The Face Inversion Effect: Parts and Wholes

Individual features and their configuration

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Abstract

The face inversion effect (FIE) is a reduction in recognition performance for inverted faces (compared to upright faces) that is greater than that typically observed with other stimulus types (e.g. houses; Yin, 1969). The work of Diamond & Carey, (1986), suggests that a special type of configural information, "second order relational information" is critical in generating this inversion effect. However,Tanaka and Farah (1991) concluded that greater reliance on second-order relational information did not directly result in greater sensitivity to inversion, and they suggested that the FIE is not entirely due to a reliance on this type of configural information.A more recent review by McKone and Yovel provides a meta-analysis that makes a similar point. In this paper, we investigated the contributions made by configural and featural information to the FIE. Experiments 1a and1b investigated the link between configural information and the FIE. Remarkably, Experiment 1b showed that disruption of all configural information of the type considered in Diamond and Carey's analysis (both first and second order) was effective in reducing recognition performance, but did not significantly impact on the FIE. Experiments 2 and 3 revealed that face processing is affected by the orientation of individual features, and that this plays a major role in producing the FIE. The FIE was only completely eliminated when we disrupted the *single feature orientation information* in addition to the configural information, by using a new type of transformation similar to Thatcherising our sets of scrambled faces. We conclude by noting that our results for scrambled faces are consistent with an account that has recognition performance entirely determined by the proportion of upright facial features within a stimulus (cf. Rakover and

Teucher, 1997), and that any ability to make use of the spatial configuration of these features seems to benefit upright and inverted normal faces alike.

Research key words: inversion effect; configural information; face recognition; expertise.

Introduction

Recognition of objects that are usually seen in one orientation is sometimes strongly impaired when the same objects are turned upside down, revealing how intrinsically difficult it is to identify them. This has been found to be particularly the case for faces, a phenomenon known as the face inversion effect (FIE). Thus the fact that recognition of human faces is more impaired by inversion than is recognition for other stimuli has underlined how faces are in some sense, special. The purpose of the experiments reported in this paper is to investigate the basis for the face inversion effect. We begin with a brief review of the evidence available and the theoretical accounts of the FIE currently in play.

In early evidence for the FIE, Yin (1969) presented participants with upright or inverted pictures of faces, airplanes, houses, and other stimuli. Following the study phase participants were then tested with stimuli in the same orientation in a recognition task paradigm. The results showed that when the stimuli were studied and tested in an upright orientation, faces were better recognized than other sets of stimuli. However, when the same stimuli were presented and tested in an inverted orientation, recognition for faces was poorer relative to the recognition levels for the other classes of stimuli. Yin (1969, Experiment 3) replicated this result in an experiment using line drawings of facial stimuli and period costumes, thus controlling for the effect of subtle shadow information in an inverted face as a potential explanation for the large effect of inversion. In the latter experiment faces were not the easiest stimuli to be recognized when presented in an upright orientation. Therefore, the large

FIE could also not be attributed to the overall difficulty in discriminating within that stimulus category. Later experiments by other researchers have confirmed Yin's results, e.g. Valentine and Bruce (1986) found a FIE for face recognition compared to recognition of houses in experiments where upright and inverted stimuli were presented in the same list during the test phase. All the previous studies in the literature had used separate test blocks. In summary, the FIE seems to be a solid and general phenomenon that cannot be explained simply as an artefact of experimental procedure, stimulus material, or task demands.

Yin interpreted his results in terms of a face-specific process. However, more recently Diamond and Carey (1986) provided an alternative account of the FIE according to which the inversion effect is due to expertise for a prototype defined category rather than the product of face-specific processes. For our present purposes, what was notable about this account was the emphasis placed on configural facial information as the basis for the FIE.

Diamond and Carey (1986) distinguished between three types of information that can be used in recognition: isolated features (e.g. the nose), first-order relational features (e.g. the nose in relation to the mouth) and second-order relational features (the variations in first-order relations relative to the prototype for that stimulus set). Thus, isolated or local features are the independent constituent elements of an object. First-order information consists of the spatial relations between the constituent elements of that object, and it is this information that defines a set of facial features as a face. Second-order information captures the variation in these spatial relationships with regard to the base prototype for objects of that type. These two kinds of relational information are both types of configural information. Because all faces tend to have the same first-order relational information in common, the essential information by which faces differ from each other is second-order in nature on this analysis. Diamond and Carey suggested that large inversion effects will only be obtained if three conditions are met. First, the members of the class of stimuli must share a based configuration, the prototype. Second, it must be possible to individuate the members of the class by means of second-order information. Finally, individuals must have the expertise (in other words, the experience with the stimuli) to exploit such second-order information. They suggested that the elements that distinguish faces, lie on a continuum from isolated/local to second-order relational, and that recognition of faces as a class differs from recognition of other types of stimuli in its reliance on second-order relational features because people have the necessary expertise to use these features.

Searcy and Bartlett (1996) and then Leder and Bruce (1998) provided compelling evidence of the effect of disrupting configural information by inversion. In one of their experiments, Searcy and Bartlett (1996) made faces grotesque by either changing local elements, such as blackening teeth, blurring the pupils, or by changing the facial configuration. When shown in an inverted orientation, faces that were distorted through configural changes seemed to be more similar to the normal version, while the "locally distorted face" still looked grotesque. Thus, configural changes did not survive the inversion process as well as local ones. In another experiment, Leder and Bruce (1998) distorted faces so as to be more distinctive, either changing local features by giving them darker lips, bushier eye brows, etc. or by changing configural information to give a shorter mouth to nose spatial relation, etc. Distinctiveness impressions caused by distorted configural information disappeared when faces were presented in an inverted orientation compared to both upright faces and faces distorted in their local aspects.

This sensitivity of configural distortions to inversion is also often suggested as the basis (at least in part) of the "Thatcher illusion" (Thompson, 1980). Here, the illusion seems to depend on the inversion of mouth and eyes within the face being hard to detect when the whole face is inverted. The explanation typically offered is that inversion reduces the use of configural information in the face, and promotes a more componential analysis of the features present.

In isolation, the mouth and eyes do not look odd, and so cause no great reaction in the viewer. When the face is shown in its normal orientation, however, we revert to configural processing, and this makes the distortions present in the mouth and eyes stand out, resulting in a strong reaction to the face on the part of most percipients.

Hole et al., (1999) suggested there is more than one type of relational processing. Thus, they interpreted their results (recognition of the top half of a composite face, constructed from top and bottom halves of different faces, is difficult when the face is upright, but not when it is inverted even for negative images) by suggesting that upright negative chimeric faces are sufficiently `face-like' to evoke holistic processing. On this view, holistic processing is elicited by anything that roughly conforms to the basic plan of a face, and it is holistic encoding that establishes that it is a face that is being perceived, as opposed to some other kind of object. Configural processing, by contrast, deals with the precise locations of the facial features relative to one another. According to the authors it may be that inversion disrupts both holistic and configurational processing, whereas constructing a photographic negative of the facial image disrupts configural processing but leaves holistic processing intact.

Undoubtedly these results all provide evidence for the powerful effect that relational information has on the processing of upright faces relative to inverted faces. However these results do not directly address the role that first and second order relationships play in causing the inversion effect itself, though they do suggest that it could be an important one.

In 1991, Tanaka and Farah directly investigated the role that second-order relational information may have in producing the FIE. In their study they trained subjects to identify dot patterns that either shared a common configuration, with each exemplar having been constructed from a prototype by means of small variations in dot position, or did not share a common configuration. In the two experiments they conducted, they found a moderate inversion effect that did not differ in magnitude between the two types of patterns. Their conclusion was that greater reliance on second-order relational information (assumed to occur in the prototype defined case) does not directly result in greater sensitivity to inversion. Some additional support for Tanaka and Farah's position comes from Tanaka and Sengco's (1997) study. The authors hypothesized that if both featural and configural information are combined into a holistic representation, then changes in configural information should affect the recognition of the individual facial features. The results from their first experiment are consistent with this hypothesis: after training with upright faces, the participants recognized facial features better in the unaltered facial context than in the context where the second-order information had been disrupted (by manipulating the distance between the eyes). In a second experiment the authors showed that manipulations that disrupted configural information did not affect recognition for facial features when the faces were presented upside down. Thus, their conclusion was that manipulating configural information, in particular second order relational information, only affects the recognition of facial features in the case of upright faces.

More evidence for this view comes from Rhodes, Brake, and Atkinson (1993). Manipulations of second order relational information (altering the internal spacing of the eyes and mouth) were more difficult to detect when faces were inverted. However, when the eyes or mouth were actually replaced with those from another face, this was more disruptive to recognition performance under inversion. They concluded that either the featural changes also affected configural information or that the assumption that featural processing is not affected by inversion is incorrect.

McKone and Yovel (2009) made a strong case for the role of local feature information in the FIE by conducting a meta-analysis that indicated that the inversion effect was not entirely due to changes in the processing of configural information contingent on inversion, but instead depended in part, at least, on the orientation of individual features. They evaluate the claim that perception base on local feature information shows no or weak inversion effects, and find that the evidence does not support this claim. Instead they argue that local feature information can make a contribution to the FIE that is the equal of that due to the processing of configural information. This position is strongly supported by Rakover and Teucher's (1997) finding that it is possible to obtain an inversion effect even with facial features presented in isolation, suggesting that configural information is not necessary to obtain such an effect. Indeed, Rakover and Teucher go further and claim that the FIE could simply be due to some non-linear combination of the effects resulting from the inversion of local features, and not depend on configural information at all.

In summary, we have some quite strong evidence suggesting that configural information is important for face processing, and is implicated in the FIE. On the other hand, there is also some good evidence that configural information does not necessarily play a significant role in the FIE, and at least some of the evidence supporting the claim that it does play a role may well be susceptible to alternative explanations. The experiments that follow seek to determine whether or not configural facial information plays a vital role in the FIE, testing the proposition that without it, there would be no inversion effect for faces.

EXPERIMENTS

In Experiment 1a, we aimed to demonstrate the typical strong inversion effect for normal face stimuli, and for comparison purposes ran a condition using scrambled faces as stimuli, in which we kept the features in their normal orientation, but quasi-randomly distributed them across the face. These latter stimuli suffer from strongly disrupted configural information (even when upright), which should entirely eliminate any effect of inversion on recognition for these stimuli if the FIE depends on this type of information. They also have the useful characteristic of being well matched for complexity with the normal faces. Thus, if we were able to entirely eliminate the inversion effect by using scrambled faces this would be evidence consistent with Diamond and Carey's (1986) position. If, instead, the FIE is still present for scrambled faces, then we can say that strong disruption of configural information is not enough to eliminate the FIE, casting doubt on its supposedly pre-eminent role in driving this effect.

EXPERIMENT 1a

Method

Materials

The study used 128 images of faces that were standardised to a grey scale colour on a black background using Adobe Photoshop. Only male faces were used. This was to enable the hair to be cropped on each image without cropping the ears (i.e. males tend to have shorter hair with ears visible whereas females often have longer hair covering the ears making this feature rather variable). In addition, all the faces had a neutral facial expression. The faces were manipulated using Gimp 2.6.Scrambled faces were constructed so as to conform to a prototype, i.e. a particular configuration, but not the normal one that our participants would be familiar with. Six facial features were used for creating the scrambled exemplars i.e. the mouth, nose, two ears and the two eyes (including eyebrows). Scrambling was carried out by selecting one such feature of the face at random, then moving it to the forehead (chosen because this is the widest space inside the face and so can accommodate any feature). Following this, a second feature was selected and moved to the space left empty by the first feature, and so on until all the 6 facial features had been moved. All the exemplars we constructed and presented to a given participant shared this arrangement of the features, but of course varied in the features themselves as they were taken from different original faces.

Figure 1 here please

Participants

The participants were 24 (16 female and 8 male) psychology undergraduates at the University of Exeter. The study was counterbalanced by splitting the participants into 8 groups. Each participant group was shown the same 128 faces, but each group saw each face in a different condition.

Procedure

The study consisted of a 'study phase' and an 'old/new recognition phase'. After the instructions, the procedure had participants look at 64 different faces (presented one at a time in random order) during the study phase. After further instructions, participants were then asked to look at 128 facial stimuli (including the 64 already seen previously) again presented in a random order. During this old/new recognition task participants indicated whether or not they had seen the face during the study phase. In the study phase each participant was shown 4 types of face with 16 photos for each face type (giving a total of 64 faces). These faces will be termed the "familiar" faces for that participant. The face types were: Normal Inverted faces; Normal Upright faces; Scrambled Inverted faces and Scrambled Upright faces. In the test phase another 64 novel faces split into the same four face types were added to this set. Each facial stimulus had a unique identifying number, to make sure that individual faces never appeared in more than one condition at a time during the experiment. To simplify their use in the experiment, the facial stimuli available were divided into sets of 16, giving 8 sets of stimuli, and each participant group was shown a different combination of the 64 facial stimuli split over the 8 sets. Each participant saw the facial stimuli corresponding to their participant group in a different order. The first event that participants saw after the instructions consisted of a warning cue (a fixation cross in the centre of the screen) presented for 1 second. This was followed by a face, presented for 3 seconds, then the fixation cross was repeated and another face presented until all 64 facial stimuli had been seen. Once all 64 faces were shown, the programme moved to the next set of instructions, which explained to participants the nature of the old/new recognition task. Participants were told that they were about to see more faces presented one at a time in random order. They were asked to press the '.' key if they recognised the face or to press 'x' if they did not. Each participant within each participant group was then shown (in a random order) the 64 faces they had already seen intermixed with a further 64 unseen faces. These unseen faces were those from the sets of facial stimuli not used during the study phase.

During the old/new recognition task, after the warning cue (1 second), facial stimuli were shown for 4 seconds and participants had to respond during this period. If participants pressed the wrong key (i.e. a key other than 'x' or '.') the feedback 'Wrong key' was shown for 2 seconds prior to the next face appearing on the screen. If participants were too slow in responding (i.e. took longer than 4 seconds), the message 'Too slow' appeared on the screen. Otherwise no feedback was given. Since in the old/new recognition task there were 128 faces to consider, three participant breaks were incorporated. These allowed participants to rest their eyes after they had viewed 32 facial stimuli. At the end of the experiment participants were shown a further message thanking them for participating.

Results

Although recorded, analysis of the response latencies is not reported here as it does not add to the analysis of the accuracy scores (which were our primary measure) , but we can confirm that our results were not affected by issues of speed / accuracy trade-off. The data from all 24 participants were used in a signal detection analysis, where a *d'* of 0 indicates chance level performance. ANOVA revealed a significant effect of Face Type, $F(1,23)=15.16$, $MSE=0.339$, $p<.001$ two-tail, a significant effect of Orientation, $F(1,23)=18.71$, $MSE=.450$, $p<.001$ two-tail, and a significant interaction between Face Type and Orientation $F(1,23)=8.512$, $MSE=0.045$, $p<.01$ two-tail. The d' means for this analysis are shown in Figure 2, which shows that the main effect of Face Type is due to performance on Normal faces being superior to that on Scrambled ones, the main effect of Orientation is due to performance on Upright faces being superior to that on Inverted faces, and the interaction is due to there being a larger inversion effect for the Normal faces than for the Scrambled ones. Simple effect analyses indicated that there was a strong inversion effect for normal faces, $F(1,23) =15.914$, $MSE=0.035$, $p<.001$ two-tail, and a reduced inversion effect for Scrambled faces, $F(1,23) =3.258$, $MSE=0.024$, $p=.08$ two-tail. In addition, we ran comparisons comparing performance on upright faces, and inverted faces. Performance in recognizing Normal Upright faces was significantly better than recognition for Scrambled Upright faces, $F(1,23) =27.839$, $MSE=0.021$ $p<.001$ two-tail, but performance on inverted faces was not reliably affected by scrambling. Finally we analysed the performance relative to chance for each of the conditions in Experiment 1a. Performance for Normal faces was significantly above chance for both conditions; Upright, $F(1,23) = 79.739$, $MSE=0.023$ $p<.001$ two-tail, and Inverted $F(1,23) = 10.742$, $MSE=0.021$ $p=.003$ two-tail. For Scrambled faces performance was also significantly above chance in both conditions; $F(1,23) = 26.212$, $MSE=0.014$ $p<.001$ two-tail for Upright stimuli and $F (1,23) = 7.233$, $MSE=0.014$ $p<.015$ two-tail for Inverted ones.

Figure 2 here please

Discussion

Consistent with the existing literature on face recognition, the results of this first experiment have shown a clear effect of inversion for normal faces. In addition, there was a smaller, near significant inversion effect for Scrambled faces, and the inversion effect for normal faces was significantly greater than that for Scrambled faces. These results are certainly consistent with McKone and Yovel's (2009) analysis, however, according to Diamond and Carey's (1986) analysis the FIE for the Scrambled faces should have been entirely eliminated by the complete disruption of their configural information. Our results seem to suggest that disrupting all the configural information is not enough to eliminate the FIE, but, frustratingly, fall short of complete clarity on this point. At this juncture we considered how best to improve on Experiment 1a to obtain an unequivocal answer to the question of whether the FIE is, in part, driven by local feature information.

There are only a few studies in the literature that have investigated the effect of scrambling on the inversion effect. As an example, Collishaw and Hole (2000) used sets of scrambled faces in their study in which the eyes were always moved as a configuration either to the upper half of the face or to the lower half. Thus, the first and second-order relational information between the eyes was always preserved. The same applied to the nose and the ears, which were always moved together, thus, for these three features the configural information was unaltered. Finally, a significant issue with their manipulation was that, on average, all the scrambled faces were not based on a single new configuration, but many different ones. Thus, they do not share a configuration in the same way that the normal faces do. Our set of scrambled faces control for this, and our manipulation also ensures that all the configural information is disrupted. But we realised that there was still at least one potential issue with our stimuli. If we compare normal faces with scrambled, it is very obvious that the scrambled faces have been smoothed as part of the scrambling process, and so have lost some of the shadows and local information that may be salient in aiding recognition. The normal faces have not been smoothed at all, and still have all their local information. If we are to truly compare the inversion effect for Normal and Scrambled faces this needs to be controlled for. Another possible issue is that we have constructed our set of scrambled stimuli around one new configuration. It may be that participants may have found it quite easy (or alternatively quite hard) to recognise this particular category of scrambled faces in their upright orientation. What may be required are more categories of scrambled faces to counterbalance across our participants groups in order to reduce any systematic error in our estimate of the inversion effect for our scrambled faces. Experiment 1b aimed to fix these issues.

EXPERIMENT 1b

Method

Materials

This time we constructed four categories of scrambled faces each represented by a particular configuration as shown in Figure 3. The scrambling was done following the same procedure used in Experiment 1a, and within the same category all the scrambled faces shared the arrangement of the features in common with the prototype. Thus, for example, each face drawn from category A had the nose, mouth etc. in the locations shown. The subjects in our experiment were presented with stimuli drawn from only one category of scrambled faces.

The four categories were counterbalanced across our eight participant groups. Finally, our normal faces were also smoothed to the same extent as the sets of scrambled faces in order to control for any effect of this manipulation.

Figure 3 here please

Participants

24 (18 female and 6 male) psychology undergraduates at the University of Exeter took part in the experiment. The study was counterbalanced, as in Experiment 1a, by splitting the participants into 8 groups.

Procedure

These were exactly the same as in Experiment 1a.

Results

The data from all 24 participants were used in a signal detection d' analysis. ANOVA revealed a main effect of Face Type, $F(1,23)=12.79$, $MSE=.272$, $p<.002$ two-tail, and a main effect of orientation, $F(1,23)=8.15$, $MSE=.424$, $p<.01$ two-tail, but this time there was no significant interaction between Face Type and Orientation $F(1,23)<1$, $p=ns$. Figure 4 gives the mean d' for each face type. Despite the lack of a significant interaction simple effects were run to allow comparison with Experiment 1a, and these showed that there was an inversion effect both for Normal faces, $F(1,23) =5.317$, $MSE=0.035$, $p<.03$ two-tail, and for Scrambled faces, $F(1,23) =5.614$, $MSE=0.017$, $p<.03$ two-tail. As in Experiment 1a, performance in recognizing Normal Upright faces was significantly better than recognition for Scrambled

Upright faces, $F(1,23) = 9.38$, $MSE=0.020$, $p<.01$ two-tail, and this time there was also a significant difference in the recognition of Normal Inverted faces and Scrambled Inverted faces, $F(1,23) = 5.051$, $p<.05$, $MSE=0.019$ two-tail, with Scrambled Inverted faces recognised worse, but note that this is a post-hoc comparison that would not survive a Bonferroni correction. Performance for Normal faces was significantly above chance for both Upright, $F(1,23) = 32.632$, $MSE=0.021$ $p<.001$ two-tail, and Inverted faces, $F(1,23) = 9.556$, $MSE=0.016$ $p=.005$ two-tail. For the Scrambled faces, performance was significantly above chance for the Upright stimuli $F(1,23) = 20.174$, $MSE=0.007$ $p<.001$ two-tail, but not significantly above chance for the Inverted ones, $F(1,23) = .458$, $MSE=0.011$ p=ns. two-tail. We note that this last result could raise concerns about a floor effect for our Scrambled Inverted condition, but as this would simply make it difficult to assay any difference between this condition and others near floor, and in fact all the other conditions were significantly superior to this one, there is little cause for concern.

Figure 4 here please

Discussion

In contrast with Diamond and Carey's (1986) theory, our results from Experiments 1a and 1b can now be said to establish that disrupting all the configural (i.e. first and second order relational information) information in a face does not eliminate the FIE. In the case of Experiment 1b, we actually obtained as strong a FIE for scrambled faces as for (smoothed) normal faces, confirming the trend for an inversion effect in the scrambled faces previously shown in Experiment 1a. We believe that there are good reasons for why this happened. Firstly, the smoothing of the normal faces on the one hand helped us in matching the two face types, and in doing so we may well have lost some recognition performance for the upright normal faces because they have less information in them than before smoothing. This goes some way to explaining why there is no Face Type by Orientation interaction in Experiment 1b, because the inversion effect for normal faces was itself reduced. The upshot is that our manipulation can now tell us the size of the FIE for normal faces relative to that obtained when all configural information is disrupted, and the surprising result we have is that the FIE for scrambled faces is as strong (the effect size for scrambled faces is slightly smaller, but overall performance is down as well so that relatively speaking a case could be made for it being larger) as the one for normal faces. A final point is to note that both normal inverted and upright faces are recognised significantly better than their scrambled counterparts. Thus, the disruption of configural information has definitely been effective in reducing overall performance, but this has not been at the expense of the FIE. We will come back to this point in the general discussion. Our main finding makes it clear that configural information is not the only source contributing to the FIE. Instead, following Rakover and Teucher (1997), we can now agree that featural information has an important role to play in generating the FIE. When we consider upright scrambled faces, clearly they have all the configural information (in the sense implied by Diamond and Carey's 1986 analysis) disrupted by scrambling, but the orientation of each facial feature is still upright (and hence in its familiar orientation). This is not true of inverted scrambled faces – can we show that this is the basis of the inversion effect we have found in Experiments 1a and 1b? In the next experiment we investigated this proposition by asking whether the disruption of the *single feature orientation information* could entirely eliminate the FIE.

The potential finding here is that the inversion effect is a direct product of the individual features of the face, and that their configuration is simply irrelevant. All that matters on this account is how many upright features there are. . Thus, if the individual features are crucial in determining any inversion effect, then if there are an equal number of features in both upright and inverted orientations in an "upright" stimulus then no inversion effect can be expected, i.e. performance at either stimulus orientation should be equivalent.

Experiment 2

Method

Materials

In this experiment we once again used the four categories of scrambled faces employed in Experiment 1b, but this time we turned half of the features interior to each face upside down. Specifically, for each of the four category prototypes we inverted one of the eyes, one of the ears and one of the nose or the mouth. As was the case in the previous experiment, each scrambled face drawn from a given category had the location and orientation of its features specified by its category prototype. Because half of the features were now presented upside down and half in their usual upright orientation we named these new stimuli 50% Feature-Inverted and Scrambled faces, but acknowledge that they possess a close relationship with Thatcherised faces. Recall that, in the original Thatcher illusion study by Thompson (1980), three features were flipped upside down. However Thompson (1980) always inverted the two eyes and the mouth to produce his Thatcherised faces. However, for our purposes there are two issues with that manipulation: (i) Inversion of the two eyes together would still maintain the normal configural relations between them and recognition performance might be affected by this; (ii) if only featural information is involved in the FIE then several studies have shown that the eyes are perhaps the most salient features in face processing (Haig, 1986 ; Hosie, Ellis, & Haig, 1988). When the eyes are concealed, face recognition is poorer than when they are visible (Haig, 1986). Also the eyes are described more frequently than other facial features when participants describe faces (Ellis et., 1975) Thus, it may be that inverting both eyes when the configural information is entirely disrupted in our scrambled condition could have more of an effect than turning just one eye upside down, even if the number of features that are inverted and upright in the stimulus are equal. Our chosen manipulation is somewhat different, and we believe it controls for these potential issues, in that we use scrambled faces (which addresses issue (i) because we scramble the features independently), and we only inverted one of the eyes, effectively controlling for issue (ii). The result of our manipulation is a set of stimuli that quite obviously differ from those used in Experiment 1b (see Fig.6). The same set of normal faces used in Experiment 1b was used in this experiment as well. Thus, in this experiment we had four within-subject conditions, Normal faces in an Upright or Inverted orientation, and 50% Feature-Inverted and Scrambled Faces in either an Upright or an Inverted orientation.

Figure 5 here please

Participants

48 (35 female and 13 male) students at the University of Exeter (mostly psychology students) took part in the experiment. We used a larger N because pilot testing indicated that participants found the 50% Feature-Inverted and Scrambled faces particularly difficult to recognise. The study was counterbalanced, as in Experiment 1a, 1b, and 2 by splitting the participants into 8 groups.

Procedure

This was exactly the same as that used in Experiment 1b, with the proviso that 50% Feature-Inverted and Scrambled faces replaced the scrambled faces used in Experiment 1b.

Results

As in the other experiments reported in this paper, analysis of latencies does not add to the analysis of the accuracy scores except for confirming that our results were not affected by any speed / accuracy trade off. The data from all 48 participants were used in the signal detection d' analysis. ANOVA revealed there was a significant main effect of Face Type, $F(1,47)=31.02$, $MSE=0.390$, $p<.0001$ two-tail, a significant main effect of orientation, $F(1,47)=26.24$, $MSE=0.150$, $p<.0001$ two-tail, and a significant interaction between face type and orientation, $F(1,47)=5.963$, $MSE=0.020$, $p<.02$ two-tail (see Fig.6). Thus, simple effect analyses were conducted showing that there was a strong inversion effect for normal faces, $F(1,47) =28.381$, $MSE=0.007$, $p<.001$ two-tail, but no reliable inversion effect was obtained for 50% Feature-Inverted and Scrambled faces, $F(1,47) =1.353$, $MSE=0.009$, p=ns. Performance in recognizing Normal Upright faces was significantly better than recognition for 50% Feature-Inverted and Scrambled Upright faces, $F(1,47) =29.965$, $MSE=0.015$, $p<.001$ two-tail, and there was also a significant difference in the recognition of Normal Inverted faces (which were worse) compared to 50% Feature-Inverted and Scrambled Inverted faces, $F(1,47) =9.832$, $MSE=0.010$, $p<.01$ two-tail. Performance for Normal Upright and Normal Inverted faces were both significantly above chance, $F(1,23) = 122.034$, $MSE=0.005$ $p<.001$ two-tail, and $F(1,23) = 38.978$, $p<.007$ two-tail. Finally, to check that participants were not suffering from a floor effect, we demonstrated that both upright and inverted 50% Feature-Inverted and Scrambled faces were recognized significantly better than chance, Upright, $F(1,47)=10.972$, $MSE=0.005$, p<002 two-tail, Inverted, $F(1,47)=4.383$, $MSE=0.004$, $p<.05$ two-tail (see Fig.6).

Figure 6 here please

Discussion

The results from Experiment 2 demonstrate the importance that single feature orientation information has in generating the FIE. We are now able to entirely eliminate the inversion effect by disrupting single feature orientation information within the context of a scrambled face, whilst maintaining performance for our 50% Feature-Inverted and Scrambled stimuli at a level significantly above chance. In some sense we felt that we had to obtain this result, as with six interior features, of which three are now inverted, whether the face is upright or inverted, three of the individual features are in their upright orientation. But this is to disregard the effect that the outline or envelope of the face could have had, however, as if this were used to determine whether a face was perceived as upright or inverted then our result would not necessarily follow. In other words, if what we have termed an upright 50% Feature-Inverted and Scrambled face were actually perceived as upright, and hence subject to specialized processing on the basis that it was a face, we might have expected an inversion effect to emerge. Because it did not, we can conclude that the individual interior features in a scrambled face (including the ears in this designation for the moment) are primary in determining any inversion effect.

Our result clearly supports the claim made by Rakover and Teucher (1997) that single features contribute to the inversion effect. In their studies they looked at single features presented in isolation in either an upright orientation or inverted. They found that recognition performance was superior for the upright stimuli. Our studies complement and enhance

Rakover and Teucher's findings because we presented our individual features all together in a novel configuration. This has the advantage of addressing an issue with Rakover and Teucher's (1997) procedure, in that presenting a single feature (NB. They considered both eyes to be a single feature) may allow participants to imagine it as belonging to a normal face, and it may be the memory for this imagined face that leads to the inversion effect, as we would expect this strategy to be more effective for upright features. Our novel configurations do not lend themselves to this strategy, but still give rise to an inversion effect.

The logical next step in order to replicate and confirm the importance of single feature orientation in the FIE was for us to compare the inversion effect obtained with scrambled faces to the lack of one for 50% Feature-Inverted and Scrambled faces. Our prediction was that if the FIE is mainly based on single feature orientation, then, within a single experiment, we should be able to show a significantly greater FIE for scrambled faces compared to 50% Feature-Inverted and Scrambled stimuli.

Experiment 3

Method

Materials

In this experiment we used the four categories of scrambled faces already used in Experiment 1b and the four categories of 50% Feature-Inverted and Scrambled faces used in Experiment 2. Hence, Scrambled and 50% Feature-Inverted and Scrambled exemplars drawn from the same category have the same arrangement of features in common. Stimuli were counterbalanced in such a way that each participant was always presented with one configuration of scrambled faces and a different configuration of 50% Feature-Inverted and Scrambled faces.

Figure 7 here please

Participants

72 (53 female and 19 male) students at the University of Exeter (mostly psychology students) took part in the experiment. We used a large number of participants because the task was likely to be considerably more difficult than in the previous experiments given that all the faces were now scrambled.

Procedure

These were the same as before.

Results

The data from all 72 participants were used in the signal detection d' analysis. ANOVA revealed that there were no significant main effects ($Fs<1$), but that there was a significant interaction between Face Type and Orientation, $F(1,71)=9.396$, $MSE=0.015$, $p<.01$ two-tail (see Fig.8). Thus, simple effects analyses were carried out showing that there was a strong inversion effect for Scrambled faces, $F(1,71)=11.217$, $MSE=0.007$, $p<.002$ two-tail, but no inversion effect for 50% Feature-Inverted and Scrambled faces, $F(1,71)=1.053$, $MSE=0.009$, p=ns. Additional comparisons revealed that performance in recognizing Scrambled Upright faces was significantly better than recognition for 50% Feature-Inverted and Scrambled Upright faces, $F(1,71)=5.714$, $MSE=0.006$, $p<.02$ two-tail, and that 50% Feature-Inverted and Scrambled Inverted exemplars were recognized significantly better than Scrambled inverted exemplars, $F(1,71)=4.362$, $MSE=0.007$, $p<.05$ two-tail. Performance for Scrambled Upright faces was significantly above chance, $F(1,71) = 43.097$, $MSE=0.003$ $p<.001$ two-tail, and performance for Scrambled Inverted faces approached significance $F(1,71) = 3.744$, $MSE=0.004$ $p=.055$ two-tail. Finally, both upright and inverted 50% Feature-Inverted and Scrambled faces were recognized significantly better than chance, Upright, $F(1,71)= 10.129$, $MSE=0.004$, $p<.003$ two-tail, Inverted, $F(1,71)=19.164$, $MSE=0.004$, $p<.001$ two-tail (see Fig.8).

Figure 8 here please

Discussion

In Experiment 3 we obtained a significant interaction driven by a strong inversion effect for our scrambled faces and no inversion effect for the 50% Feature-Inverted and Scrambled stimuli. These results confirmed that we are able to obtain a strong inversion effect for a set of faces that have all their configural information disrupted, and that the FIE can be entirely eliminated by disrupting single feature orientation information. Our results also showed a clear advantage for scrambled faces in an upright orientation compared to upright 50% Feature-Inverted and Scrambled faces, and a disadvantage for inverted scrambled faces compared to inverted 50% Feature-Inverted and Scrambled ones. The advantage can be easily explained by assuming that expertise for each of these features in their usual orientation brought about by our extensive experience with face sis beneficial. In some sense, the disadvantage then follows from this analysis as well. If having a feature in its upright orientation is beneficial, then we can assume that when inverted some or all of this benefit is lost. It may even be that inverted features drawn from stimulus sets we are familiar with incur a penalty that makes them harder to recognise than unfamiliar control stimuli, as McLaren's (1997) work with checkerboards might suggest, though for the moment this remains more a logical possibility than something that our present data allow us to establish. In any case, we start from the position that inverted features are less beneficial than upright ones. Upright scrambled faces have 6 upright features, upright and inverted 50% Feature-Inverted and Scrambled faces have three upright features, and inverted scrambled faces have no upright features. Thus, the pattern of performance in our data can be completely explained by the proportion of upright features in the set of faces in question. The reason that inverted scrambled faces are so difficult to recognise according to this analysis is that all their features are upside down, which hampers them relative to inverted 50% Feature-Inverted and Scrambled faces (3 features upright) and leads to a strong inversion effect compared to upright scrambled faces (6 upright features). Thus, the claim would be that the inversion effect in scrambled faces is entirely driven by the proportion of upright features in the stimulus, irrespective of location or configuration, a position entirely in line with that adopted by Rakover and Teucher (1997).

General Discussion

We have arrived at a position that is rather different to the position with regard to the face inversion effect for pictures of faces first reported by Yin (1969). Many would ascribe the majority of this effect (if not its entirety) to the configural information in faces, specifically to the particular spatial relationships between the features that make up a face, and to our expertise in making use of the small variations in these relationships that individuate faces (e.g. Diamond and Carey, 1986). Instead, we have found that, once the stimuli are appropriately controlled for the amount of detail present in them, performance can be completely accounted for by the proportion of individual features that are upright in a stimulus. Experiment 1a hinted that this might be so because the inversion effect did not entirely disappear after scrambling the faces, but it did not control for the amount of facial information present in normal and scrambled faces, making a comparison of the inversion effect in each difficult to interpret. In Experiment 1b, using smoothed normal faces and scrambled faces, the inversion effect was of a similar magnitude for both classes of stimuli, despite that fact that the normal faces still possessed configural information that had been severely disrupted in the scrambled faces. Experiment 2 demonstrated that the inversion effect for scrambled faces did indeed depend on the orientation of the individual features within the face, and in Experiment 3 we were able to replicate the substantial inversion effect for scrambled faces, and confirm that it disappeared if three of the six interior features were themselves inverted to create a new type of scrambled stimulus.

It might be argued that our scrambled faces are themselves defined in terms of a prototype, and so in some sense possess configural information. But it is not structure that our participant's would be familiar with when entering the experiment, and so any effect of expertise would be confined to the familiarity participants have for each one of the facial features seen in their usual upright orientation. Learning of the novel configuration used for our scrambled faces would be expected to happen as rapidly for the inverted configurations as for the upright ones, and so could not be expected to contribute to the inversion effect. Our conclusion is that the inversion effect observed with scrambled faces is driven by single feature information. If this information is disrupted, then so is the inversion effect.

Another advantage of our manipulations in Experiment 1a and 1b is that they are drastic. By scrambling all the features within a face we made sure that all the configural information (in the sense of what Diamond and Carey term first and second order relational information) normally seen in a normal face was severely disrupted. It is important to underline this, because if we look at the literature, many studies have used sets of distorted faces, where for example, the eyes were sometimes shifted apart and the mouth moved upwards, and sometimes the eyes were closer together and the mouth shifted downwards (e.g., Leder & Bruce, 2000; Rhodes et. al, 1993,). However, the problem with these manipulations is that if you average all the distorted faces you will get something approaching a normal face with the usual configural information. Thus, the manipulation is, in some sense, simply one of adding noise, with the disruption of configural information taking place on a relatively minor scale. Another advantage of our scrambling manipulation was that by moving the randomly selected feature to the space left empty by the previously moved feature we ensured that, for example, the eyes would never align as in normal faces. We believe this to be a better manipulation than that used by some other studies in the past, where the scrambling process was based on splitting the face into three internal regions, such as the mouth, nose, and eyes, and the shuffling was being done by moving regions as a whole, giving a final result that always left the configural information between the two eyes untouched (e.g., Donnelly et al., 1994). For this reason, we believe that our scrambling process was particularly effective in disrupting participants ability to make use of the configural information in a face, making it all the more remarkable that the inversion effect not only survived, but was comparable in size to that in normal faces once a comparable level of smoothing was applied. Our experiments, then, are a direct experimental test of the hypothesis advanced by McKone and Yovel (2009) that there is a substantial component of the inversion effect due to local feature orientation, and our results strongly support their conclusion, based on a meta-analysis of 22 papers, that this is indeed the case.

If, in our hands, scrambling does not greatly affect the inversion effect, can we show that it has any effect at all? If we look at Experiment 1b and compare the normal inverted faces with the scrambled inverted ones, both sets of faces have all their interior features upside down. However, the scrambled faces also have all their configural information disrupted, and performance on them is significantly worse. There is a similar effect for upright normal and scrambled faces. Equally, in the second experiment, we can see that inverted 50% Feature-Inverted and Scrambled faces are still recognized worse than normal inverted faces, and that a similar effect obtains for upright faces. A possible explanation of the advantage for normal faces is that they do still have their configural information. This suggests that configural information is more important for overall performance rather than being specific to the FIE. There is a main effect of Face type (Normal vs. either Scrambled or 50% Feature-Inverted and Scrambled) in Experiment 1a, $p<.001$ two-tails; Experiment 1b,$p<.002$ two-tails; and Experiment 2, $p<.001$ two-tails. This analysis supports the claim that our disruption of configural information has been effective in reducing overall recognition performance. Why should this be so?

One of the remarkable things about the claim that the inversion effect in faces is due to disruption of our ability to process configural information, is that it is exactly this type of information that might be expected to survive inversion. Inversion does not alter the spatial relationships between features at all, nor does it alter any variation about some configurational average (2nd order information) unless we assume that its computation is tied to some template that has a fixed orientation. So, it may well be that the advantage we see for normal faces relative to scrambled ones in our experiment genuinely reflects the benefit of either expertise for, or better processing of, configural information in a face, a benefit that manifests equally for both upright and inverted faces because it is not tied to any particular orientation, but depends only on the spatial relationships within a face. This leaves open the question of whether there are any effects of configural information that are orientation specific to any extent, all we can say is that the experiments reported in this paper do not provide us with any evidence for this type of effect.

Which brings us to the question of whether there is any role for configural information in generating the inversion effect for faces? There is a great deal of evidence reviewed in our introduction consistent with the proposition that it does, but the logic of our experimental results suggests the answer is "no". We confess to being reluctant to draw such a firm conclusion on the basis of the present studies. Our results go somewhat beyond what McKone and Yovel (2009) might expect, in that they were willing to allow a component of face inversion due to configural information. Given that the experiments reported here are much better suited to establishing that individual feature orientation plays a role in generating the inversion effect than proving that configural information does not, we feel that an analysis of the role of configural information in the FIE will have to wait for further research. But on the basis of the results we have obtained, the position taken by Rakover and Teucher (1997), that attributes the inversion effect to the proportion of individual features in their upright orientation, is one that receives considerable support. Our experiments are the first to manipulate feature orientation in the context of a scrambled face and compare performance to properly controlled standard face images, and they are entirely congruent with Rakover and Teucher's results with isolated features and their analysis of the inversion effect.

In many ways our results are also consistent with those of Gold, Mundy and Tjan (2012), who found that recognition performance for an upright or inverted face could be satisfactorily predicted from performance on isolated features, but that performance to those isolated features in an inverted face was poorer. Thus, the configuration "helped" feature processing in some way, and this assistance was lost on inversion. Our use of scrambled faces eliminates this effect of configuration, and enables us to see the "pure" effect of feature orientation in upright and inverted scrambled faces. However, we appear to disagree with their results in one minor respect, in that we found that the benefit accruing from the standard configuration (i.e. a normal face) applied to both upright and inverted faces, not just to the upright face.

Our results are also consistent with studies that suggest that the inversion effect has a substantial component driven by individual features (e.g. Yovel and Kanwisher, 2004; Riesenhuber, Jarudi, Gilad and Sinha, 2004), but these studies have been criticised by Rossion (2008) who argued that they underestimated the contribution from holistic processing. Yovel (2009) and Riesenhuber and Wolff (2009) have responded to these criticisms, and Rossion (2009) has replied in turn. All we feel able to contribute to this debate is to note that 1) there is undoubtedly a contribution from individual features to the FIE and 2) this debate clearly indicates that it would be unwise to rule out a contribution from configural information as well. The reason we feel able to commit to 1) is that our demonstration of an FIE in scrambled faces is not subject to the criticisms made by Rossion of other demonstrations of this type, if we assume that holistic processing is entirely disrupted by this manipulation, and we note that the rank ordering of performance by number of features in an "upright" orientation is also consistent with our claim. Even if we allow a robust version of Hole et al's (1999) holistic processing construct, which would imply that our scrambled faces could be identified as faces and so generate an inversion effect, we would then have to explain why this holistic processing ceased to apply to the 50% Feature-Inverted and Scrambled faces. If the explanation was that a certain number or proportion of facial features had to be upright for holistic processing to apply and only the upright Scrambled faces met this criterion, then we are left in some difficulty in explaining why performance on the 50% Feature-Inverted and Scrambled faces is superior to that on the Inverted Scrambled faces – surely they should be the same? Conclusion 2) clearly indicates that further research on the role of configural information in the FIE is needed.

We finish by briefly considering the impact of our research on the case made for expertise with the face category as the basis for the inversion effect. Some of the strongest evidence for this type of explanation of the FIE comes from studies such as those of McLaren (1997) with checkerboards and Tanaka and Gauthier (1997) with Greebles that show that familiarisation with a new prototype-defined category can produce an inversion effect with stimuli drawn from that category. This inversion effect is then assumed to play some role in the FIE. The standard explanation for the inversion effect with these stimuli is that participants learn the configuration of features that defines the category (the prototype), and then become expert in detecting and using small deviations from this configuration (e.g. see McLaren's 1997 explanation based on McLaren, Kaye and Mackintosh, 1989). This may or may not be true, but our results suggest that it does not apply to faces, because our scrambling manipulation should completely disrupt any benefit due to familiarity with a configuration. Instead, the prediction that could be made based on the present results is that it is not the overall configuration of features that is the basis of the inversion effect in the studies with Greebles or checkerboards, but instead that the effect is based on familiarity with more local features, a prediction that we intend to test in the near future.

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Figure captions

Figure.1. Examples of stimuli used in Experiment 1a showing the four different conditions. The dimensions of the stimuli were 7.95cm x 6.28cm. The stimuli were presented at a resolution of 1920 x 1080. Participants sat 1m away from the screen on which the images were presented.

Figure.2. The X axis representsthe four different stimulus conditions (in order, from left to right, Normal Inverted, Normal Upright, Scrambled Inverted and Scrambled Upright), and the Y axis gives the meand' for each of the four facial conditions in the old/new recognition phase of Experiment 1a.

Figure.3. This figure shows the four prototype-defined categories of scrambled faces in pairs (upright then inverted), plus an example of the set of normal faces at the bottom illustrating the effect of smoothing compared to the normal faces used in Experiment 1a.

Figure 4. The X axis givesthe four different stimulus conditions (from left to right; Normal Inverted, Normal Upright, Scrambled Inverted and Scrambled Upright), each illustrated by a typical exemplar, and the Y axis shows the meand' for each of the four facial conditions in the old/new recognition phase of Experiment 1b.

Figure .5. Comparison of the stimuli used in Experiment 1b (on the left side) and the stimuli used in Experiment 2 (on the right side). These latter ones were manipulated by inverting half of the interior features.

Figure.6. The X axis represents the four different stimulus conditions (in order, from left to right, Normal Inverted, Normal Upright, 50% Feature-Inverted and Scrambled Inverted and 50% Feature-Inverted and Scrambled Upright), and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 2.

Figure.7. This shows the four configurations of scrambled faces and the four configurations of 50% Feature-Inverted and Scrambled faces used in Experiment 3.

Figure.8. The X axis represents the four different stimulus conditions (in order, from left to right, Scrambled Inverted, Scrambled Upright, 50% Feature-Inverted and Scrambled Inverted and 50% Feature-Inverted and Scrambled Upright), and the Y axis gives the mean d' for each of the four facial conditions in the old/new recognition phase of Experiment 3.

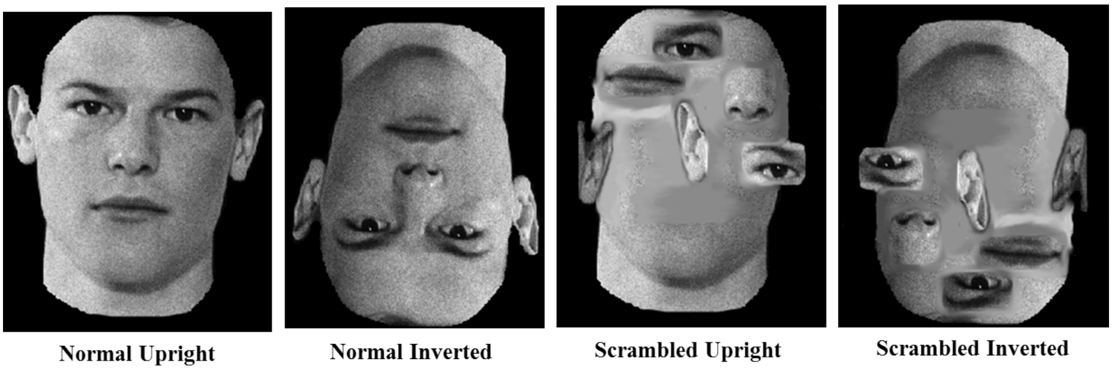

Normal Upright
Normal Inverted
Scrambled Upright
Scrambled Inverted

Figure 1

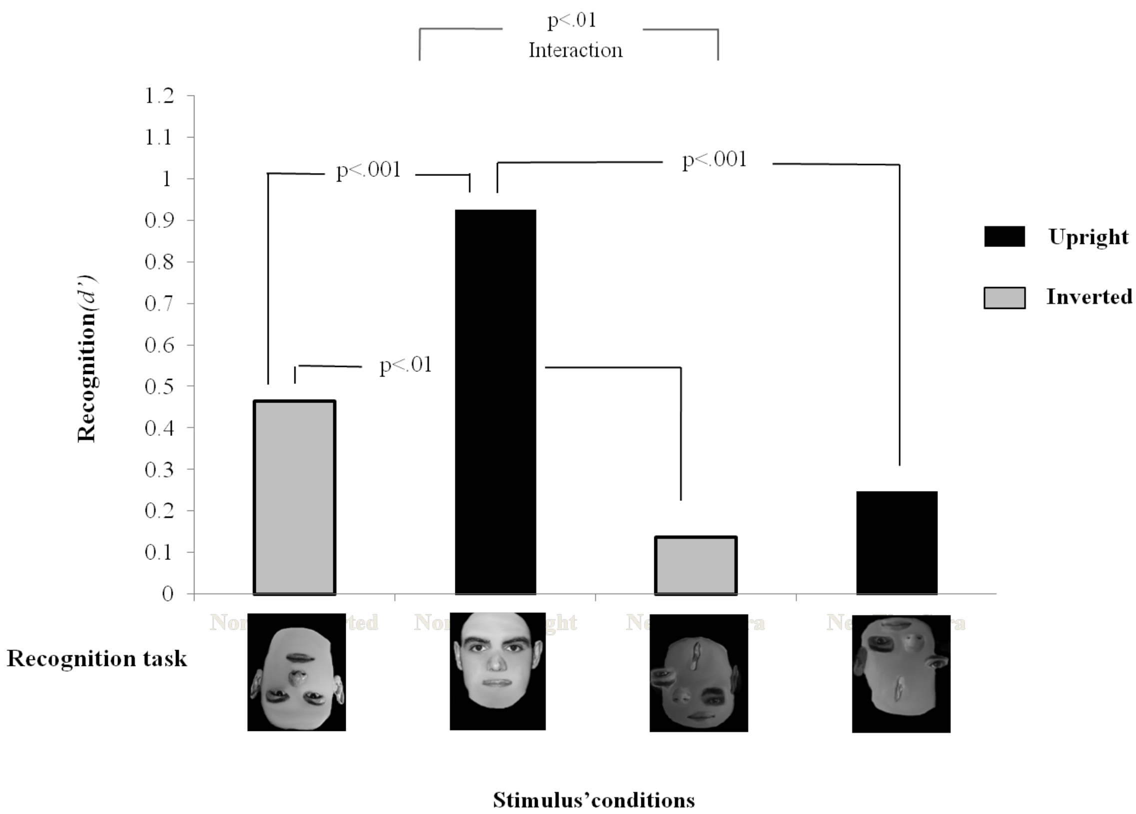

p<.01
Interaction
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Recognition(d')
p<.001
p<.001
p<.01
Upright
Inverted
Recognition task
Stimulus'conditions

Figure.2.

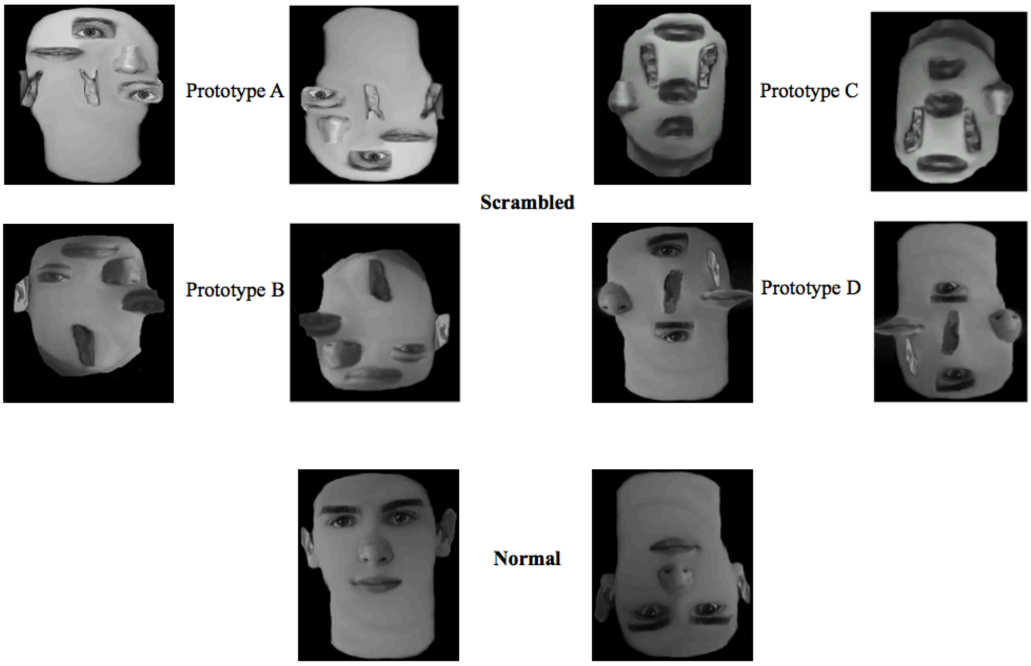
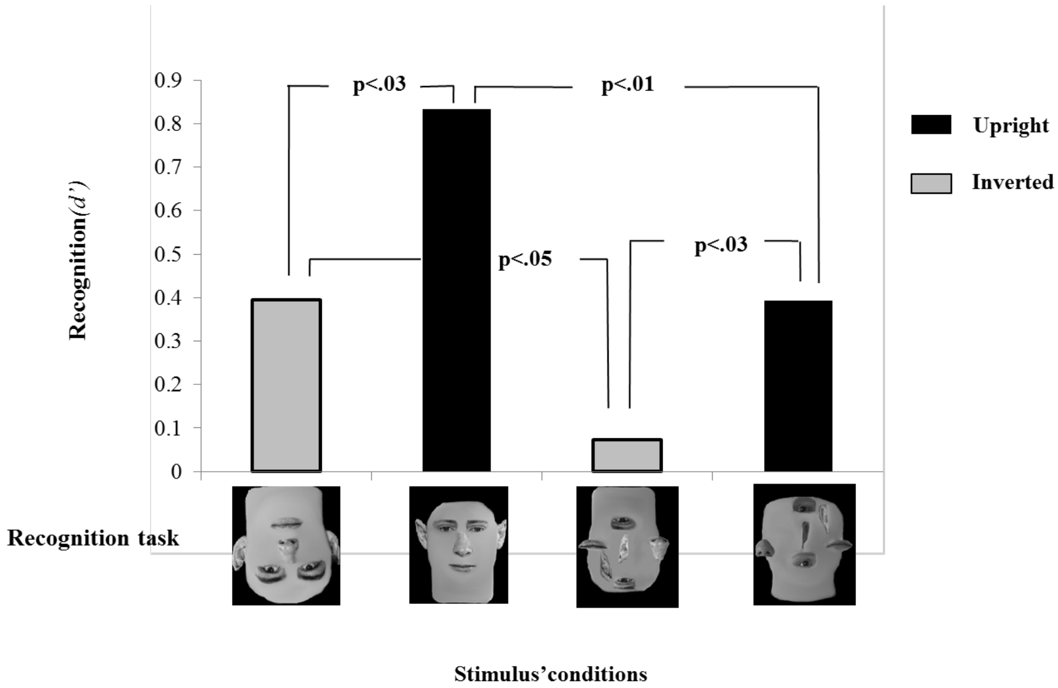

Prototype A
Prototype C
Scrambled
Prototype B
Prototype D
Normal

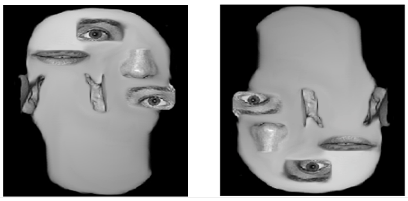
Figure.3.



0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Recognition(d')
p<.03
p<.01
p<.05
p<.03
Upright
Inverted
Recognition task
Stimulus'conditions

Figure.4.

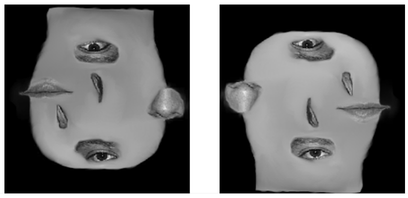
Stimuli used in the scrambled faces experiment 1b.



Upright Inverted

Single feature orientation **unaltered**

50% Feature-Inverted and Scrambled facial stimuli.



Upright Inverted

Single feature orientation **disrupted**

Figure.5.

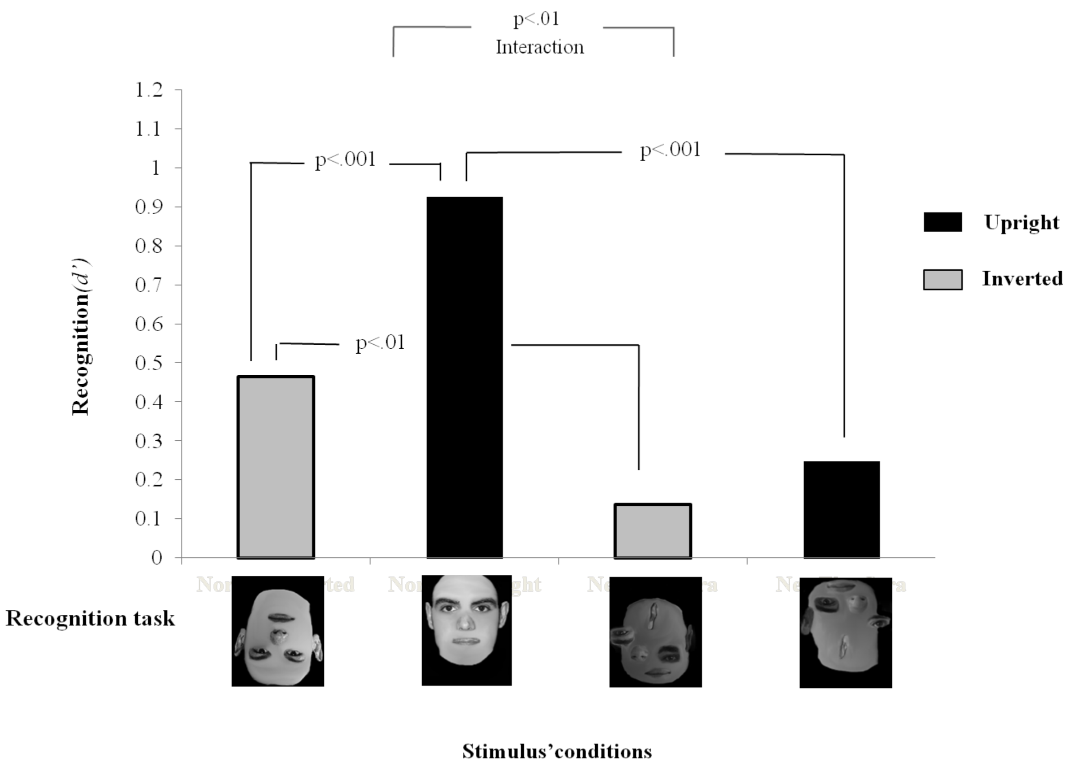

p<.01
Interaction
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Recognition(d')
p<.001
p<.001
p<.01
Upright
Inverted
Recognition task
Stimulus'conditions

Figure.6.

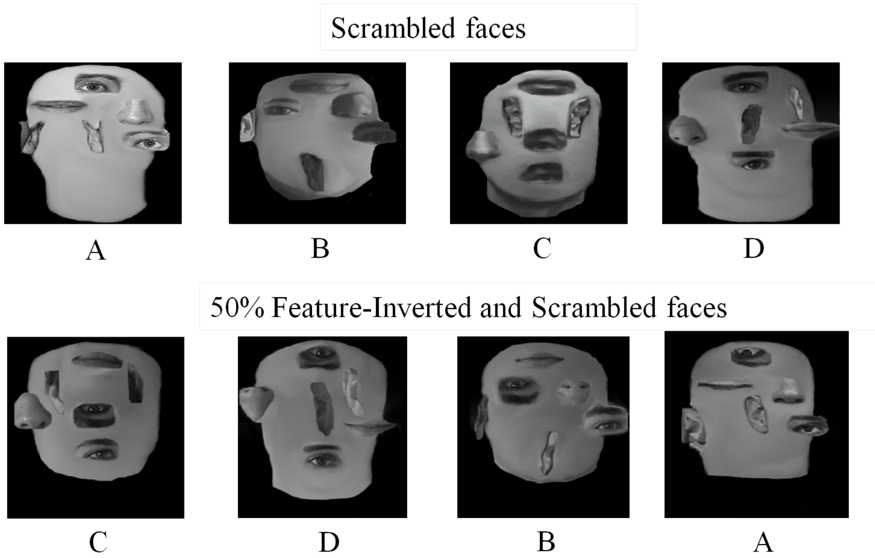

Scrambled faces
A
B
C
D
50% Feature-Inverted and Scrambled faces
C
D
B
A

Figure.7.

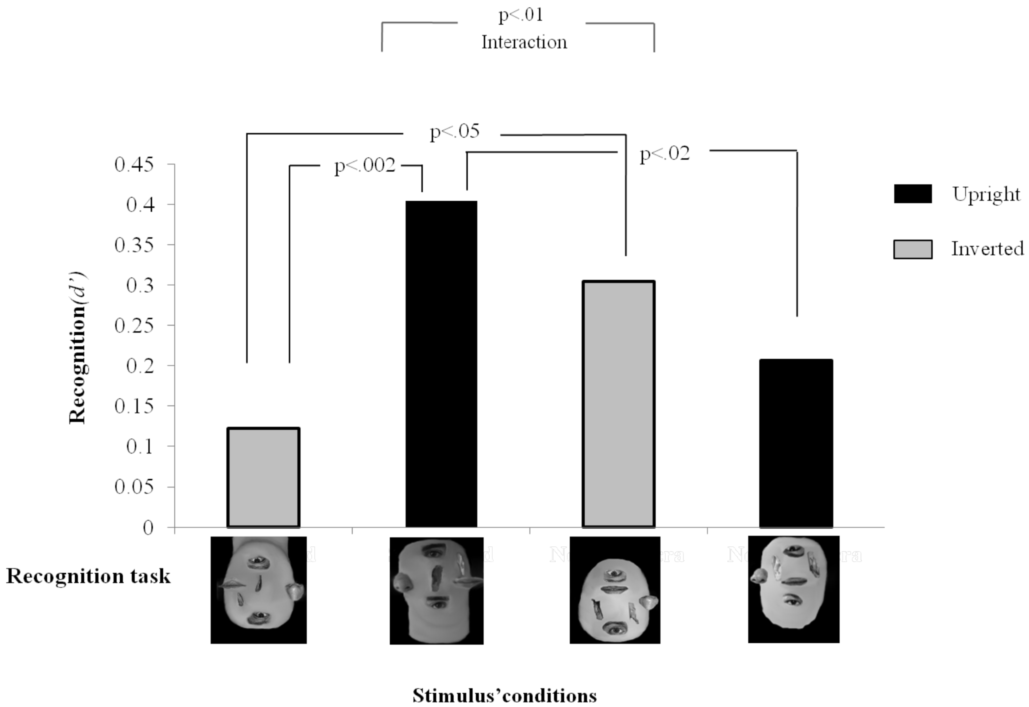

p<.01
Interaction
p<.05
p<.002
p<.02
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Recognition(d')
Upright
Inverted
Recognition task
Stimulus'conditions

Figure.8.