<tr>
<th>Exp</th>
<th>N</th>
<th>Normal Stimulus</th>
<th>Effect of</th>
<th>Effect of direction of displacement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Negation</td>
<td>Inversion</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>29</td>
<td><img src="image" alt="Image" /></td>
<td>Signif</td>
<td>Signif</td>
<td>Can not be analysed. Normal, Negative and Inverted face images. The first demonstration that negation and inversion affect performance in a largely perceptual task that does not require subjects to compare a face to a representation previously stored in memory. Subjects' ability to make a simple perceptual judgement about the location of the parts of a face seems to have been affected by negation and inversion despite the presence of a comparison stimulus of the same type. As predicted by the face-superiority explanation.</td>
</tr>
<tr>
<td>2</td>
<td>23</td>
<td></td>
<td>Signif</td>
<td>Signif</td>
<td>Horiz&gt;Vert for all types. Up=Down for all types. In&gt;Out for neg &amp; neg-inv, but In=Out for norm &amp; neg. A replication of experiment 1, but with the inclusion of a fourth image type - negative-inverted. Negation and inversion effects same as in expt. 1 but also shown to be additive in that subjects are less sensitive to feature displacements in negative-inverted images than in either negative or inverted images. This result suggest that these effects have independent causes, and is not predicted by some explanations of the effects.</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all types. Up=Down for all types. In=Out for all types. Same procedure as for expt 2, but using non-face stimulus. A critical demonstration that the perceptual negation and inversion effects seen in the previous two studies do not generalise to a non-face stimulus. Seems that negation and inversion affect a subject's sensitivity to feature displacements in the case of face, but not non-face images. Why should this be? It seems that the details of the context are affecting low level perceptual processing - as predicted by the face-superiority explanation.</td>
</tr>
</tbody>
</table>

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### Chapter 18

#### A Summary of the results

<table>
<thead>
<tr>
<th>Exp</th>
<th>N</th>
<th>Normal Stimulus</th>
<th>Effect of Negation</th>
<th>Effect of Inversion</th>
<th>Effect of direction of displacement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td><img src="image" alt="Normal Stimulus" /></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all types. Down&gt;Up for all types. In&gt;Out for neg and neg-inv types, but In=Out for normal and inverted types.</td>
<td>Same procedure, but using images containing only the internal features of the face. Lack of inversion and negation effects suggests that the face surround is a necessary feature for the emergence of these effects. However, caution is needed here as there are trends present in the data suggesting a tendency (not significant) for subjects to be less sensitive to feature displacement in the inverted, and to a lesser extent, the negative image, than the normal image.</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td><img src="image" alt="Normal Stimulus" /></td>
<td>Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all types. Down&gt;Up for all types. In&gt;Out for neg, inv and neg-inv types, but In=Out for normal type.</td>
<td>Composite stimulus composed of external features of face and three dots used in expt 3. Gives rise to negation but not inversion effect. This is first demonstration of a stimulus that give rise to one of these effect but not other and suggests independent causes. Given the results of expt 4 this suggests that the facial surround is both necessary and sufficient to give rise to the negation effect. Also suggests that the inversion effect requires presence of both internal and external facial features.</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
<td><img src="image" alt="Normal Stimulus" /></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all types. Down=Up for all types. In&gt;Out for neg-inv, but In=Out for normal, Neg and Inv types.</td>
<td>A new stimulus composed of internal features of face, but with facial surround replaced by an ellipse. Stimulus designed to test possibility that the face outline was only critical in emergence of the effects because it served as a fixed reference point, and not because of its psychological signficance. Lack of negation and inversion effects suggest that the &quot;faceness&quot; of the surround is critical. However there was some evidence that inversion on its own was affecting performance - therefore replicate in experiment 7.</td>
</tr>
</tbody>
</table>
### Chapter 18: A Summary of the Results

<table>
<thead>
<tr>
<th>N</th>
<th>Normal Stimulus</th>
<th>Effect of Negation</th>
<th>Effect of Inversion</th>
<th>Effect of direction of displacement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td><img src="image1" alt="Image" /></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all. Down&gt;Up for neg &amp; inv types, but = for norm &amp; neg-inv. In&gt;out for neg-inv but = for other types</td>
<td>A replication of experiment 6. Is critical as if this stimulus gives rise to either negation or inversion effects then could argue that the role of the surround lies only in that it provides a fixed reference point (that was missing in non-face stimulus used in expt 3). As in previous experiment, no effects of negation or inversion suggesting that the importance of the surround to the emergence of the effects lies in its “faceness” rather than its low-level physical characteristics.</td>
</tr>
<tr>
<td>8</td>
<td><img src="image2" alt="Image" /></td>
<td>Not Signif</td>
<td>Signif</td>
<td>Horiz&gt;Vert for all. Down&gt;Up for all types. In&gt;Out for neg and neg-inv ellipse, but not for normal &amp; inv ellipse or faces.</td>
<td>Normal, neg, inv &amp; neg-inv ellipse patterns (as in expts. 6 &amp; 7) with a block of normal faces. Subjects are significantly more sensitive to displacements in faces than features-in-an-ellipse patterns. However, unlike expts 6 &amp; 7, effect of orientation is significant. Suggests that ellipse patterns can just sustain an inversion effect, but given sensitivity is lower than for real faces it seems that ellipse is not an adequate replacement for the face surround.</td>
</tr>
<tr>
<td>9</td>
<td><img src="image3" alt="Image" /></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Horiz&gt;Vert for all. Down&gt;Up for neg and neg-inv dots only. In&gt;Out for faces, norm &amp; neg-inv dots but not neg or inv dots</td>
<td>A comparison of sensitivity to feature displacement in faces and three-dot patterns. Subjects were more sensitive to displacement in faces than dot patterns. Suggests a processing advantage for faces. As in expt 3, no effect of negation or inversion for dots. One group of subjects completed dot trials then faces - other group did faces first then dots. No effect of this order factor. This suggests that it is not possible to prime the subjects to process the non-face patterns in the same way as the face images.</td>
</tr>
</tbody>
</table>
## A Summary of the results

<table>
<thead>
<tr>
<th>Exp</th>
<th>N</th>
<th>Normal Stimulus</th>
<th>Effect of Negation</th>
<th>Effect of Inversion</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>24</td>
<td><img src="image1" alt="Image" /></td>
<td>Not Signif</td>
<td>Not Signif</td>
<td>Was predicted that the dots-in-an-ellipse patterns would not give rise to either negation or inversion effect. This seems to be confirmed. However, although subjects were more sensitive to feature displacement in faces than in ellipses, the difference between faces and normal ellipses was not significant. This seems to be attributable to two factors. Firstly, subjects were not as accurate with faces as in previous experiments, and secondly there is a tendency to be less sensitive in inverted ellipse patterns.</td>
</tr>
<tr>
<td>11</td>
<td>21</td>
<td><img src="image2" alt="Image" /></td>
<td>Signif</td>
<td>Not Signif</td>
<td>A new stimulus comprising the three dots used in exp 3, but with a rectangle surround. Designed to test possibility that superior performance with faces was due proximity of the face surround rather the &quot;faceness&quot; of the image. Rectangular surround provides a reference point same distance from dots as face edge is from eyes. Subjects are still more sensitive with faces. However, rectangles give rise to an unexpected negation effect. Seems at odds with shape-from-shading explanation.</td>
</tr>
<tr>
<td>12</td>
<td>36</td>
<td><img src="image3" alt="Image" /></td>
<td>Signif</td>
<td>N/A</td>
<td>A new procedure using full colour images of familiar face (and smaller displacements). Three new manipulations are also introduced through the independent manipulation of hue and luminance levels (Hue-, Luminance- and Full-negative). Designed to test shape-from-shading and pigmentation explanations of the negation effect. Pigmentation explanation predicts effect of Hue-negation, shape-from-shading predicts no effect. Results reveal no effect of Hue-Negation but significant effect of Luminance-negation.</td>
</tr>
</tbody>
</table>
Chapter 18

<table>
<thead>
<tr>
<th>Exp</th>
<th>N</th>
<th>Normal Stimulus</th>
<th>Effect of</th>
<th>Effect of direction of displacement*</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>43</td>
<td>N/A</td>
<td>Signif</td>
<td>Horiz&gt;Vert for both upright and inverted. Down=Up and In=Out for both upright and inverted</td>
<td></td>
</tr>
</tbody>
</table>

Notes

13 43 N/A Signif Horiz>Vert for both upright and inverted. Down=Up and In=Out for both upright and inverted.

Same colour images of a familiar face as used in experiment 12, but here presented either upright or inverted. A significant effect of orientation demonstrates that the inversion effect reported in experiments 1 and 2 generalises to other faces, to colour images and to familiar faces. However, some indication that the task was too difficult and that floor effects might be obscuring differences in sensitivity to various directions of displacement.

* Only differences that are significant with both the accuracy and the certainty data are reported here.
18.2 Direction of displacement

In each of experiments 2 to 13 the sensitivity to the different direction of displacement were compared. Three comparisons were made for each image type: inwards against outwards displacements, horizontal against vertical displacements, and upwards against downward displacements. These comparisons were chosen as the work of Haig (1984) and Hosie, et al. (1988) suggested that the differing sensitivity to these types of displacement reflected some aspect of the perceptual processing of a face. I will now consider what conclusions can be drawn from each of these three comparisons.

18.2.1 Comparing sensitivity to horizontal and vertical displacements

For each of experiments 2 to 11 and 13, subjects were significantly more sensitive to horizontal displacements of the features than vertical displacements. Only in experiment 12 did this difference fail to emerge as significant for some of the image types, and even in this case, when considering both the certainty and the accuracy data the difference only failed to achieve significance in the case of the luminance-negated faces. It seems relatively unlikely that the failure to observe a significant difference in the case of luminance-negated images was due to some aspect of the stimulus, as this difference was significant for both familiar and unfamiliar faces and for colour and thresholded images. A much more likely explanation is that this is simply a type II error. This suggestion is perhaps reinforced by the observation that the new procedure adopted in experiments 12 and 13 resulted in an increase in the task difficulty, and thus floor effects might be obscuring otherwise significant differences in this experiment.
If we accept that subjects are more sensitive to horizontal than vertical displacements regardless of the nature of the stimulus or the transformation applied to it, then it seems safe to conclude that this difference in sensitivity is a consequence of some low-level characteristic common to all the stimuli used. As suggested in previous chapters, the most likely explanation is that for all these images a vertical displacement of 1 pixel resulted in a change in the distance between the "eyes" and the nearest fixed reference point of 1 pixel. However, in the case of horizontal displacements a 1 pixel change altered the distance between the two "eyes" by 2 pixels. Hence, we might have reasonably expected subjects to be considerably more sensitive to horizontal than vertical displacements, and this difference probably tells us nothing about the perceptual processing of face-like, as opposed to non-face-like images.

This suggestion could be tested by modifying the procedure adopted in these studies. It would be possible to displace only 1 of the eyes and to then cut-out and re-centre the pair of eyes within the face (alternatively horizontal displacements could be half as large as vertical displacements). However, it might be better to adopt a more traditional psychophysical procedure that would allow the accurate assessment of the threshold for detection of horizontal and vertical displacements. It is possible that such procedures would reveal a real difference in sensitivity to horizontal and vertical displacements, and perhaps even that this difference might vary with image type, but for the moment the safest prediction seems to be that no such differences would emerge.
18.2.2 Comparing sensitivity to upwards and downwards displacements

The results of the comparisons of the sensitivity to upwards and downwards displacements across experiments 2 to 13 are summarised in table 18.2.

If we first consider the normal (upright-positive) thresholded faces used in experiments 2, 8, 9, 10 and 11 it appears that subjects were significantly more sensitive to downwards than upwards displacements of the eyes in the normal face in the case of experiments 8, 9 and 11, but not in the case of experiments 2 or 10. Although it was not possible to analyse the data from experiment 1 in the same way, the presence of a significant Sign by Direction interaction seems to be attributable to the absence of a difference in sensitivity between upwards and downwards displacements. Thus if we accept this statistically untested observation from experiment 1, we have exactly equal numbers of significant and non-significant differences across a total of 6 experiments. This lack of consistency could be attributable to a lack of sensitivity in the procedure adopted. In particular it is quite possible that the failure to control viewing distance might have caused this variability in the results. If there was a small but real difference in the ability to detect upwards and downwards displacements this could be obscured easily by changes in the distance between the observer and the screen. This problem is compounded by the fact that, when considering any one direction of displacement, two of the three sizes of displacement used (2, 4 and 6 pixels) might be contributing nothing to the power of the procedure as the largest displacements might be too easy but the smallest too difficult. Thus in some cases we might be attempting to measure the difference in sensitivity on the basis of very few observations, with the others either being at ceiling or at floor.
In experiments 12 and 13 colour images of a familiar face were used. In both these cases subjects were equally sensitive to upwards and downwards displacements of the eyes. However, as noted in the previous section, in both these experiments the level of overall task difficulty was higher than in the previous studies and this might be obscuring differences that would otherwise be significant. It is certainly not safe to consider whether the use of either colour or a familiar face has modified the pattern of sensitivities.

When we consider the relative sensitivity to upwards and downwards displacements in the non-face and the transformed images the picture is even more confused. The only pattern apparent is that this difference tends to be significant for either none of the images used in an experiment or all of them (see table 18.2). This suggests that the prevailing experimental conditions might have a major influence on whether or not this difference is significant. This possibility is reinforced by two further observations. Firstly, in experiment 3 subjects were equally sensitive to upwards and downwards displacements for all image types, but in experiment 9 using the same stimuli the subjects’ performance with the downwards displacements was significantly better than with the upward displacements for all four types[^1]. Secondly it is also interesting to note that in those experiments where this difference in sensitivity seems to be significant across all pattern types (for example experiments 8 and 11) it is also significant for normal faces (and vice versa). Thus it may well be the viewing conditions that are determining whether such a difference in sensitivities arises, and the nature of the stimuli may be of little consequence.

[^1]: In the case of the normal and inverted patterns this difference was only significant with the certainty data.
Finally, it should be noted that in many of the cases where subjects were significantly more sensitive to downwards than upwards displacements, subjects were also noted to be performing at below the level predicted by chance. Thus in experiments 4, 5 and 8 subjects correctly identified upward displacements in less than 50% of the trials, and in the case of experiment 11 this was also the case for all except the normal patterns. Thus, only in the case of experiment 9 does a significant difference in the sensitivity to upwards and downwards displacements arise without the subjects also performing at below the chance level on the upward trials. In each case this tendency to perform at below chance levels was not significant, but it should be noted that the statistical procedure used has very little power (a chi-square comparison of the numbers of subjects performing above and below chance levels).

Taken together all of these factors strongly suggest that the presence or absence of this difference in sensitivity to upwards and downwards displacements is as much determined by the prevailing viewing conditions as by any characteristic of the stimulus. As the viewing conditions were not controlled within or between the experiments in this series it would be very unwise to try to draw any conclusions on the basis of these results.
### A Summary of the Results

Table 18.2 A summary of the differences in sensitivity to upwards and downwards displacements for experiments 2 to 13.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Image type</th>
<th></th>
<th></th>
<th></th>
<th>Faces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Normal</td>
<td>Negative</td>
<td>Inverted</td>
<td>Neg-inv</td>
</tr>
<tr>
<td>2: Faces</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>3: Three dots</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4: Internal features of face</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>-</td>
</tr>
<tr>
<td>5: Face outline with dots</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>-</td>
</tr>
<tr>
<td>6: Features in an ellipse</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7: Features in an ellipse</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>-</td>
</tr>
<tr>
<td>8: Features in an ellipse &amp; Faces</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>?</td>
</tr>
<tr>
<td>9: Three dots &amp; Faces</td>
<td>?</td>
<td>$\gamma$</td>
<td>?</td>
<td>$\gamma$</td>
<td>$\gamma$</td>
</tr>
<tr>
<td>10: Dots in an ellipse &amp; Faces</td>
<td>-</td>
<td>$\gamma$</td>
<td>?</td>
<td>$\gamma$</td>
<td>-</td>
</tr>
<tr>
<td>11: Dots in a rectangle &amp; Faces</td>
<td>?</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
<td>$\gamma_{BC}$</td>
</tr>
<tr>
<td>12: Colour negation - faces</td>
<td>-</td>
<td>- (Hue)</td>
<td>- (Lum)</td>
<td>- (Full)</td>
<td>$\gamma_{BC}$</td>
</tr>
<tr>
<td>13: Colour inversion - faces</td>
<td>-</td>
<td></td>
<td>$\gamma_{BC}$</td>
<td></td>
<td>-</td>
</tr>
</tbody>
</table>

**Key:**
- $\gamma$ Significant difference
- ? Significant only with certainty data
- - Not significant
- Not applicable
- $\gamma_{BC}$ Displacement detected in less than 50% of trials
18.2.2 Comparing sensitivity to Inwards and outwards displacements

As discussed earlier, Haig (1984) reported that subjects were more sensitive to inwards than outwards displacements of the eyes for unfamiliar faces, but Hosie, et al. (1988) found no difference with familiar faces. Hosie, et al. (1988) suggested that this difference in sensitivity was a function of the familiarity of the face, and that with a familiar face subjects were highly sensitive to any displacement. The results of the experiments reported in this thesis offer little support for this suggestion. Although subjects were equally accurate at detecting inwards and outwards displacements in the normal (upright positive) familiar face used in experiments 12 and 13, the certainty data revealed a significantly greater score for the inwards than the outwards displacements in experiment 12. Furthermore, subjects were found to be equally sensitive to inwards and outwards displacements in the normal unfamiliar faces used in experiments 2, 8 and 10. Thus we have considerable evidence of equal sensitivity to inwards and outwards displacements in unfamiliar faces, and some evidence of greater sensitivity to inwards than outwards displacements in familiar faces. All of these observations are contrary to the suggestion made by Hosie, et al. (1988).

The only trend that has emerged from these comparisons of sensitivity to inwards and outwards displacements is a particularly puzzling one. Repeatedly, and apparently regardless of the image type, this difference has been significant with images that have been negated (that is either negative or negative-inverted images). It was observed in a previous chapter that this result seemed to be attributable to an unexplained tendency for negation to reduce the sensitivity to outwards displacements more than inward displacements. This possibility does seem worthy of further investigation, but this will require the adoption of a procedure that allows the more accurate assessment of detection thresholds.
With regard to the relative sensitivity to inwards and outwards displacements, the only conclusion that can be drawn at present is that the suggestion made by Hosie, et al. (1988) is not supported. It is not at all clear what is determining whether this difference is or is not significant, but a simple explanation in terms of the familiarity of the face does not easily explain the data reported in this thesis. It may well be that Hosie, et al. (1988) failed to observe a difference in sensitivity to inwards and outwards displacements because what they measured was not actually sensitivity but the subjects' reports of how different the face appeared following the feature displacement. It would be quite possible for a small change to be detectable without it significantly affecting the appearance of the face.
### Chapter 18

#### A Summary of the results

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Image type</th>
<th>Faces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Negative</td>
</tr>
<tr>
<td>2: Faces</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>3: Three dots</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4: Internal features of face</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>5: Face outline with dots</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>6: Features in an ellipse</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7: Features in an ellipse</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>8: Features in an ellipse &amp; Faces</td>
<td>-</td>
<td>Y</td>
</tr>
<tr>
<td>9: Three dots &amp; Faces</td>
<td>Y</td>
<td>-</td>
</tr>
<tr>
<td>10: Dots in an ellipse &amp; Faces</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11: Dots in a rectangle &amp; Faces</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>12: Colour negation - faces</td>
<td>?</td>
<td>Y(Hue)</td>
</tr>
<tr>
<td>13: Colour inversion - faces</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Key:**
- Y: Significant difference
- ?: Significant only with certainty data
- -: Not significant
- Not applicable

Table 18.3  A summary of the differences in sensitivity to inwards and outwards displacements for experiments 2 to 13.
Chapter 18

A Summary of the results

18.2.4 What conclusions can be drawn?

What conclusions can be drawn concerning the relative sensitivity to the four directions of displacement employed in these experiments? Perhaps the only safe conclusion is that the procedure adopted in these experiments is not adequate to answer these questions. With the exception of the relatively uninteresting difference in sensitivity to horizontal and vertical displacements, any differences in sensitivity that do exist are small. It would require many more observations, with trials including both smaller and larger displacements, as well as very tightly controlled viewing conditions to be able to confidently answer questions about the relative sensitivity to different directions of displacement in faces and non-faces. However, these questions were always subsidiary to the main focus of this research to which I will now return.
Chapter 19

Developing a model of face perception
Chapter 19 Developing a model of face perception

19.1 A "true" face-superiority effect?

In chapter four I reviewed the literature concerning a variety of perceptual effects collectively called the object-superiority, or context-superiority effects. What all these effects have in common is that they demonstrate that a component or "feature" of a pattern is more accurately and/or more quickly identified when it is presented as part of a coherent pattern than when presented either in the context of a non-coherent (jumbled) pattern or on its own. One of these effects has been called the face-superiority effect (Homa, et al., 1976), but in chapter four I argued that this title was misleading as the face-superiority effect does not differ, either qualitatively or quantitatively, from other object-superiority effects. All of these effects seem to reflect the influence of higher-level cognitive systems responsible for the identification of specific objects, on lower-level perceptual systems responsible for the detailed perception of the parts of these same objects, and thus the influence of top-down on bottom-up processes.

I have argued that it might be possible to explain apparently face-specific effects, such as negation and inversion, in terms of these object-superiority effects, and hence by reference to factors affecting the visual processing of face and non-face stimuli. The feature displacement paradigm adopted in this thesis was chosen because it involved no memory component. This attempt to demonstrate an inversion and negation effect using a procedure that did not require the face to be stored in memory was likely to be problematic. Valentine (1988) suggested that the emergence of the inversion effect was dependent upon the use of a task that required the image of a face to be compared to one stored in memory, and that two previous studies which had employed a purely perceptual task (matching two faces) had not observed a decline in
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performance associated with stimulus inversion (Valentine, 1986; Bruyer & Velge, 1981). There was therefore good reason to predict that experiment 1 might not reveal an inversion effect. The highly significant effects of both negation and inversion revealed in the first two experiments thus provide unexpected support for the face-superiority explanation of these two effects.

Experiments 1 and 2 clearly demonstrated that a procedure that does not require faces to be represented in long-term memory can give rise to both an inversion and a negation effect. The participants only had to compare the three, simultaneously presented, patterns and detect which had been altered. At no time were they required either mentally to rotate the image or to compute the inverse of its contrast (negate it), as all three images presented were always of the same type (that is, either all were upright, all were inverted, all were negated or all were negative-inverted). This is a rather surprising result. Why should we be less able to compare two simple black and white patterns when they are presented one way up than when rotated by 180 degrees?

Experiment 3 demonstrated that this was not a universal effect, as participants’ sensitivity to feature displacement in non-face stimuli was independent of orientation or contrast polarity. This result provided support for the existence of a "true" face-superiority effect: participants were more able to make simple perceptual judgements about features of a pattern when those same features were contained within, and formed part of, a coherent facial context than when the context was either absent (experiment 3) or distorted by negation and inversion (experiments 1 and 2). It seems that the face provided a context within which the early visual processing of the features making up the face could be refined and focused leading to greater sensitivity to small changes in their configuration. Some caution is required here, however, as it
has not been demonstrated that participants are more sensitive to feature displacement in a face than a non-face pattern that illustrates a coherent object. It is possible that the sensitivity to feature displacement in a face is no greater than in a non-face object. It could be argued that the pattern of dots used in experiment 3 did not represent a real object and it is therefore premature to claim conclusive evidence of a "true" face-superiority effect.

Experiments 4, 5, 6 and 7 were designed in an attempt to identify which aspects of the context were critical for the emergence of the negation and inversion effects, and provided evidence that these effects were dependent on different aspects of the context and were probably independent of each other. In experiment 8 a pattern that contained some face-like characteristics was shown to be less accurately perceived than a true face, despite still giving rise to an inversion effect; and in experiment 9 the non-face stimuli previously used in experiment 3, were shown to be significantly less accurately perceived than face-stimuli. Taken together, these result suggests that the effectiveness of the facial context decreases as the stimuli becomes progressively less face-like, and that as a result of this, upright positive faces are more accurately perceived than inverted or negated faces, which in turn are more accurately perceived than non-faces.

The effect of the coherent face context is to enhance the participants' sensitivity to feature displacement, and the negation and inversion effects result from a partial loss of this perceptual advantage imparted by the coherent, upright facial context. Yin (1969) stated that faces were special in that their recognition was particularly disrupted by stimulus inversion. It now appears that if faces are special, then this is because they are particularly accurately perceived when presented in their normal orientation. The effect of inversion (and negation) on face recognition represents the loss of an
advantage conferred on the normal, upright face, and not a particular sensitivity to this type of manipulation *per se*.

The results from this series of experiments have proved to be entirely compatible with a novel explanation of the negation and inversion effects. This explanation is couched in terms of a particular perceptual sensitivity for the upright positive face, and an interaction between higher-level knowledge about the structure and variability of faces with lower-level perceptual processes involved in the accurate perception of the features making up the face. Thus, we could justify describing the negation and inversion effects as examples of a face-superiority effect.

19.2 Comparing the face-superiority and other explanations of the negation and inversion effect

There are two important aspects of this new explanation of negation and inversion; firstly it explicitly locates the locus of the effects at the stage of the early visual processing of the stimuli, and secondly, it emphasises the superior processing of the upright face rather than the poor recognition of the inverted or negated face. These characteristics of the face-superiority explanation differentiate it from the alternative explanations of the inversion and negation effects considered in chapters 2 and 3. These alternatives will now be re-assessed in light of the results of the experiments reported in this thesis.
19.2.1 Valentine's face-space model

Valentine (1991) argued that negation and inversion reduce the accuracy of the visual encoding because the image needs to be mentally transformed into the upright, positive form before it can be compared to the faces stored in memory, and that these mental transformations introduce noise and thus reduce the accuracy of the final representation. Although emphasising the effect on the encoding of facial characteristics, this explanation differs from the face-superiority explanation in that it seems to locate the effect at a rather later stage in the processing sequence. Presumably a full and detailed representation of the image must have been formed before being transformed so that it is upright and positive. Thus the noise introduced by the mental transformation of the image is interfering with the processes responsible for encoding the facial characteristics represented in the face-space (let us call this *memorial encoding*). In the face-superiority explanation on the other hand, the upright face is advantaged relative to all other objects because more information can be extracted from the image in the first place, and thus the locus of the effects is at the stage of the perceptual, rather than the memorial encoding of the face. If, as Valentine suggests, mental transformations introduce error into the memorial encoding, then this will only further increase the magnitude of the advantage for the upright-positive face compared to the inverted and/or negated face which has already been introduced at an earlier stage in the processing. Another way to describe this distinction would be to say that for Valentine's model the locus of the effect would seem to be at some point after the stage labelled "Structural Encoding" in both the Bruce & Young (1986) and the Ellis (1986) models of face recognition, whereas the face-superiority explanation would seem to locate these effects somewhere within this stage.
Valentine's explanation would also have some difficulty in accounting for the results reported in this thesis. The participants in these studies did not need to mentally rotate the images as they were not required to compare them to their memory of previously encountered faces. All three of the images making up a trial were always of the same type, either all normal, all inverted, all negative, or all negative-inverted, and so comparisons should have been as easy at one orientation or contrast polarity as another. It is, of course, possible that such transformations were being computed anyway; but this does not help Valentine's position for several reasons. If such transformations were being undertaken this must only have happened for the face-stimuli as there was no effect of negation or inversion with the non-faces used in experiments 3 and 9. Valentine's model does not distinguish between face and non-face objects, but implies that the special sensitivity of faces to inversion results from the need to represent faces more accurately if they are to be reliably individuated. Valentine does not suggest faces are more affected by the noise introduced through these transformations, simply that the noise introduced will have a greater effect on the recognition of faces than non-faces because faces need to be represented more accurately to allow for later individuation.

In defence of Valentine's model, it could be argued that negation and inversion are relative terms, and are essentially meaningless for non-face stimuli such as those used in experiments 3 and 9, so perhaps these transformations are only computed for face stimuli. This still does not help Valentine's position, as if this was the case we would expect to find that the performance on the upright-positive trials would be broadly comparable to that achieved with non-face stimuli which had not been mentally transformed, and we now know that this is not the case as the participants in
experiment 9 were significantly less sensitive to feature displacement in non-faces than in upright-positive faces.

Taken together the results from the thirteen experiments presented in this thesis demonstrate that the upright face is perceived more accurately than the negative or inverted face, which is perceived approximately as accurately as a non-face pattern. This pattern of results suggests a perceptual advantage for the upright face, and not a disadvantage for the negative and/or inverted face; there is some privileged processing of the upright face, not impoverished processing of the negative and/or inverted face.

This is the pattern of results predicted by the face-superiority model; as an image becomes less face-like then the perceptual advantage inferred by the face context declines until a heavily transformed face is perceived only as accurately as a non-face. Negation and inversion only disadvantage face perception relative to the upright positive face, and not relative to the non-face. Any explanation of these effects that is couched in terms of an absolute disadvantage for the negative or inverted face (such as Valentine’s) will therefore fail to account for this data.

Valentine’s model is, however, very successful in one respect. It not only accounts for, but also predicts the additive relationship between the negation and inversion effects demonstrated in experiment 2, whereby a stimulus that is both negated and inverted is less accurately perceived than a stimulus that is either just negated or just inverted.
19.2.2 The Diamond & Carey explanation

Diamond & Carey (1986) argued that faces were examples of a class of stimuli which could only be differentiated on the basis of second-order relational features as all faces share the same basic arrangement of the features (two eyes above one nose etc.). Diamond & Carey explain the disproportionately large effect of stimulus inversion on recognition performance for faces by assuming that the ability to encode second-order relational features is particularly affected by inversion, and thus they suggest that a deeper level of visual processing is required for the individuation of face stimuli compared to non-face stimuli. The true face-superiority explanation, on the other hand, suggests that a deeper level of perceptual processing is made possible by a knowledge of the structure of the face, and thus at this level, the difference between these two explanations is rather small.

In chapter 2 I identified two major weaknesses of Diamond & Carey's explanation. Firstly, there is no direct evidence for the critical assumption that the encoding of second-order relational features is especially orientation sensitive. Two previous attempts to test this hypothesis directly have suggested that first- and second-order relational feature encoding is equally affected by stimulus inversion (Tanaka & Farah (1991) and Rhodes, et al. (1993); see chapter 2). Secondly, this is a rather rigid, all-or-nothing account which suggests that inverted faces are processed in the same fashion as non-faces, leading to the prediction that an inverted face would be immune to the effects of other apparently face-specific manipulations, such as negation. The demonstration of an additive relationship between the negation and inversion effect (this thesis; Bruce & Langton, 1994; Jeffreys, 1993) seriously undermines this position.
In experiment 9 of this thesis the participants were required to make judgements about a second-order relational feature in two different types of stimulus (the relative location of the "eyes" in faces and in dot patterns). Diamond & Carey’s account would predict that performance with these two stimuli would be broadly equivalent, as in both cases accurate encoding of the same second-order relational features was required. Furthermore, the task could only be undertaken with reference to these second-order features, and so for both stimuli inversion should reduce the accuracy with which this judgement could be made. In fact both these predictions were shown to be erroneous. Firstly, the ability to make a judgement about a second-order relational feature was affected by the nature of the context within which the feature occurred, with participants being more sensitive to changes to such a feature in a face rather than a non-face. Secondly, only in the case of the face stimuli did inversion have an effect on the ability to encode a second-order relational feature. With both the faces and the dot patterns the task could only be completed by reference to this second-order relational feature, yet inversion had no effect on performance with the dot patterns. Thus this result both undermines the central tenet of Diamond & Carey’s explanation and suggests that it is the presence of the face context that is allowing a more accurate perceptual processing to occur rather than the nature of the task that is requiring it.

Diamond & Carey’s model also fails to account for the perceptual advantage enjoyed by the upright face, focusing instead on a predicted disadvantage for processing the inverted stimulus. Diamond & Carey argue that because faces all share so many characteristics we are forced to rely on these second-order relation features when attempting to individuate faces. The true face-superiority explanation turns this argument on its head, making a virtue out of this potential obstacle. Rather than seeing
the similarity of all faces as a problem which necessitates a more detailed perceptual analysis of the stimuli, the true face-superiority explanation sees this similarity as providing us with implicit knowledge about the structure and variability of faces. This knowledge can then be used to provide a processing "template" that can assist in a more detailed perceptual analysis of those aspects of the image most likely to encode the higher-order invariant properties of the face.

In chapter 2 I highlighted the problem of deciding what constituted a second-order relational feature. The true face-superiority explanation has the distinct advantage that it does not require features to be classified in this, or any other way. Rather, it is assumed that a more focused and detailed analysis of those aspects of the stimulus most likely to provide valuable information will be made possible by the implicit knowledge of the structure of the face. The new question introduced by this approach is "What is a face?". Although experiments 3-7 began to address this question we are not yet in position to define what characterises a pattern as face-like.

Thus, the Diamond & Carey model fails to account for the data reported here for several distinct reasons. Firstly, it emphasises the negative consequences of inversion and fails to account for the advantageous processing of the upright face. Secondly it predicts that the perception of all stimuli (whether face or non-face) which must be identified on the basis of second-order relational features will be disadvantaged by stimulus inversion, and yet in a result reminiscent of that of Tanaka & Farah (1991) I have shown that this is not the case (experiments 3 & 9). Thirdly, this model neither predicts, nor easily accounts for the additive relationship between the negation and inversion effects reported in experiment 2.
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The one point of similarity between the Diamond & Carey model and the face-superiority model is that both locate the locus of the effect at the stage of the perceptual encoding of the stimulus, though the former does so by explaining how the perceptual processing of the inverted face is disadvantaged by inversion, while the latter explains why the perceptual processing of the upright face is advantaged.

19.2.3 Goldstein & Chance’s schema theory

As discussed in chapter 2, Goldstein & Chance (1980) argued that the disproportionate sensitivity of faces to orientation was due to the development of a rigid face schema, the structure of which reflected the disproportionate exposure to upright (and own-race) faces. The main evidence for this was the increase in the size of the inversion effect with age (see chapter 2); Goldstein & Chance felt that the increasing expertise with upright faces shown by children between the ages of approximately 5 and 12 years of age was due to the development of a rigid face schema, but that this schema increased the efficiency with which upright faces were encoded at the cost of reducing the efficiency of processing for faces that fell outside the range of the schema. Thus as recognition performance with inverted and other-race faces declines, performance with upright and own-race faces would increase as the child becomes increasingly reliant on his/her developing face schema.

There are a number of problems with this explanation (see chapter 2 for a full discussion of these), including the considerable uncertainty about the precise nature of the developmental trends in the recognition performance for upright, inverted and other-race faces, and the lack of a consistently reported negative correlation between performance with upright and inverted faces. In comparison to the explanations offered
by both Diamond & Carey (1986) and Valentine (1991), Goldstein & Chance's model is rather less specific about the precise causes of the inversion effect, but it is much more in line with the face-superiority explanation than the other two, in that it explicitly describes a processing advantage for the upright face. In a sense, the face-superiority model is also a schema model. Some of the explanations of the context effects discussed in chapter 4 are couched in terms very similar to the schema model (see for example, Gorea & Julesz, 1990; Davidoff & Donnelly, 1990). Let us consider Goldstein & Chance's model in a little more detail.

As Goldstein & Chance (1980) point out, the term Schema has been used by different authors to describe different constructs, but Goldstein & Chance take as their model the definition of a schema offered by Vernon (1955). They describe a schema for face recognition in the following way:

"Schemata function by producing expectations, by determining what aspects of the stimuli will be attended to, by reducing necessity for conscious, voluntary processing to a minimum, by making attending and encoding automatic yet accurate and exceptionally quick."

(Goldstein & Chance, 1980, page 48)

and the schema is seen as:

"exclusively processing incoming face-like stimuli" (page 57).

Clearly, this schema explanation has a great deal in common with the face-superiority explanation of the negation and inversion effects that I have been developing. In particular, both describe a mechanism that advantages the processing of the upright
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face, and in both this advantage arises out of considerable experience of upright faces. Although the mechanism by which the schema affects the processing of the face stimulus is not made clear by Goldstein & Chance, their description of the schema producing expectations and focusing attention are clearly compatible with the notion of a processing template and focused processing that I have been developing. In both these cases it is the knowledge of the variability of faces acquired through enormous experience with them, that helps determine the nature of the processing undertaken. In Goldstein & Chance's description it is not clear whether the schema acts at the perceptual stage, or at the representational stage, or indeed at both of these stages; but there is nothing in this description of a schema limiting and refining the processing being undertaken that is incompatible with the notion of focused perceptual processing being advanced in this thesis.

Perhaps the only real point of departure between Goldstein & Chance's schema explanation and the face-superiority explanation relates to what happens to stimuli that fall outside the realm of the schema. Goldstein (1975) developed the notion of schema rigidity to describe the manner in which the schema develops and Goldstein & Chance (1980) incorporate this idea into their model. The process of schema development is described in the following way:

"Development is reciprocal; changes in the schema organisation are brought about by interaction with incoming stimuli which deviate from the central tendency, and the now modified schema is able to process efficiently a wider range of stimuli. Though the schema organization is in almost constant flux, at any one moment in time its organization is precise." (Goldstein & Chance (1980), page 48)
During this development, and as a result of repeated exposure to similar faces, the schema becomes increasingly specialised and more efficient at processing the target group of stimuli. As an inevitable consequence of this development more and more stimuli will fall outside the target group and will be less and less efficiently processed:

".. when schemata become highly refined - very efficient - in handling a particular subclass of stimuli, processing stimuli from another subclass becomes increasingly less effective. It is as though the schema becomes increasingly more deeply engraved with the features defining the subclass and therefore cannot effectively handle stimuli falling outside the subclass." (Goldstein & Chance (1980); page 57)

Thus, non-face stimuli, or transformed face stimuli, that engage (or are engaged by) a face schema, will be processed less accurately and more slowly than non-face stimuli that do not engage the schema. In contrast to the face-superiority model that predicts an advantage for the processing of face-like stimuli but no disadvantage for the processing of transformed faces (relative to non-faces in both cases), the schema model predicts both an advantage for the face and a disadvantage for the transformed face.

The results from the experiments reported in this thesis do not allow us to differentiate conclusively between these two different predictions as we must exercise caution when comparing absolute performance levels between experiments. However, the results do seem to suggest a processing advantage for faces that slowly declines as a stimulus
becomes less face-like through transformation⁴⁹. Perhaps the best evidence for this position is the fact that in experiment 2 the doubly transformed face (negative-inverted) was perceived less accurately than either the negative or the inverted face, and that performance seemed to fall off towards the level achieved with the non-face stimuli used in experiments 3 and 9. It could be argued that the schema explanation would also predict an additive relationship between the negation and inversion transformations⁵⁰, but there can be no doubt that the model predicts that transformed faces would be recognised less well than non-faces.

19.2.4 The shape-from-shading explanation

In chapter three I identified just two viable explanations of the negation effect: the shape-from-shading explanation and the pigmentation explanation. Of these, the shape-from-shading explanation seems much more compatible with the data reported in this thesis (it is not easy to see why a change in the apparent pigmentation of the face should make participants less sensitive to small changes in the location of the eyes), and seems to be strongly supported by the results of experiment 12.

⁴⁹This suggestion is supported by the results of an experiment recently undertaken (with the assistance of Jess Prior). Sensitivity was assessed to feature displacements in normal, negative, inverted and negative-inverted faces and to normal (neither inverted nor negated) three-dot patterns (as used in experiment 3). As predicted, the sensitivity to feature displacement in the three-dot patterns was the same as in the transformed faces. However, in this experiment the negative-inverted faces were no less accurately perceived than either the negative or the inverted faces. This failure to replicate the additive result reported in experiment 2 is probably due to a failure to match viewing conditions and is not critical to the argument being developed here.

⁵⁰It is not clear that a negative-inverted face would be "doubly disadvantaged" by the existence of the face schema. It could be argued that the negative-inverted face would not engage the schema and so escape the negative consequence of its application.
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The pigmentation explanation assumes that changes to the apparent pigmentation of the features (for example blonde hair becoming dark) will result in a failure to match the face to one stored in memory causing recognition errors in an identification task. This is a description of a memory effect, and as such this explanation for the failure to recognise negative faces is compatible with descriptions of the inversion effect that have their locus at the stage of the memorial encoding of the face, such as Valentine’s face-space explanation.

The shape-from-shading explanation, on the other hand, describes a failure of the perceptual encoding of the face. It is assumed that negation disrupts the perceptual processes that normally give rise to the formation of a detailed three-dimensional representation of the surface structure of the face based on the shadow and shading information present in the image. It is much easier to see how a disruption of these basic perceptual processes might lead to the reduction of the sensitivity to feature displacement in faces, as demonstrated in experiments 1, 2 and 12. This explanation is therefore much more compatible with the perceptual explanations of the inversion effect such as Goldstein & Chance’s schema theory, Diamond & Carey’s second-order relational feature theory and the face-superiority framework. Diamond & Carey’s hypothesis that the perceptual encoding of second-order relational features is particularly sensitive to stimulus orientation is neither compatible nor incompatible with the shape-from-shading explanation; this model is specifically designed to account for the inversion effect and can not easily incorporate any other effect. Goldstein & Chance’s schema theory, by comparison, is a rather more general account of a perceptual processing advantage enjoyed by face stimuli, and as such can more easily incorporate the shape-from-shading account of the negation effect. Quite simply, a negated face, like an inverted face, is engaged by the face schema but is outside its
range and so the processing of these stimuli is slowed and less accurate than an upright or positive face. The only problem with this account is that it has some difficulty in explaining the apparent independence of these two effects. It should not be possible to produce face-like stimuli that are sensitive to only one of these two effects, such as the stimuli used in experiment 5 that gave rise to a negation effect but not an inversion effect or the stimuli used by Bruce & Langton (1994) that gave rise to an inversion effect in the absence of a negation effect. According to Goldstein & Chance, a stimulus that is sufficiently face-like to engage the face schema should always be less accurately perceived when transformed by either negation or inversion.

The face-superiority explanation both locates the cause of the effects at the stage of the perceptual processing of the stimuli, and is general enough to incorporate the shape-from-shading explanation of the negation effect while still allowing the negation and inversion effects to operate independently of each other. The processing "template" that focuses and directs the perceptual processing of face-like stimuli is seen as having been derived from extensive experience of many different faces and will come to incorporate information concerning the higher-order invariant properties of faces. In effect the template will be able to direct the processing towards those aspects of the stimulus that contain the information most useful for recognition of the face. Thus, negation can operate within this framework by disrupting the encoding of three-dimensional structure independently of the action(s) of stimulus inversion.

19.3 Summarising these explanations

The major characteristics of each of these explanations of the negation and inversion effects, and the similarities and differences between them, are summarised in table 19.1 below. Inspection of this table reveals that, although each of the three alternatives
have some characteristics in common with the face-superiority explanation, there are also critical differences between all four. In particular, the predicted sensitivity of perceptual processing is different for each of these (see the right-most column of table 19.1).

The face-superiority explanation developed above would perhaps be more accurately called a framework. The face-superiority effect, and the context-superiority effects more generally, have provided a broad framework within which I have been able to account for the pattern of results given by the experiments described in this thesis, and develop an explanation for the negation and inversion effects. In the following sections of this chapter I will attempt to develop this framework into a model of face perception that more explicitly describes the early processes involved in the perception of faces, and makes some testable predictions.
Table 19.1 A summary of the characteristics of, and differences between, the face-superiority explanation of the negation and inversion effects and three alternative explanations

<table>
<thead>
<tr>
<th>Model</th>
<th>Locus of effect</th>
<th>Nature of advantage/disadvantage</th>
<th>Negation &amp; Inversion effects additive/independent?</th>
<th>Predicted accuracy of perceptual processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valentine (1991)</td>
<td>Memorial encoding</td>
<td>Disadvantage for inverted faces relative to upright and non-faces</td>
<td>Yes / Yes</td>
<td>(Faces=Non-faces)&gt;Any transformed-object</td>
</tr>
<tr>
<td>Diamond &amp; Carey (1986)</td>
<td>Perceptual encoding</td>
<td>Disadvantage for any inverted object(^{51})</td>
<td>No / Not Applicable</td>
<td>(Faces=Non-faces)&gt;Any Inverted object(^{52})</td>
</tr>
<tr>
<td>Goldstein &amp; Chance (1980)</td>
<td>Not specified, but probably both perceptual and memorial encoding</td>
<td>Both an advantage for upright faces and a disadvantage for inverted faces</td>
<td>Probably Yes / No</td>
<td>Faces&gt;Non-faces&gt;Transformed-faces</td>
</tr>
<tr>
<td>Face-superiority explanation</td>
<td>Early perceptual processing</td>
<td>Variable advantage for face-like objects relative to non-faces</td>
<td>Yes / Yes</td>
<td>Faces&gt;Transformed-faces&gt;Non-faces</td>
</tr>
</tbody>
</table>

\(^{51}\)But this disadvantage will only be apparent with objects which are members of a class which can only be differentiated on the basis of second-order relational characteristics.

\(^{52}\)Dependent on task demands - this prediction assumes that the task requires the encoding of second-order relational characteristics.
19.4 Developing a model of face perception:

The focused process model

Several authors have offered models of the cognitive processes involved in the recognition of faces (for example, Hay & Young 1982; Rhodes, 1985; Ellis, 1986; Bruce & Young, 1986), and the research generated by these models has considerably enhanced our understanding of the higher cognitive processes involved, but none has attempted to make explicit the perceptual processes that must underlie individuation. The Ellis and the Bruce & Young models both involve a stage labelled "Structural Encoding", and the Hay & Young model has two stages labelled "Representational Processes" and "Visual Processes" while Rhodes has a series of "Visuo-spatial representations" leading to a "View-specific representation". What none of these models make explicit is the extent to which the processes described are specific to face stimuli. In order to have a set of processes that are engaged only by face stimuli it would probably be necessary to classify all incoming stimuli as either face or non-face. Ellis (1983) included such a stage in his description of the hemispheric asymmetries involved in face processing, but Bruce & Young (1986) chose not to do so for three reasons:

"First, it prejudges the issue of whether faces actually do require a special type of analysis. We do not want to do so at present, even though we (like Ellis) now strongly suspect that specialized processes are involved. Second, even if face-specific analyses do occur, it is not clear to us that an explicit face "switch" is needed. Appropriate analysers might just pick up the input to which they are attuned,
thereby classifying the input implicitly. Third, we are uncertain about the level of visual information processing at which the decision to classify an input as a face is taken... It could be that classification as a face is an essential first step that must be taken before processing is directed to other components in our system, or it might be that classification as a face is achieved on the basis of a very general global structural description simultaneous with the classification of particular faces on the basis of more detailed local information." (Bruce & Young (1986), page 321).

The results presented in this thesis allow us to begin to describe some aspects of the perceptual processing that underlies face recognition, and to begin to construct a very basic model of the processes involved. Clearly certain aspects of such a model are bound to be speculative, but it is hoped that by making explicit the assumptions and hypotheses involved, this will encourage further work in this area.

The model offered is called the "Focused-process model" to emphasise the fact that the perceptual processing of the visual input is focused by prior knowledge of the structure of faces. The model is illustrated in figure 19.1. The details of this model, and the justification for its characteristics will now be considered. I shall use the three questions posed by Bruce & Young (1986) (see above) as a framework for describing this new model of face perception.
19.4.1 Question 1: Do we need a face "switch"?

I have argued that the negation and inversion effects should be considered as examples of a face-superiority effect whereby the perceptual context of the face and previous knowledge and experience of the structure and variability of faces, focuses and refines the perceptual processing of the visual input. This notion forms the central theme of the model offered, and the idea that the bottom-up visual processing of the image is influenced by top-down knowledge of the face is explicitly incorporated in terms of the focused feedback processing loop built into the model. This feedback-loop operates by checking all visual input for the presence of a face-like pattern. When such a pattern is located within the field of view the perceptual processing is directed and focused by the processing template that incorporates all the implicit knowledge of the structure of faces. This focused processing results in a richer stream of data from the perceptual system that is again checked for the presence of a face. The perceptual processing is thus increasingly elaborate and detailed as all the available information about the structure of the face is extracted from the image.

The focused-process model therefore explicitly incorporates a face/no-face decision node, but as the model also seeks to incorporate an explanation of other context-superiority effects, it includes decision nodes for a variety of other familiar object categories for which individuation might be required.

19.4.2 Question 2: Do faces require a special type of analysis?

The focused-process model of face perception suggests that face recognition requires more accurate perceptual encoding than the recognition of other non-face objects that
are not individuated in the same way, but that this more detailed encoding is achieved through a more detailed perceptual processing of the face rather than through the intervention of any special processes. Thus, face perception is seen as being quantitatively, but not qualitatively different from the perception of other objects. The only face-specific structures within this model are the face/no-face decision node and the processing template - the representation of the knowledge of face structure and variability. Once a face-like pattern is detected a more detailed processing is undertaken, and for example, a greater than normal use might be made of shape-from-shading cues to 3-D structure, or a more detailed description of the relative locations of the parts of the object might be undertaken, but none of the processes involved are specialised as such. Thus, face recognition is mediated by the same perceptual processes that underlie the recognition of all other objects. However, faces are processed in more detail than other objects and use is made of the knowledge of the faces to direct the processing toward those characteristics of the face likely to be most useful for individuation.

19.4.3 Question 3: When is the decision to classify a stimulus taken?
The focused-process model does not explicitly describe the stage at which this decision node is located, but this might be at the stage at which objects are classified as being members of "basic level" categories (Rosch, 1978). What is more important to this model than the location of this "switch" is that when activated it results in higher-level processes influencing the very early visual processing of the stimulus. The decision node might be located some distance "down-stream", but its influence is felt at the very earliest stages of the perceptual processing. This position is supported by Davidoff & Donnelly (1990) who argued that the face-superiority effect was due to
the accessing of a base-level description of the object (face) in long term memory, and that this base-level description must contain information concerning the spatial arrangements of the parts. Gorea & Julesz (1990) hypothesised a rather more low-level effect, suggesting that the output of face detector units such as those hypothesised by Perrett, et al. (1982) to exist in the temporal cortex, must be influencing the activity of those areas of the visual cortex such as V1 (Hubel & Wiesel, 1968) responsible for the detection of line segment orientation. We are not in a position to differentiate between these two possible arrangements, and so the precise location of the decision node is deliberately not specified.
Figure 19.1  The focused-process model of face perception
19.5 Some alternatives to the focused-process model

It is possible to construct alternatives to the focused-process model which can account for the findings reported in this thesis. These alternatives will be considered briefly.

19.5.1 The "blind-process" model

It is possible to specify an alternative form of the model that does not include a face/no-face decision node. This model can account for the data presented in this thesis if we assume that all stimuli are processed in an identical fashion, but that the perceptual processing undertaken is more appropriate for some types of stimuli than for others. Hence, faces are perceived more accurately because some of the more detailed processing undertaken benefits the perception of patterns which share certain characteristics with faces. It is not easy to dismiss this version of the model (henceforth the "blind-process" model), which is in some ways more parsimonious than the focused-process model as it completely eliminates the need for the decision node. This illustrates the point made by Bruce & Young (1986) that such a switch might not be necessary. The disadvantage of the blind-process model is that it implies a rigid structure where the perceptual processing cannot be adapted to meet the task requirements. We would have to assume that the ecological significance of the face has been reflected in the nature of our perceptual mechanisms so that we have evolved mechanisms which are particularly suited to face recognition, but used unmodified with all stimuli. Although not impossible, it seems rather more likely that the visual system is economical in terms of the processing undertaken, and adapts the processing in the light of experience, task demands and stimulus characteristics. A related
disadvantage with the blind-process model is that although it is possible to explain the face-superiority effect it is rather more difficult to account for other context-superiority effects (for example, the chair-superiority effect demonstrated by Davidoff & Donnelly, 1990) other than on the basis that all these perceptual contexts are benefiting from the face-specialised processing.

19.5.2 The "process-until-termination" model
It is also possible to visualise a variant of the blind-process model which has no decision node and in which all inputs are processed in the same way. In this variant of the model the perceptual processing becomes increasingly focused and directed as it continues. Within this framework the processing might be limited or curtailed by either time (the image may no longer be available) or by task requirements (e.g. object recognition has been achieved). This process-until-termination model is rather more economical than the blind-process model, but still assumes that all visual inputs may potentially be processed in an identical manner. The major problem with this version of the model is its failure to explain the results of experiment 9 where although the task requirements were identical, dot patterns were shown to be less accurately perceived than face patterns.

19.6 The focused-process model and the negation and inversion effects
A major advantage of the focused-process model over the blind-process and the process-until-termination model is that the focused-process model offers greater
flexibility in that it can account for the disruption to face perception caused by both image transformations such as negation and inversion in a number of different ways.

19.6.1 Two possible loci for the negation and inversion effects

Within the framework of the focused-process model the negation and inversion effects could operate at either the stage of the face/no-face decision node or at the point of the focused processing.

19.6.1.1 The face/no-face decision node: Image transformations such as negation and inversion could disrupt the perceptual processing of the face by preventing the image from being classified as a face, and thus preventing a more focused processing of certain aspects of the image being undertaken. Face and non-face images would therefore be processed identically, and the potential perceptual advantage gained from prior knowledge of the structure of faces would be lost. This is not unlike the Diamond & Carey (1986) explanation of the inversion effect, where an inverted face is thought to be processed like all other non-face objects.

19.6.1.2 The focused processing: Alternatively, it could be that negation and inversion disrupt and limit the finer and more focused perceptual processing that is undertaken with a face image. The visual system might classify the image as a face, and attempt to undertake a more detailed analysis of certain aspects of the face, but be unable to do so because of the disruptive effects of the transformations on these specific aspects of the perceptual processing. So, in this case, the negated face is classified as a face, and a more detailed perceptual analysis is then attempted. However, if that analysis is partially dependent on information derived from the shape-from-shading cues
encoded within the image then the face image will be perceived with little more accuracy than the non-face image.

19.6.2 The evidence concerning the loci of the effects

There are several reasons for preferring the version of the model that locates the inversion and negation effects at the point of the focused processing, rather than at the face/no-face decision node. Locating the effect at the face/no-face decision node results in an all-or-nothing process where an image is either recognised as a face, and specially processed, or not recognised as a face and processed normally. Such a model has considerable difficulty in explaining why the negation and inversion effects should have apparently different and distinct causes and why it should be possible to induce one without the other. In experiment 5, I was able to induce the negation effect without the inversion effect, and Bruce & Langton (1994) have identified a stimulus that gives rise to the inversion effect but not the negation effect.

A model in which these effects operate at the level of the decision node would also have considerable difficulty in accounting for the additive relationship between the two transformations whereby a face that is both negated and inverted is less accurately perceived (and indeed later recognised) than one that is either negated or inverted. Precisely this additive relationship was demonstrated in experiment 2 in this thesis and has since been demonstrated by Jeffreys (1993) and by Bruce & Langton (1994). Earlier I argued that this additive relationship undermined the explanation for the inversion effect offered by Diamond & Carey (1986) as it seems to predict that the addition of a second image transformation (such as negation) will have no further effect on recognition. Indeed, Valentine (1991) makes a similar point when discussing
the relationship between the race effect and the inversion effect (see chapter 2). In a
sense then, this version of this model is an implementation of the Diamond & Carey
explanation of the inversion effect.

A model that locates the negation and inversion effects at the point of the focused
processing is better able to account for the observation that the perceptual advantage
decreases as the stimuli becomes progressively less face-like. The gradual loss of the
perceptual advantage enjoyed by the face stimuli could be caused by the progressive
loss of stimulus characteristics which are required for the more focused processing of
a face. In other words, although broadly face-like, a stimulus might lack the perceptual
characteristics on which the focused processing is based. Of course, even if the locus
of the effects is normally at the point of the focused processing, there must be some
point at which a highly distorted or transformed face is no longer recognised as a face.

Finally, the demonstration in experiment 9 that order of presentation had no effect on
performance, suggests that knowledge that the stimulus can be thought of as a face
does not affect the accuracy of perceptual processing. It is possible that the face/no-
face decision node is unaffected by conscious processes and cannot be primed, but it
would perhaps be surprising if this were the case. The context-superiority effects seem
to demonstrate that perceptual processing is a drawn-out process in which top-down
processes are involved in tuning the bottom-up processes. It would be surprising if one
of the steps in this sequence, especially one of such ecological significance to a social
animal, did not make use of all available information. Surely then, having to complete
a series of 24 face trials before being presented with a very similar non-face pattern
and an identical task, we might expect the decision node to be at least biased toward
a "face" decision. The fact that there is no evidence of such biasing means either that
priming cannot take place in this way or, perhaps more plausibly, that the outcome of this decision process can only affect the performance if the stimulus contains sufficient information to allow a more detailed analysis. One way of further examining this question of conscious control might be to make use of ambiguous or reversible figures such as the famous faces/vase figure. Using this figure it would be possible to compare the accuracy of simple perceptual judgements when seeing the face and when seeing the vase (a technique similar to that adopted by Wong & Weisstein, 1982).

Although not conclusive, these points do seem to suggest that the locus of the image transformation effects is at the stage of the further, focused processing.

19.7 Prosopagnosia and the focused-process model

The existence of neurological disorders such as prosopagnosia which appear to specifically affect face recognition has been cited as evidence that faces are processed differently from other types of visual object (see chapter 1). A full discussion of the literature relating to prosopagnosia is beyond the scope of this thesis, but I will briefly identify a few points of contention within the literature which are relevant to the development of the focused-process model of face perception.

There is some debate as to whether prosopagnosia is a disorder of the perceptual systems, or of the memory systems. This question was recently considered by Bruce & Humphreys (1994) who reviewed the available literature and concluded that there was evidence that in some cases of prosopagnosia, the lesion was affecting only the perceptual, and not the memory systems, and that in some of these cases, there did seem to be evidence that the perceptual deficit was specific to faces. Bruce &
Humphreys cite the work of Sergent & Poncet (1990) and Sergent & Signoret (1992) in support of this suggestion of the existence of a face-specific perceptual prosopagnosia. This work of Sergent is of particular interest as it involved the use of a task that made no demands on the patients' memory. Participants were asked to judge the similarity of pairs of line drawings of faces which differed on the basis of between 1 and 3 characteristics. The pattern of responses obtained were then fitted to a variety of multidimensional scaling solutions. "Normal" participants tested in this way seemed to judge the similarity of faces on the basis of the configuration of several features rather than individual features, but some of the prosopagnosic patients produced a pattern of results that suggested the features were being treated independently. Bruce & Humphreys interpret this as evidence of a deficit in the configural encoding of faces. Sergent & Signoret (1992) used this same procedure with non-face items that were all members of a visually homogenous class of objects (Ferrari cars). Normal participants and many of the prosopagnosic patients seemed to tackle this task using a configural approach similar to that adopted by normals when comparing faces. However, one patient who used a feature-based approach with faces, showed evidence of using a configural approach with the cars. This would seem to suggest that the ability to extract these configural descriptors from an image was not universally affected in prosopagnosics, but that in some cases at least, this deficit was indeed specific to faces. Bruce & Humphreys conclude

"...the results suggest that the perception of facial configurations can be severely impaired without there being necessarily damage to putatively equivalent processes for objects" (page 172).
We must be cautious in interpreting this result, as it is based on a single patient, and the conclusions are reliant upon certain critical assumptions about the equivalence of the processes underlying the perception of faces and cars (a point discussed by Bruce & Humphreys); however, there does seem to be good reason to believe that in some cases prosopagnosia can be the result of largely perceptual disorders and that these might be fairly specific to faces.

So how does this consideration of prosopagnosia relate to the proposed focused-process model of face perception? The first point to make is that this model can easily account for a face-specific perceptual disorder. The focused-process model was specifically designed to account for perceptual effects related only to face-like patterns, and so this model easily incorporates this description of prosopagnosia. The model also predicts that two distinct forms of the condition should be identifiable.

19.7.1 Two forms of prosopagnosia

A lesion could affect two distinct points within the model and still produce apparently face-specific deficits. Firstly, the decision node could be destroyed or damaged causing the system to fail to identify face-like patterns within the visual field. This would result in a very pure prosopagnosia where no other perceptual deficits would be present. Patients with such a lesion would no longer benefit from the focused processing that normally results from knowledge of the structure of the face. It is also interesting to note that a further prediction here is that these patients would not show the perceptual effects of either negation and/or inversion demonstrated in this thesis and would perceive a face stimulus only as accurately as a non-face stimulus because they could not engage the more detailed processes that advantage the face stimulus.
An alternative locus for the effect would be at the point of the focused processing. In such cases the lesion would limit the effectiveness of the perceptual processes that are required by the face-specific processing. As it is not envisaged that any of the perceptual processes involved in the focused processing are unique to faces, we would expect that the effect of such lesions would also emerge in other tasks involving non-face stimuli. Although these patients would display a rather more general perceptual disorder it is quite possible that, under normal conditions, the problem might present as fairly face-specific, and the full extent of the damage to the perceptual system might only become apparent when the task required an unusually detailed perceptual analysis of the image. When tested using the paradigm developed in this thesis, such patients might still perceive face stimuli more accurately than non-face stimuli (depending on the degree of deficit) and might still demonstrate a negation and/or inversion effect.

The patient described by Sergent & Signoret (1992) would seem to fit the first of these two descriptions in that he seems to have a perceptual disorder which is specific to face stimuli. I would argue that this results from his failure to classify the stimulus as a face and to focus his perceptual processing accordingly.

It is interesting to note that a lesion at this point (the decision node) would also account for species specific prosopagnosias. Several such cases have been identified and there is evidence of a double dissociation of function, with patients having been described who can still recognise their cattle following a lesion that leaves them unable to recognise even familiar faces, and other cases who show preserved human face recognition but a loss of ability to recognise their livestock (see McNeil & Warrington, 1993). This is easy to account for if we assume that new decision nodes
are created as a new category of visually similar items is learned (such as sheep). A lesion that affected the more detailed perceptual processing directly would affect a patient's ability to recognise animals of all species, but a lesion that affected a decision node would result in a deficit specific to that object category.

This does not mean that all cases of prosopagnosia result from a perceptual dysfunction; it seems likely that many are primarily disorders of memory (see Bruce & Humphreys, 1994, for a discussion). The importance of this model lies in the fact that it can account for cases of prosopagnosia that are both perceptual in nature and face-specific.

The blind-process version of the model can also account for a purely perceptual prosopagnosia, but this model is not as flexible having no point at which a lesion can result in a deficit that is completely specific to faces (because it lacks a decision node). Similarly, it is not easy to see how the process-until-terminate model can explain a "pure" perceptual prosopagnosia.

19.8 The development of face perception

Ellis (1975) identified three lines of evidence to suggest that faces were processed differently from other stimuli; the effect of inversion, the existence of conditions such as prosopagnosia, and the development of face-processing abilities. We have seen that the model described here can account for the first two of these three lines of evidence. I will now consider the third.
As described in chapters 1 and 2, there is some debate about the nature of the developmental trends in face recognition, but most authors agree that the recognition performance with upright faces increases between about 5 and 15 years of age (with a possible dip in performance around puberty), but that performance with inverted faces does not show the same developmental trend. This differential increase in expertise with upright faces leads to the development of an increasing inversion effect.

It has been argued that this increasing inversion effect reflects a difference in processing strategy between younger and older children, with age resulting in an increasing reliance on configural rather than feature based cues to recognition (see for example, Carey, et al., 1980). There are however several problems with this explanation (see also chapter 2). In some currently unpublished research conducted in collaboration with Nicky Towell (also of the University of Westminster) I have used a perceptual task based upon the one described in this thesis and have measured the speed with which young children can identify either changes to the configuration of the features or the replacement of a feature within a face. This research has, to date, provided no evidence that young children are any less sensitive to configural changes than are adults or older children. In related research being undertaken as part of her PhD under the supervision of myself and Nicky Towell, Jess Prior has asked children to describe faces. Although young children use far fewer words to describe a face, and cannot provide as useful a description, there is no doubt that some of the words or phrases they use are describing configural features. In a similar vein, Carey & Diamond (1994) used the chimeric faces technique devised by Young, et al. (1987) that was described in chapter 2. They concluded that there was no evidence that adults were more reliant on configural cues to recognition than were children. There is therefore increasing evidence that the development of the inversion effect does not reflect a change in processing strategy.
A rather unusual effect was reported by Hole, et al. (1993) who devised a procedure that allowed them to measure the decision latency to upright and inverted faces with very young children. They found that virtually all children of 4 years of age or less showed what they called an "inverted inversion effect" whereby the children were quicker to recognise a familiar face amongst a set of unfamiliar distractor faces when all the faces were inverted than when upright. Interestingly, there was a clear trend such that by 5-6 years of age there was no effect of orientation, and by 7-8 years a normal inversion effect began to emerge. Hole et al. argued that previous studies had failed to identify this effect because they had not studied children younger than 5 years of age (in fact, Carey & Diamond, 1994, also found that young children were quicker with inverted than upright composite faces). If this proves to be a reliable result it will be very difficult to explain. Perhaps the best explanation would be one couched in terms of a reliance on a face processing strategy that is potentially time-consuming until practised. The focused-process model provides exactly such a framework; the focused processing invoked by the realisation that a face is present might reasonably be expected to be rather time consuming and perhaps not very accurate, and hence useful, at first. Only with experience and general cognitive development will the full benefit of this processing be realised and the traditional advantage for the upright face emerge.

Thus the focused-process model has the ability to explain both the increase in performance with age for upright faces and perhaps even the unexpected "inverted-inversion" effect.
19.9 Criticisms of the model

The most obvious criticism of the focused-process model is its simplicity. It could be argued that it does not warrant the title of "model", but rather that it is a description of a feed-back processing loop. The other major limitation is that it is very difficult to falsify. The description of prosopagnosia offered above, for example, allows for both perceptual and memory based disorders that can be either face-specific or more general, and so makes very few testable predictions. However, it is possible to make a few predictions:

1. A species specific prosopagnosia (see above) should always be entirely "pure" in that it should not be possible to measure any impairment in the ability to make basic perceptual judgements outside the context of the face of the affected species.

2. A patient who demonstrates a face-specific disorder and shows no deficit in the ability to identify members of some other class of visual object should never demonstrate an impairment in the ability to make basic perceptual judgements.

3. In a patient who shows a non face-specific impairment it should be possible to identify an impairment in the ability to make basic perceptual judgements.

4. A patient who shows a face-specific impairment should show no effect of negation or inversion using the perceptual paradigm described in this thesis. This need not be the case for a less specific agnosia.
It is even more difficult to identify testable hypotheses concerning the nature of the negation and the inversion effect. However, it should not be possible to demonstrate that a negative or an inverted face is being treated equivalently to a non-face. Importantly, there is some very recent evidence that suggests just this. Costen, Ellis, and Shepherd (1994) used a backward-masking paradigm to study the processes involved in the recognition of well known faces. They showed that the ability either to classify as familiar, or to name, a briefly-presented familiar face was significantly disrupted if an unfamiliar face was briefly presented immediately following the presentation of the familiar face. Varying the stimulus-onset-asymmetry between the two presentations altered the strength of the effect, and it is thought that this reflects the point in the processing that the first stimulus has reached by the time the mask stimulus is presented. Costen et al. compared the effects of face and non-face masking stimuli, and whereas a non-face stimuli could be presented about 40-50 msec after the face without disrupting identification performance, a face mask presented less than about 100-150 msec after the target face presentation severely disrupted performance. This suggests that the target and face mask are competing for the same face-processing resources, and by using a variety of types of masks, including jumbled and inverted faces, they were able to suggest that the interference was probably occurring at the stage of the structural encoding of the face (with reference to the Bruce & Young, 1986 model of face recognition).

This is compatible with the model I have offered, and could even be seen as evidence of face-specific perceptual encoding. However, one result which can not be incorporated into the focused-process model of face perception is that inverted faces were no more disruptive to face identification than non-face stimuli. This seems to support the notion that an inverted face is seen as a non-face; the very suggestion
directly rejected by this model. At first sight this seems to be a critical finding, however, there are some problems in interpreting this result as the effectiveness of the inverted face mask was actually midway between that of an un-patterned mask and a face-mask, and was not significantly different from either. Thus, although the inverted face was only as effective a mask as was the non-face, it was not significantly less effective as a mask than was a face; a pattern of results that suggests the procedure lacks power. This result, however, should not be dismissed lightly and the backward-masking paradigm seems to offer the potential to test certain critical features of the focused-process model.

19.10 Conclusions

The focused-process model of face perception described in this chapter is very simple. However, it seems to have sufficient utility to warrant a formal description. The model is an implementation of the face-superiority framework described in the previous chapters and has just two principal features, a face/no-face decision node and a refined and elaborated processing of face stimuli. Despite this simplicity the model is useful because it describes the early perceptual processes that mediate the later recognition of the human face.
Chapter 20

Conclusions and Future Research
20.1 Some conclusions

The following conclusions can be drawn on the basis of the results of the experiments presented in this thesis.

1. It is possible to demonstrate the negation and inversion effects using a paradigm that does not require subjects to represent the faces in long term memory or to compare the faces to representations previously stored in long term memory.

2. The effect of negation and inversion on the recognition of faces can be explained in terms of a perceptual effect that limits the accuracy of the perceptual processing undertaken with negated and inverted faces compared to upright faces.

3. Both the negation and inversion effects can be explained within the general framework of context-superiority effects, where the "normal" face is seen as providing a context which acts to enhance the accuracy with which the features making up the face are perceptually processed. Within this framework, it is possible that these effects are examples of "true" face-superiority effects, as the effective strength of the context seems to be stronger for coherent, normal faces than for other non-face objects and non-coherent face images.
4. There is very strong evidence that these effects result from processes that advantage the processing of the upright, positive face relative to other stimuli, and not by disadvantaging the processing of the inverted and/or negative face relative to other objects. The whole, upright, positive face stimuli, provides a context which, perhaps due to acquired knowledge of the nature of faces and/or their constrained structure and limited scope for variability, focuses and directs the processing towards those features of the face which are most likely to encode person-specific information.

5. As a stimulus is changed to look less face-like, the size of the negation and inversion effects reduce due to a decrease in the strength of the face context which in turn decreases the relative advantage for the upright, positive face.

6. The true face-superiority explanation of the negation and inversion effects suggests that knowledge of the structure of the face focuses and refines the perceptual processing of the face. This description of a top-down process influencing the early visual processing of the face implies that it should be possible to identify the low level perceptual processes that are enhanced by the presence of the facial context.

7. The negation and inversion effects have been shown to be largely independent of each other and might therefore result from the disruption of different perceptual processes.
8. In the case of negation, the decrease in processing accuracy seems to result largely from a loss of shape-from-shading cues that hamper the process of forming a three-dimensional representation of the face.

9. It is not clear which perceptual processes are disrupted by inverting a face.

10. The model proposed by Valentine (Valentine, 1991) cannot adequately account for these data. Valentine's model suggests that negated or inverted faces are first transformed in order to compute the upright or positive form, and that this results in a more error-prone encoding process and a less accurate representation of the face. This is a description of a process that disadvantages the inverted or negated face relative to other objects, but I have demonstrated that the negation and inversion effects result from the more accurate processing of the upright face relative to both transformed faces and non-faces. The negated and/or inverted face is processed approximately as accurately as (or even slightly more accurately than) a non-face.

11. An alternative model called the focused-process model of face perception is offered in which feedback from the object recognition systems alerts the visual system to the presence of a face-like pattern within the field of view. Additional processing of the image is then undertaken which concentrates on those aspects of the information contained within the image and those parts of the image that are most likely to contain information useful to face recognition.
Chapter 20 Conclusions

20.2 What next? Some suggestions for future research

All the experiments reported in this thesis have used essentially the same methodology, and with some modification this procedure might allow us to investigate several other aspects of face perception.

20.2.1 The race effect

At several points in the introductory chapters of this thesis I considered the literature on another face recognition "effect"; the race effect. An obvious question for future investigation is whether the race effect can also be demonstrated using the feature displacement paradigm developed in this thesis. If we were able to demonstrate that participants more accurately detected the displacement of facial features in the face of a member of their own race than of another race, and if we were able to demonstrate a true cross-over interaction with two different race faces each being more accurately perceived by participants of the same race, then we would be able to argue that the race effect can also be considered within the framework of the true face-superiority effect. The face of a member of another racial group, especially a racial group with which one has little contact, could be seen as providing a less powerful facial context than the "normal" (own-race) face.

20.2.2 Colour negation

The use of colour images in the last two experiments reported in this thesis has helped identify the role of shape-from-shading in the negation effect, and has demonstrated
that the perceptual effects reported in the previous experiments were not limited to thresholded images. However, what I have not yet explored is whether the effects of colour negation (either full, hue or luminance) are comparable to the effects of monochrome negation. Indeed, what are the effects of representing a colour image in monochrome, and does this image transformation also reduce the accuracy of the visual processing of the image?

It is important that we understand the effect of rendering an image of a face in black and white, as so much of the face recognition research conducted to date has used monochrome images. Bruce (1988) argued that the perception of the flat, 2-D, monochrome images of the face used in such research might not be the same as the perception of live faces. Live faces possess the properties of hue, texture and motion, all of which are missing in the images used in most experimental studies of face recognition; and it is therefore unwise to try to build our understanding of face perception on the results of such studies. Most of the studies reported in this thesis have used just such impoverished images, and it is therefore very important that experiments 12 and 13 demonstrated effects of negation and inversion comparable to those shown with the thresholded images used in the previous studies.

20.2.3 Moving faces

The high quality colour images used in experiments 12 and 13 are more realistic than the monochrome images used in the earlier studies but, being static images, are totally devoid of motion cues. A real understanding of the perception of faces will only come from the study of moving faces as there are many aspects of an object’s structure and form that are revealed by motion. In the past there has been a tendency to see motion
as a problem for the visual system to overcome. However, it may be that motion provides the visual system with solutions to some of the problems inherent in the perception of a static image. The processing template described in the focused-process model must have developed largely as a result of experience of moving faces; and a moving face may present the visual system with a quite different set of perceptual invariants from a sequence of static images. It is therefore important that we study the perception of moving, as well as static faces. To this end, we are currently investigating the nature of the inversion and negation effects with video sequences of moving faces.

Perhaps a future direction for such work might lie in combining moving video sequences of faces in motion with representations of the detailed 3-D structure of the face and head of the type developed by Bruce & Langton (1994). It would then be possible to manipulate a face by altering each frame of a video sequence and, given a computer model of the three dimensional structure of the face, ensure that a feature displacement, for example, would have a consistent appearance as the face moved relative to the observer. Such a procedure would require a rather sophisticated image processing system, but such software already exists and no doubt within a few years will be available to psychologists.

20.2.4 Colour negation and recognition memory

Experiment 12 demonstrated that hue negation had no effect on the sensitivity to feature displacements, and this suggested a shape-from-shading, rather than a

53 This work is being conducted by Graham Pike as part of his PhD research programme under my supervision.
pigmentation, explanation of the negation effect. However, the negation effect has most frequently been demonstrated using a recognition memory, or episodic memory paradigm, ("Have you seen this face before?"). It is therefore important to attempt to investigate the effects of hue-, luminance-, and full-negation within such a task. Given the rather different task demands of the feature displacement and the recognition memory procedures, it is quite possible that different sources of information are being tapped in these two cases. The relative saliency of the different cues within an image might be a consequence of the prevailing task-demands, and thus a change from a feature displacement task to a recognition memory task might suggest a greater role for the pigmentation cues.

More generally we should be cautious about generalising from a perceptual paradigm to a memory paradigm. In earlier chapters I have argued that, as face identification is dependent on very fine perceptual judgements, the decrease in perceptual sensitivity that I have shown to be introduced by inversion and negation must be also limiting the ability to individuate faces. It is, however, possible that the feature displacement effect is an epiphenomenon: the fact that sensitivity to feature displacement is affected by negation and inversion could be telling us nothing about the processes underlying face recognition. Individuation might be dependent on the perceptual sensitivity to a completely different set of features from those being manipulated in these experiments. The perceptual sensitivity to the characteristics of the face that actually underlie recognition might be unaffected by negation and inversion. In part, these concerns can

---

54 I have now undertaken this research (Kemp, Pike, White & Musselman, submitted). The results show that for a recognition memory paradigm involving previously unfamiliar faces, there is a significant effect of both hue-negation and luminance-negation, but that for a face classification task (familiar/unfamiliar) there is no effect of hue-negation but a significant effect of luminance-negation. These results suggest that shape-from-shading is an important cue to recognition, but that in some tasks participants are also making use of pigmentation information.
be addressed by investigating the extent to which relative cue saliency varies with the demands of the face-processing task.

20.2.5 Psychophysical measures of sensitivity

The inability to compare absolute performance levels between experiments has become an increasingly serious limitation of the approach adopted in this thesis. This limitation can only be overcome by imposing rigidly controlled viewing conditions. What is required is a more traditional psychophysical approach, where the viewing conditions are very tightly controlled and a single, experienced viewer completes many hundreds of trials under identical conditions. With such an approach it would be possible to make valid comparisons of the sensitivity to feature displacement in each of the types of stimuli used in these experiments. However, it should also be noted that the use of such a procedure would have obscured some interesting trends present in the data reported here. For example, the tendency for subjects to identify small upwards displacements at less than chance level with some image types would not easily be detected by such a procedure.

20.2.6 Developmental aspects of face perception

In collaboration with various colleagues at the University of Westminster, I am currently investigating the development of face perception skills. We are using a variety of perceptual procedures derived from the feature displacement technique (employed in this thesis) which has been modified so that it is accessible to very young children. A major limiting factor in previous developmental research has been
the use of a traditional two phase recognition memory paradigm which is unsuitable for children younger than 5 years of age. Such procedures tend either to give rise to a floor effect with the youngest participants, or a ceiling effect with the older participants, or both of these. I have argued that we should adopt a procedure that can be completed without modification by even the youngest participants, and should use decision time as the dependent variable to avoid ceiling effects. The use of such a technique gave rise to the unexpected observation of an "inverted inversion effect" with children of 2-4 years of age (Hole, et al., 1993), and using the same apparatus we have also measured decision time to the detection of feature displacements and replacements in familiar and unfamiliar faces with young children.\(^5\)

As children develop their drawings increase in complexity. It has been suggested that the levels of artistic sophistication displayed by children reflect the development of various cognitive functions (see for example, Karmiloff-Smith, 1990). Relatively little of this research has considered children's drawings of the human face, but informal observation would seem to suggest that level of sophistication of the drawings is not only limited by the children's motor coordination (see figure 20.1). It may be that children's drawings of faces can give us some insight into the cognitive process underlying face recognition.

### 20.2.7 Non-performance measures of face processing

Jeffreys (1993) reported that the scalp recorded potentials associated with the perception of a face were reduced in amplitude when the face was either negated or

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\(^5\)This research is being conducted in collaboration with Nicky Towell of the University of Westminster and Graham Hole of Sussex University. Some of the feature replacement research has been undertaken by Jess Prior as part of her PhD under the supervision of Richard Kemp and Nicky Towell.
inverted. It would be interesting to investigate whether the amplitude of this scalp potential is related to the "faceness" of a stimulus as revealed by the feature displacement procedure. In particular, would a stimulus that appears to be immune to inversion or negation as measured by the feature displacement procedure also show no effect on the amplitude of the scalp recorded potential? We are planning to investigate these questions as part of a new research programme currently being formulated at the University of Westminster.

20.2.8 Prosopagnosia

As discussed in chapter 19, the focused-process model does make some predictions about the nature of the relationship between certain types of prosopagnosia and other perceptual deficits. It would be very useful to be able to measure the sensitivity of prosopagnosics to feature displacements in upright/inverted and positive/negative faces. It is not clear whether the sensitivity of such patients would be lower than normals, and whether this would hold true for all prosopagnosics or indeed patients with other visual agnosias. Similarly, it is not clear whether these patient groups would also show the effect of inversion and negation on sensitivity to feature displacement revealed by the intact participants used in this thesis. The results of such studies could prove to be critical to the focused-process model, and it is even possible that the feature displacement paradigm could be developed into a neurological tool to allow one to distinguish between perceptual and memorial forms of prosopagnosia.

Figure 20.1  Drawings of a face produced by a young artist, Joseph Earp. (4.5 yrs).
20.3 In conclusion

The last twenty years have seen an enormous growth in face recognition research and the publication of thousands of related reports. All this scientific endeavour has resulted in a significant increase in our understanding of the processes involved in face recognition, but the majority of this work has concentrated on the encoding and representation of faces in long term memory. Surprisingly little of this research has investigated the perceptual processes which must underlie these higher cognitive functions.

This concentration on memory-related work is perhaps the natural consequence of the Devlin report (Devlin, 1976) which was the stimulus for much of the recent British face recognition research. Lord Devlin was asked to investigate several well-publicised failures of eyewitness identification which led to wrongful convictions in British courts in the 1970’s, and noted the lack of relevant psychological research. Perhaps inevitably, most of the research subsequently undertaken in the U.K. focused on our memory for unfamiliar faces. Only a minority of papers have investigated the perceptual processes underlying the representation of a face in memory, and as a result there has been a tendency to assume that a factor found to affect a subject’s ability to recognise a face is acting directly on the memory processes at either encoding or recall. The possibility that face recognition performance might be influenced by processes directly acting on the perceptual processing of the face has been largely ignored.

Kemp, Towell & Pike (in preparation) point out that despite the volume of face recognition research conducted in recent years, we are not in a position to answer even fairly simple applied questions such as "How well can subjects match a photograph
Chapter 20

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to a live face?" and "What are the minimum viewing conditions necessary to allow correct identification?". Clearly there is a need to redress this balance and consider faces as the complex perceptual stimuli they are, rather than think of them only as objects to be represented in memory.

This thesis was envisaged as an investigation of the perceptual processes underlying face recognition, and for this reason all the studies employed a paradigm that does not require the faces to be represented in memory. It has been possible to demonstrate that the effect of negation and inversion on the recognition memory for faces can be explained in terms of the perceptual processing of the image. Quite simply, a negated face might not be recognised (remembered) as well as a positive face because it can not be perceived as accurately.

A face is in the eye of the beholder long before it is in his or her memory. Tanaka & Farah (1993) showed us that we could not recognise Larry’s nose outside the context of Larry’s face (see chapter 4); in this thesis I have demonstrated that, outside the context of his face, we might not even be able to see Larry’s nose. Yin (1969) argued that the disproportionate effect of inversion on face recognition provided evidence that faces were processed by special mechanisms. The results presented in this thesis suggest that, if faces are special then it is not because they are peculiarly difficult to recognise when inverted, but rather because they are especially accurately perceived when upright.

Richard Kemp
June 1995
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Appendix 1

An example of a response booklet is given on the following pages. This booklet was prepared for experiment 11, but the answer booklets for all other experiments had the same basic format except that:

1. In experiment 1 participants were asked to identify which of the two lower images was *the same as* the top image. In all subsequent experiments this instruction was reversed and the participants were asked to identify which of the two lower images was *different from* the top image and hence was the *odd-one-out*. Participants reported that this revised instruction was easier to remember.

2. In experiments 8, 9, 10 and 11 there were two blocks of trials. In experiments 8, 10 and 11 participants undertook a block of 96 experimental trials followed by a block of 24 normal face trials. In experiment 9 half of the participants completed the experimental trials before commencing the face trials. The remaining participants completed the face trials before starting the experimental trials. In each of these experiments the second block of trials was preceded by a brief reprise of the instructions (modified slightly to reflect the nature of the stimuli) and a selection of practice trials.

3. For some of the experiments participants were asked to indicate which of the trial types they thought were the easiest by answering a series of simple multiple choice questions following the last trial.
On each of the overhead slide I am going to show you there are three images. The image at the top of the slide is always unmodified. One of the other two images has been modified so that the upper pair of "eyes" are not in their original position. Your task is to decide which of these two images has been modified. Remember, the top image is always unmodified so you can use this as a comparison. In effect you have to decide which image is the "odd one out".

Record your answers on this answer sheet. If you are CERTAIN that the left image is the one that has been modified then you should circle the words CERTAINLY LEFT on the answer sheet. If on the other hand you think that it was probably the right image that was modified then circle the words PROBABLY RIGHT. In this way indicate which image you think was modified and how certain you are about your decision.

Please ensure that you give an answer for each trial. If you don't know the answer then make a guess - very often you will find that you will get the right answer by guessing. You will be shown each overhead transparency for about 5 seconds. If you feel that you are falling behind then please let me know.

You will be given a few practice trials before the experiment proper starts.

**PRACTICE TRIALS**

1. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
2. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
3. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
4. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
5. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
6. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
   LEFT LEFT LEFT RIGHT RIGHT RIGHT
7. CERTAINLY PROBABLY POSSIBLY POSSIBLY PROBABLY CERTAINLY
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NOW TURN OVER THE PAGE TO START THE EXPERIMENTAL TRIALS.
Appendices

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Appendices
The following trials are exactly the same as the previous 96 trials except that the image in the following trials will be that of a face.

In these trials one of the bottom pair of images has been modified by having the "eyes" moved. Decide which has been modified in this way and indicate your decision on the answer sheet as before.

You will be given a few practice trials before the experiment starts.

**PRACTICE TRIALS**

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Thank you for your assistance.

Richard Kemp
Division of Psychology.