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Manipulating the face contour reduces overall recognition performance for scrambled faces

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Abstract

This study (n=64) investigated the influence of manipulating the face contour on the face inversion effect (better recognition performance for upright vs inverted upside-down faces) and on face recognition in general. The study used upright and inverted scrambled faces which suffer from disruption of the configural information (spatial relationships among the facial features) typically found in normal faces. This is because we aimed to isolate the face contour information from the configural information. A delayed- matching task was adopted to ensure a high level of recognition performance, especially for inverted faces. The results revealed no significant difference between the inversion effect for scrambled faces with the normal contour vs that for scrambled faces with the manipulated (blurred) contour. Critically, we found an effect on overall recognition performance whereby scrambled faces with the blurred contour suffered greatly from the manipulation. Our results suggest that the face contour affects overall face recognition performance.

Keywords: Face Recognition; Face Inversion Effect; Configural information; Holistic information

Introduction

The ability to recognise faces in one crucial in our everyday lives, it shapes our social interactions and is key to successfully forming relationships. Recognising upright faces is a task that most people do over and over every day and as such the difficulty associated with face recognition is often overlooked, but it can be observed more clearly when studying faces which have been inverted. The disparity in recognition performance between upright and inverted faces is referred to as the face inversion effect, a phenomenon which when discovered by Yin (1969) was found to be greater for faces than for other non-face stimuli (houses, planes etc.). Initially this difference was ascribed to an unidentified neural process or mechanism used only for the recognition of faces which is impaired by inversion (Scapinello & Yarmey, 1970; Valentine & Bruce, 1986; Haxby, Hoffman & Gobbini, 2000; Yovel & Kanwisher, 2005). This was due in part to Yin's observation that participants described using different methods to remember the different stimuli; trying to pick out distinguishing features to remember for most stimulus types while trying to get a general impression of the entire stimuli for faces.

This account of facial specificity has been opposed in further literature, notably by Diamond and Carey (1986) and their findings relating to expertise. They found that the large inversion effect for faces is not unique to them but rather than an equivalent inversion effect can be found for other stimuli, provided the participants have expertise with those stimuli e.g., dogs recognised by dog breeders. They suggested that the commonality between stimuli which are shown to produce a large inversion effect is that they are prototype defined and therefore individuals within a stimulus set share a configuration. Configural information consists of first-order relational information, referring to overall arrangement of features in a face or object (e.g., the nose above the mouth, the eyebrows above the eye etc.), and second-order relational information, referring to the individual variations in this arrangement compared to the prototype of the stimulus set. The argument put forth by Diamond and Carey (1986) is that the large inversion effect seen for faces is found whenever prototype defined stimuli are distinguishable using second-order relational information and the subject has sufficient expertise with the stimuli to utilise that information. It is therefore our wealth of expertise with faces that allows us to use the configural information they provide when upright to recognise them successfully, and the disruption to our ability to exploit that information in inverted faces is the driving force behind the face inversion effect. This account based on expertise with prototype defined stimuli is supported by later work using artificially generated stimuli which participants were trained on to give them a level of expertise when recognising them.

McLaren (1997) conducted experiments using artificial non-mono-oriented, prototype defined checkerboard stimuli for which the development of expertise can be fully controlled. These stimuli were tested in a variety of behavioural paradigms, and it was found that a large inversion effect (like that for faces) can be found when participants are presented with a familiar category of checkerboards and that this effect is not present with checkerboards drawn from a novel category. Further studies using checkerboards have shown this inversion effect was found only when checkerboards were drawn from a prototype-defined category vs when they were drawn from a non-prototypical category (i.e., no shared configuration) thus supporting Diamond and Carey's (1986) theory that expertise with configural information is strongly contributory to face recognition and the face inversion effect (McLaren & Civile, 2011; Civile, Zhao et al., 2014; Civile, Quaglia et al., 2021).

The mechanisms underpinning face recognition are not the only point of debate in the literature; since the face inversion effect has been applied as an index of face recognition the different types of information that contribute to it have also been investigated. This includes the three distinct types identified by Diamond and Carey (1986), featural information, first-order relational information, and second-order relational information. Research in this area has manipulated these types of information in a variety of ways and in a number of different behavioural paradigms to explore their individual roles in the inversion effect. Initially this was achieved using dot patterns, Tanaka and Farah (1991) generated exemplars which could either be discriminated using first-order relational information or second-order relational information and trained participants to recognise them. Their findings indicated that first and second-order information are equally impacted by inversion and may therefore both contribute to the inversion effect. In subsequent work Tanaka and Farah (1997) also showed that second-order configural information impacts the inversion effect for face stimuli. Individual features of the faces were recognised either in their original configuration or with the second-order relational altered to create a new configuration and it was found when faces were upright this manipulation reduced recognition performance, but it had no effect when faces were inverted (resulting in a reduced inversion effect). These findings indicate that we are able to utilise configural information when faces are presented upright but that our ability to do this is impaired when faces are inverted. Featural information has also been considered in this area of research and it was shown that both featural and configural information can be altered to increase the perceived distinctiveness of a face in the upright orientation but that when inverted the configural manipulation results in a significantly greater reduction in distinctiveness than the featural manipulation (Leder & Bruce, 1998). This indicated once again that configural information may be contributary to the inversion effect but that featural information is not. To further investigate this notion McKone and Yovel (2009) conducted a meta-analysis of 22 studies looking at featural information in relation to the inversion effect. While findings varied greatly between studies, when considered together it was found that contrary to previous assertions, featural information can impact the face inversion effect and it was argued that this impact is as great as that made by configural information.

The main role of featural information is further supported in a body of work conducted by Civile, McLaren et al (2014) which aimed to investigate how different types of information impact the face inversion effect by systematically manipulating that information. In their first experiment first and second-order relational information (i.e., configural information) were altered in a set of stimuli known as scrambled faces, these were generated by rearranging the spatial configuration of the features of the face with one first moving to the forehead and the next moving to fill the space left by the previous until all has been moved. It was discovered than in an old/new recognition paradigm this manipulation resulted in a reduction in overall recognition performance but did not have a significant impact on the inversion effect i.e., both upright and inverted stimuli were sensitive to configural disruption. In contrast to much of the previous literature this indicates that relational information is not the only factor driving the face inversion effect. In light of these findings Civile, McLaren et al. (2014) carried out further experiments focussing on the role of featural information on the face inversion effect. This involved the creation of another new set of stimuli called 50% feature inverted and scrambled faces. The scrambling manipulation was the same as that previously described but these faces had an additional alteration to the individual features with half of them (one eye, one ear and either the nose or mouth) being inverted. Using the same old/new recognition paradigm it was shown that this combination of featural and relational manipulation was sufficient to eliminate the face inversion effect suggesting that single feature orientation is a strongly contributing factor.

Follow up work by Civile, McLaren et al. (2016) went on to investigate whether manipulation to single feature orientation can reduce the inversion effect and whether either first or second-order relational information are important in the production of the inversion effect. In this instance the single feature manipulation from Civile, McLaren et al (2014)'s work was used with 50% of the features inverted but the scrambling manipulation was not employed. This resulted in stimuli called new Thatcherised faces which had altered featural and second-order relational information but typical first-order relational information. In the original Thatcher illusion (Thompson, 1980; Civile, Elchlepp et al., 2012; Civile, Cooke et al., 2020) the features inverted are both eyes and the mouth, but this was changed in Civile, McLaren et al (2016) to address the issue posed by the highly salient nature of the eyes in face recognition (Ellis, Shepherd, & Davies, 1979; Haig, 1984; Hosie, Ellis, & Haig, 1988). As in their previous work the features inverted by Civile, McLaren et al. (2016) were one eye, one ear and either the nose or mouth. In an old/new recognition task it was found that new Thatcherized faces demonstrate a significantly reduced inversion effect compared to normal faces but unlike the 50% feature inverted and scrambled faces the inversion effect is not eliminated. These results suggest that featural information plays a causal role in the inversion effect and that first-order relational information is important given that when it is relatively unaltered a significant inversion effect remains but when it is altered the inversion effect is eliminated.

Taken in summary Civile, McLaren et al. (2014) and (2016) provide evidence that only when featural, first-order relational, and second-order relational information are all manipulated simultaneously is the face inversion effect eliminated. In addition to these types of information it has been suggested that holistic processing may also be involved in the face inversion effect. Hole, George, and Dunsmore (1999) found that when participants were required to recognise the top half of a composite face (comprised of the top half of one face and the bottom half of another) there able to do so more accurately when the face were inverted as opposed to upright. They interpret these results in relation to the idea that the upright exemplars are identifiably "face-like" in that they conform to the broad layout of a face, and this elicits holistic processing which make it difficult to separate and disregard the bottom half of the face as they would need to do to successfully recognise only the top half. This is not the case for the inverted stimuli which they theorise is the reason for the observed difference in performance between upright and inverted stimuli.

To assess the role of holistic information in face recognition McCourt, McLaren and Civile (2021) and (2022) conducted a range of experiments in which holistic information (indexed by the face outline) was altered in normal, scrambled, and new Thatcherised faces. This was done in some experiments by blurring the contour of the face such that it no longer resembled the characteristic shape of a face (and thus according to Hole, George and Dunsmore (1999) should no longer elicit holistic processing), and in others by by creating a new star shaped contour based on the dimensions of the original. They used the old/new recognition paradigm seen in previous literature to assess impact of these manipulations on face recognition (Civile, McLaren et al., 2011). Their findings showed no different result based on the type of contour manipulation that was employed (blurring or replacing the contour). Importantly, they found that for normal faces manipulating the contour significantly reduced the face inversion effect and overall face recognition performance compared to normal faces with the regular contour. Furthermore, the authors found that for new Thatcherized faces manipulating the contour did not affect the size of the inversion effect despite reducing overall face recognition performance. In addition, the results from the scrambled faces showed that overall recognition performance was not impacted by contour manipulation but that the inversion effect was significantly reduced. Furthermore, performance for normal contour upright scrambled faces was significantly higher than that for blurred contour upright scrambled faces. One potential explanation for this result may be that, given the difficult nature of the recognition task and the scrambled stimuli being arguably the most difficult to recognise, performance for the inverted stimuli may be constrained by a "floor effect". Additional analyses confirmed that whereas upright scrambled faces from both sets (normal contour, blurred contour) were recognized significantly above chance, neither the normal contour inverted scrambled faces, nor the blurred contour inverted scrambled faces were recognised significantly above chance. The authors suggested that the decrease for overall recognition performance may have not be recorded due to the inverted stimuli being already at floor for the normal contour stimuli thus there was not performance to be affected by the blurring contour manipulation.

The current work aims to address this issue by replacing the old/new recognition task used in McCourt, McLaren et al (2021) and (2022) with an easier delayed matching task which would ensure a high level of performance for inverted faces as well. The specific task used was adopted from the prosopagnosia literature (Farahe et al., 1995) and the more recent literature that used this task to ensure similar level of performance between the face and checkerboard inversion effects (Civile, Quaglia et al., 2021). In doing so we hoped to improve performance prior to the contour manipulation and therefore gain a more accurate picture of the effect it is having on recognition performance and the face inversion effect to investigate the idea that holistic information plays a role in face recognition but does not impact upright and inverted faces differently.

Method

Subjects

A total of 64 participants (28 Female, 36 Male; Mean Age=28.5, Age Range=18-57, SD=9.38) took part in this study. They were recruited through the third-party service Prolific and were paid in line with Prolific Academic's fair pay policy. The sample size was determined from previous studies utilising the same scrambled faces (from the same prototype categories), counterbalancing of the participant conditions and stimuli, and behavioural paradigm (McCourt et al., 2021, 2022; Civile, Quaglia et al., 2021).

Materials

This study was presented to participants remotely using the online platform Gorilla. The stimuli comprised of 4 categories of scrambled faces, with each category having a distinct configuration of facial features once scrambled. The original image set consisted of 128 male faces with a neutral expression. Faces were standardised to greyscale on a square black background, and the hair and neck were cropped to isolate the faces. To create the scrambled faces 6 features were considered, the eyes (including the eyebrows), the ears, the nose and the mouth. For all stimuli one of the features was moved to the forehead (this being the largest open space on the face) and then another feature was moved into the space left by the last, this continued until all features had been moved to a new position. The features were moved in one of four patterns generating four distinct prototypes which were the basis for the four categories of scrambled faces, the result of this was that within a category each individual stimuli had the same featural configuration as the category prototype. From these sets of scrambled faces, we created the scrambled blurred-contour faces, this was achieved by blurring the contour of the face out until no characteristic face shaped outline remained (Figure 1). The manipulation of stimuli was achieved using Gimp 2.0 and all were made 7.95cm x 6.28cm. During the experiment participants saw only one category of scrambled normal-contour faces and one different category of scrambled blurred-contour faces. Stimuli presentation was counterbalanced across 8 participant groups such that each group saw a different combination of scrambled normal-contour and scrambled blurred contour-faces (Civile, Mclaren et al., 2014, 2016; McCourt et al., 2021, 2022).

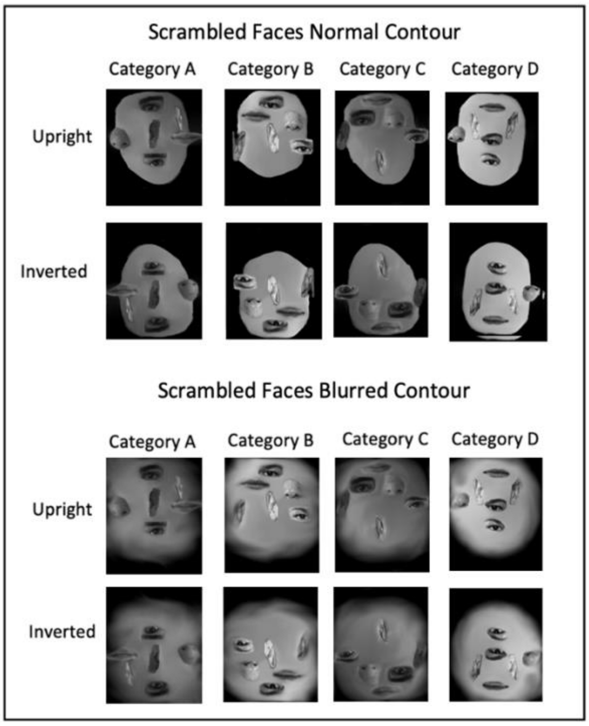

Figure 1. Examples of stimuli used in the study showing one stimulus from each category, upright and inverted. Each exemplar from a given category has the same featural configuration.

Procedure

This experiment used a delayed matching task, same as that used by Civile, Quaglia et al (2021) and often used with prosopagnosia patients this task is much easier than the old/new recognition task previously used in the literature and as a result overall performance tends to be higher, eliminating the possibility of a floor effect skewing the data. The experiment began with a practice task which aimed to associate the response keys with the correct response, participants saw the words “SAME” or “DIFFERENT” in random sequence with a 1s fixation cue between each presentation, they were asked to respond to these using the “x” and “.” keys (response keys were counterbalanced across groups) this continued for 48 trials and participants were given feedback (either a tick or a cross) after each response, they were given 2s to respond before being timed out with the feedback “Too Slow”. Their responses matched those they would be asked to give in the matching task i.e., if the pressed “x” for the word “SAME” in the practice task they would be asked to press “x” when the faces were the same in the matching task. After receiving some additional instructions participants moved on to the matching task. In this each trial consisted of a fixation cue shown for 1s, followed by a study face shown for 1s, then a pixelated mosaic mask shown for 1.5s, and a test faces which participants were given 2s to responded to. They were told to simply look at and try to remember the first face and then when the second face appeared to respond using the “x” and “.” keys based on whether it was the same or different as the first face. No feedback was given detailing whether their response was correct or incorrect but if no response was given after 2s the feedback “Too Slow” was displayed before the next trial began. Participants completed 128 trials with a break of up to 1 minute halfway through to rest their eyes. Half of the trials involved SAME trials and the other half DIFFERENT trials. Within SAME and DIFFERENT trials half of the stimuli were presented upright and half inverted. Study face and test face always matched in the orientation presented (Civile, Quaglia et al., 2021; Waguri et al., 2021; Waguri et al., 2022).

Results

We calculated d-prime (d’) sensitivity (Stanislaw & Todorov, 1999) for each stimulus type in the matching task. This measure considers both the hit rate (the proportion of trials where the answer was SAME and participants responded SAME), and the false alarm rate (the proportion of trials where the answer was DIFFERENT and participants responded SAME). The best performance is seen where the hit rate is maximised, and the false alarm rate is minimised and therefore the greater the difference between these two the better the participant’s sensitivity. The d’ measure captures this difference, and to do so it uses the z transforms of the two rates: $d' = z(H) - z(F)$ with values of 1 adjusted slightly down and values of 0 adjusted slightly up. The p-values reported are all two-tailed, and we report the F or t value along with measures of effect size (η^2_p). For completeness, we analysed the reaction time data for the four experiments to check for any speed–accuracy trade-off. No effects of speed-accuracy trade-off were found. These analyses are not reported because they do not contribute anything to the interpretation of our results.

Performance for all stimulus types was compared against chance (d’ of 0) and unlike in McCourt, McLaren et al (2021), all were found to be significantly above chance ($p<.001$), eliminating the impact of a potential floor effect for the inverted faces.

A 2x2 ANOVA was conducted with the factors Orientation (upright vs inverted) and Face Contour (normal vs blurred). We found a significant main effect of *Orientation,* $F(1,63) = 23.21$, $p < .001$, $\eta^2_p = .269$ with performance for upright faces (M = 2.13, SD = .77) being higher than that for inverted (M = 1.80, SD = .69) ones, indicating an overall inversion effect, the inversion effect for each face type is shown in Figure 2. Importantly, there was also a significant main effect of *Face Contour*, $F(1,63) = 4.28$, p = .043, $\eta^2_p = .064$ with performance for normal contour (M = 2.03, SD = .73) being significantly higher than that for the manipulated contour (M = 1.90, SD = .72) indicating a reduction in overall performance for the blurred contour faces (Figure 3). There was no significant interaction between Orientation x Face Contour $F(1,63)=1.778$, p = .187, η^2_p = .027, and there was a robust inversion effect for both scrambled faces with normal contour, $t(63) = 2.82$, p = .006, $\eta^2_p = .11$, and for scrambled faces with the blurred contour, $t(63) = 4.43$, $p < .001$, $\eta^2_p = .023$. In any case, the inversion effect was numerically bigger for blurred faces.

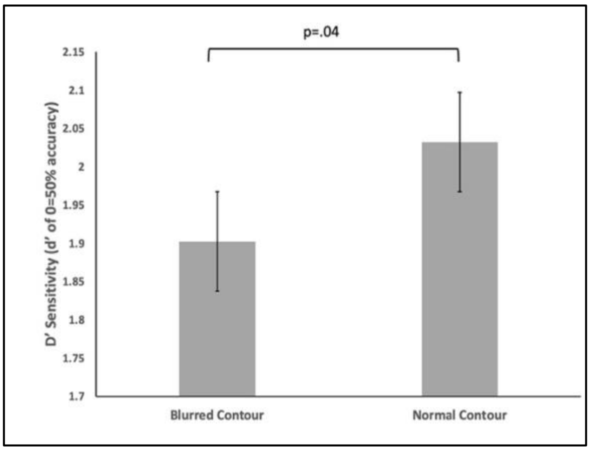

Figure 2. The inversion effects for normal contour and blurred contour faces. The x-axis showing the four stimulus categories and the y-axis showing d' sensitivity for each condition in the matching task. Error bars show SE of the mean.

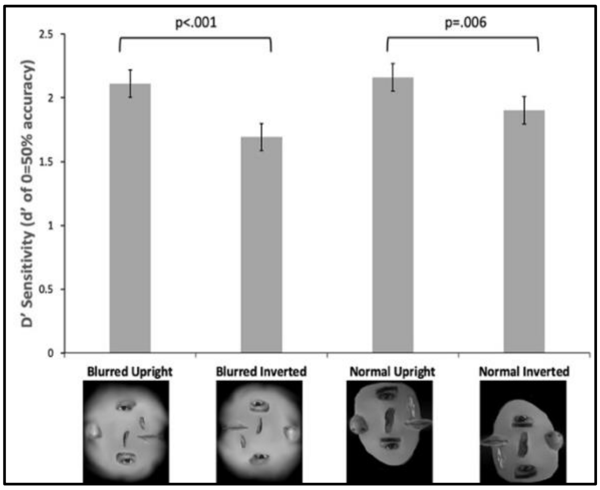

Figure 3. Overall recognition performance for blurred contour and normal contour faces. The x-axis showing the face type and the y-axis showing d' sensitivity. Error bars show SE of the mean.

Discussion

In this paper we report results from a behavioural experiment investigating the perceptual processes and types of visual information that drive both face recognition and the face inversion effect which has been so critical in the face recognition literature. Here our specific focus has been on configural information and holistic information (indexed by the face contour) and the roles they play. This work follows sequentially from the work of Civile, McLaren et al (2014) and (2016) and McCourt, McLaren et al (2021) and (2022) which have demonstrated a robust inversion effect can be obtained for faces where the configural information has been greatly disrupted. Furthermore, McCourt, McLaren et al (2021) have also shown how the additional disruption to holistic information through manipulation of face contour can significantly reduce the inversion effect for scrambled faces.

The results reported here add support to the finding that configural information is not essential to obtain a robust face inversion effect with sets of scrambled faces, and this has now been reliably replicated in a variety of experiments and in different behavioural paradigms. (Civile, McLaren et al., 2014, 2016; McCourt et al., 2021, 2022). Importantly, our results show that manipulating the contour of the scrambled faces significantly affects overall recognition performance. This is a key finding because it reveals how holistic information (indexed by the face contour) plays a role in face recognition performance when a delayed-matching task is used which ensures a good level of performance even for the inverted faces. This finding would seem to confirm McCourt, McLaren et al (2021)'s suggestion that in their studies, the lack of a reduction in overall performance for scrambled faces with a blurred contour may have been due to a floor effect recorded for the inverted faces. McCourt, McLaren et al (2021) and (2022) also showed that for normal faces as well as for new Thatcherized faces when the contour is manipulated overall recognition performance is significantly reduced. Our results contribute to this by showing that manipulating the face contour affects overall recognition performance also for scrambled faces when using a task that can ensure all stimulus conditions are recognized significantly above chance.

Interestingly, our results also revealed that in this case the contour manipulation did not significantly affect the size of the inversion effect for scrambled faces. In McCourt, McLaren et al (2021), the authors using an old/new recognition task showed that despite overall performance not being affected by the contour manipulation, the scrambled faces showed a significantly reduced inversion effect compared to scrambled faces with the normal contour. One potential explanation was that the reduction of the inversion effect for scrambled faces recorded in McCourt, McLaren et al (2021) is not only due to the manipulated contour but also to an overall decrement in recognition to begin with due to the difficult task. Hence, because scrambled inverted faces were already at floor, the only condition where performance could be affected after manipulating the contour was the upright one. Thus, manipulating the contour of the scrambled upright faces would have reduced performance compared to the scrambled upright faces with the normal contour (as confirmed by the additional statistical analysis reported by McCourt, McLaren et al 2021), reducing the inversion effect because at the same time scrambled inverted faces were not affected by the manipulation due to a floor effect. Future work should study this further by extending the same matching task to both sets of normal faces and new Thatcherized faces, with a regular or an altered contour as used in McCourt, McLaren et al (2021) and (2022).

Overall, these results advance our understanding of the role that holistic information has on face recognition, and they may also prove crucial in resolving the debate around facial specificity versus expertise. These are often considered in opposition to one another with evidence for the expertise account, such as that provided by McLaren (1997) and the range of checkerboard experiments that followed, taken as evidence against the facial specificity account. However, it is possible that expertise with the configural and featural information accounts for the face inversion effect and that the basic plan of a face elicits a holistic processing mechanism unique to faces which accounts for another aspect of face recognition (perhaps overall recognition performance). Exploring whether altering holistic information impacts non-face stimuli in a similar way to faces in future research may help discern whether this is a plausible explanation.

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