Title
Manipulating the face contour affects face recognition performance leaving the Face Inversion Effect unaltered

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 44(44)

Authors
McCourt, Siobhan
McLaren, IPL
Civile, Ciro

Publication Date
2022

Peer reviewed

Manipulating the face contour affects face recognition performance leaving the Face Inversion Effect unaltered

Siobhan McCourt (sm1002@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK
I.P.L. McLaren (i.p.l.mclaren@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK
Ciro Civile (c.civile@exeter.ac.uk)
School of Psychology, College of Life and Environmental Sciences,
University of Exeter, UK

Abstract

The following studies investigated the perceptual processes that are the basis of the face inversion effect (FIE). We evaluated the effects of disrupting holistic information conveyed by the face contour/outline. In Experiment 1 (n=144) we blurred the contour of the faces and using an *old/new recognition task* we found that a robust inversion effect similar to that for normal faces remains for these new no-contour faces. However, a significant reduction in overall performance was found for no-contour vs normal faces. In Experiment 2 (n=74) instead of blurring we inserted a novel face contour to replace the normal one and found the same pattern of results as in Experiment 1. Our results suggest that the holistic information provided by the face contour does not on its own influence the FIE, however it plays a role in face recognition more generally.

Keywords: Face inversion effect, Face recognition, Configural processing, Holistic processing

Introduction

The mechanisms underlying face recognition have been under debate since the first report of the face inversion effect (FIE). This refers to the phenomenon by which recognition performance for face stimuli is impaired when the stimuli are presented inverted (upside-down) compared to when they are upright (Yin, 1969; Civile, McLaren & McLaren, 2011; Civile, McLaren & McLaren, 2014; Civile, McLaren & McLaren, 2016) and this impairment is greater for faces than for non-face objects (Yin, 1969). The disparity between the inversion effect for faces and objects such as cars, planes, and houses was initially thought to be the results of a specialised processing mechanism that is unique to faces and makes them particularly sensitive to orientation, resulting in a greater disadvantage when they are inverted (Yin 1969; Valentine & Bruce 1986; Yovel & Kanwisher, 2005). However, studies using dog stimuli later demonstrated that an inversion effect equivalent to that for faces can be found for dog images when the participants are expert dog breeders, contradicting the pure specificity account of face processing (Diamond & Carey, 1986). It was theorised from these findings that there are three distinct types of information that are useful for recognition: isolated features such as the nose, first-order configural relations such as the nose in relation to the mouth, and second-order configural relations which is the variation of the first-order in relation to the prototype for a given stimulus group (e.g., Western Caucasian male faces). Isolated features and first-order relations are those which are fundamentally consistent across faces and enable us to recognise an image as a face but second-order configural information is that which varies from face to face and enables us to distinguish one face from another (Diamond and Carey, 1986). Based on this, Diamond and Carey posited that rather than there being a specialised mechanism for processing faces, it is expertise with a prototype-defined category that results in the FIE. McLaren (1997), McLaren and Civile (2011), Civile, Zhao et al (2014), Civile, Verbruggen et al (2016) strengthened the argument for the expertise account by showing that a robust inversion effect can be obtained with prototype-defined categories of checkerboards provided that participants were pre-exposed to those categories. This finding supported Diamond and Carey's claim that expertise with stimuli that share a prototype is a contributory factor to the inversion effect. Subsequently, researchers have explored how manipulation of the second-order configural information of prototype-defined stimuli would impact this effect.

Supporting the idea that second-order information is affected by inversion and thus contributes to the FIE by removing the advantage that expertise usually gives us for faces are findings from Leder and Bruce (1998). They used faces which had been rated as average in distinctiveness and manipulated them to increase their distinctiveness by altering either the featural or configural information. They found that featural and configural manipulations both resulted in higher perceptions of distinctiveness for the upright faces compared to the originals, but that the apparent distinctiveness of faces with the configural manipulation was reduced significantly more than those with the

In J. Culbertson, A. Perfors, H. Rabagliati & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual Conference of the Cognitive Science Society*.

featural manipulation when faces were inverted. This was taken as evidence that the FIE occurs due to disruption to face-specific processing as opposed to general image disruption.

Some accounts of face recognition argue for a holistic approach and posit that while second-order configural information contributes to the FIE, it does so in combination with featural information. Tanaka and Farah (1993) conducted experiments testing recognition of individual face parts either in isolation or as part of a whole face. They found that recognition performance for an individual feature of the face was disproportionately better when presented in the context of the whole face compared to when presented in isolation. They further found that this advantage for whole object recognition was not present in scrambled faces, inverted faces, or houses. They interpret these results as evidence that disruption to second-order configural information impacts our ability to recognise individual features in upright but not inverted faces, thereby reducing the FIE. This "holistic" account of face processing is supported by subsequent research from Tanaka and Sengco (1997), who altered the second-order configural information of face stimuli by either moving the eyes closer together or farther apart and trained (study phase) participants with these stimuli. Participants were tested on recognition of facial features (e.g., eyes, nose, mouth) in isolation (presented without the surrounding of the face), new configuration (presented in a face with different eyes spacing from the study phase), and old configuration (presented in a face with same eyes spacing as in the study phase). It was found that participants recognized features best when presented in the old configuration. Importantly, participants were not sensitive to configural disruption on inversion.

The role of configural information in the FIE was tested by Civile, McLaren et al (2014) using a set of scrambled faces. The stimuli were created from four prototype categories, in all groups one feature (one of the eyes, ears, nose, or mouth) was moved to the forehead and then a feature was moved to fill the gap left by that feature now on the forehead. The four prototypes differed in which feature was moved to the forehead, and the order in which subsequent features were moved. Using a similar old/new recognition task as in Civile, Zhao et al (2014) they presented participants with both normal and scrambled faces to memorise, and then tested their recognition performance by asking them to identify which stimuli they had seen before from a set that comprised of 50% old and 50% new faces. They found that despite disruption to the configural information through this scrambling, a significant inversion effect equivalent to that for normal faces still remained and it was concluded that configural information is not essential to the FIE. To investigate the specific roles of featural and configural information Civile, McLaren et al (2014) generated a set of face stimuli called "50% Feature-Inverted and Scrambled faces". These had half of the facial features inverted and half upright in a scrambled face, thus no matter the orientation of the stimuli, half of the facial features are always upright, and half are always inverted. This enabled them to also investigate the role of the individual features in the face inversion effect, a complete elimination of the inversion effect for these stimuli would indicate that featural information plays a causal role in the FIE. Their findings confirmed this and as result the authors concluded that featural information does play a significant role in the FIE and disruption to the configural information does not on its own reduce the inversion effect, but it is eliminated when *single feature orientation* is also disrupted.

Further research using scrambled face stimuli aimed to investigate whether or not second-order configural information is at all necessary to obtain the FIE. Civile et al (2016) generated a new set of face stimuli called new Thatcherised faces which aimed to control for the effect of single feature orientation previously shown by Civile, McLaren et al (2014). This was achieved by inverting one eye, one ear and either the nose or mouth in an otherwise normal face, thereby disrupting featural and second-order configural information but leaving first-order configural information intact. They again used the old/new recognition paradigm with these new stimuli and the scrambled faces from Civile, McLaren et al (2014). It was found that as before the scrambled faces showed a robust inversion effect and that the new Thatcherised face also showed a significant inversion effect. This indicates that first-order information is sufficient to obtain the FIE, as it remains present when featural and second-order information are altered but first-order configuration is not. One explanation given by Civile et al for this is that first-order configural information may elicit the use of holistic processing for upright faces and therefore when new Thatcherised faces are upright participants are able to utilise holistic processing to aid recognition, but this is not possible when they are inverted, which results in increased salience of the featural information, thereby impairing performance.

This explanation stands in agreement with the theory of Hole, George, and Dunsmore (1999) that argues for the existence of two types of processing that are involved in face recognition. These are holistic processing and configural processing. They claim that configural processing occurs due to the prototypical position of individual facial features in relation to one another and they posit that holistic information is elicited by stimuli that have the outline of a faces and that this outline is what helps identify as a face rather than anything else. Civile et al (2016) therefore suggested that because upright new Thatcherized faces still follow the expected basic outline of a face, they may elicit holistic processing which results in greater performance for upright vs inverted faces. This theory also offers and explanation for the results of Civile, McLaren et al (2014) as the scrambled faces also follow the basic outline of a face, regardless of the alteration to configural information.

To investigate the role of holistic information in the FIE, McCourt, McLaren, and Civile (2021) built on the work of Civile, McLaren et al 2014, using those scrambled face stimuli but disrupting the holistic information generated by the face contour. Scrambled faces had their outline blurred to alter their contour while the scrambling manipulation remained the same. An old/new recognition task was used in which participants were presented with both normal-contour scrambled faces and blurred/no-contour scrambled faces. The results showed that, as expected, there was a robust inversion effect for the normal-contour scrambled faces, but no significant inversion effect was obtained for scrambled faces with no-contour. This finding indicates that holistic information as indexed by the face contour can play a causal role in the FIE for sets of scrambled faces that had altered configural information.

The current work aims to assess the effect of disrupting holistic information via face contour manipulation on normal faces. To do this, two experiments were conducted, the first using the same contour manipulation as in McCourt et al (2021) and the second introducing a new-contour manipulation. The inversion effects for these manipulated contour faces were then compared to that for normal faces.

Experiment 1: Method

Subjects

Experiment 1 consisted of 144 naïve participants (98 female, 46 male; Mean age=23.1, age range=18-55, SD=7.04). Of these 72 were recruited through the University of Exeter and received course credit for their participation and 72 were recruited through the online platform Prolific and were compensated in accordance with Prolific Academic's fair pay policies. Analyses with *Recruitment Type* as a factor (University or Prolific) found no significant main effect nor interactions with any other factors. The sample size was decided based on previous studies that used the same stimulus counterbalance, and behavioural paradigm (Civile et al., 2014; Civile et al., 2016; McCourt et al., 2021). We also conducted a post-hoc power analysis for our sample size using G*Power software, based on the effect size ($\eta^2_p = .03$) recorded from the overall 2 x 2 interaction (Face Type x Orientation). This revealed a statistical power of 1 (Effect size f = .18, 1 group, 4 measurements [2 face types, 2 orientations]).

Materials

The stimuli used for this study were the same in Civile et al (2014). They consisted of 128 male faces (7.95cm x 6.28cm) with a neutral expression in which the hair and neck had both been cropped and the photos had been standardised to greyscale on a black background. The no-contour faces were created by blurring away the original face outline (Figure 1a). The faces were manipulated using Gimp 2.10. Stimuli were counterbalanced across 8 participant groups such that any given face is seen in a different orientation and with a different contour by different participants.

The behavioural task

During a study phase, participants were shown 64 faces evenly split between the different stimulus types (16 upright and inverted normal faces; 16 upright and inverted no-contour faces). Trials consisted of a fixation cue presented in the middle of the screen for 1s and then a face presented for 3s in the middle of the screen. Stimuli were presented one at a time in random order, no response was required participants were simply asked to remember as many of the faces as possible. Following this phase participants began the old/new recognition task in which they were shown 128 faces (64 that had been shown in the study phase and 64 that were novel split by the four stimulus' conditions) presented one at a time in random order. Participants had 3s to respond with either the "X" or "." keys (counterbalanced) to indicate whether or not they had seen the face before. If no response was given in this time they were timed out and the next trial began (Civile, McLaren et al., 2014, 2016; McCourt et al., 2021).

Results

Accuracy data from each condition was used to calculate a d-prime (d') sensitivity measure (Stanislaw & Todorov, 1999) for the recognition task (old and new stimuli for each stimulus type) where a d' = of 0 indicates chance-level performance. d' was computed using the difference between the z transforms of hit rate (H) and false alarm rate (FA): $d' = z(H) - z(F)$. Each p-value reported is two-tailed, and we report the F or t value along with measures of effect size (η2p). We assessed performance against chance (d' of 0) and for each condition we found a $p < .001$. We analysed the reaction time data to check for any speed–accuracy trade-off. We do not report these analyses here because they do not add anything to the interpretation of our results.

A 2 x 2 within-subjects ANOVA using as factors *Face Type* (normal contour, no-contour) x *Orientation* (upright, inverted) revealed a significant main effect of Face Type, $F(1, 143) = 4.57$, $p = .034$, $\eta^2_p = .03$, with overall performance for normal faces being higher (M = .49, SD=.46) than that for no-outline ones (M=.39, SD=.45). A significant main effect of Orientation (i.e., the inversion effect), $F(1, 143) = 48.65$, $p < .001$, $\eta^2_p = .25$, was also found. No significant interaction (Face Type x Orientation) was found, $F(1, 143) = .90$, $p = .34$, $\eta^2_p < .01$. Hence, a significant inversion effect was found for both normal faces, $t(143) = 5.96$, $p < .001$, $\eta^2_p = .19$, and no-contour faces, $t(143)= 4.72$, $p < .001$, $\eta^2_p = .13$. A further analysis revealed that accuracy for upright normal faces (M=.67, SD=.64) was significantly better than that for no-outline faces (M=.54, SD=.60), $t(143) = 2.06$, $p = .041$, $\eta^2_p = .02$. Only a numerical difference was found between inverted normal (M=.30, SD=.54) vs inverted no-outline (M=.25, SD=.57) faces, $t(143) = 1.08$, $p = .283$, $\eta^2_p < .01$ (Figure 1b).

Discussion

These results suggest that the disruption of holistic information is having an impact on overall face recognition performance, however it does not influence the FIE. Importantly, whereas in McCourt et al (2021) the same blurring manipulation applied to scrambled faces (first and second-order configural information disrupted) significantly reduced the inversion effect, we find that this is not the case when the same manipulation is applied to normal faces. This would suggest that this disruption of holistic information through blurring the face contour is not enough to elicit a reduction in the inversion effect unlike when holistic information is disrupted in combination with configural information (McCourt et al 2021). This may indicate that both types of information are integral to face recognition process and thus both need to be disrupted in order to significantly reduce the FIE. However, there were some concerns regarding the stimuli that we used. Blurring the edges of the image degraded the overall quality and this may have contributed to the reduction in overall performance for no-contour faces. In addition, the manipulation removed the sense of objecthood from the images; not only did they look less like a normal face, they also looked less like any recognisable object than the normal stimuli. For this reason, we decided to alter the manipulation of the outline and conduct a second experiment using these new stimuli.

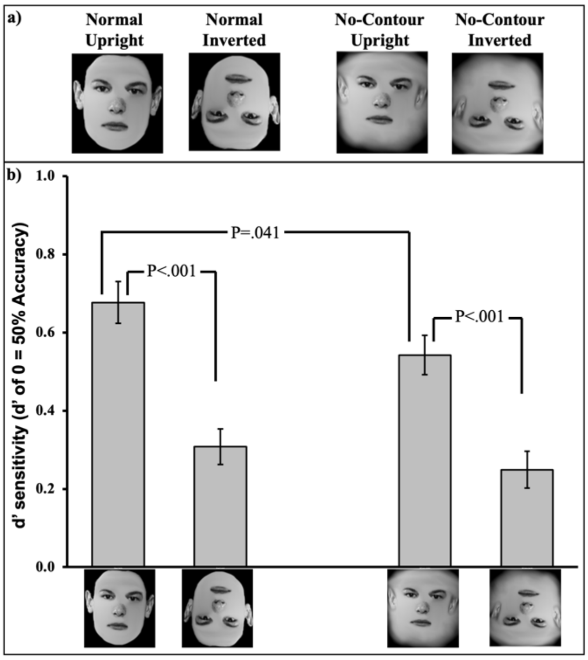

Figure 1a shows some examples of stimuli used in Experiment 1. **Figure 1b** reports the results from the old/new recognition task. The x-axis refers to the four different stimulus categories. The y-axis shows the mean *d'* accuracy for each condition. Error bars are s.e.m.

Experiment 2: Method

Subjects

We recruited 74 naïve participants for this study (36 Female, 38 Male; Mean age=24.9, age range=18-71, SD=8.30), who were compensated in accordance with the Prolific Academic's fair pay policies.

Materials

The stimuli for this experiment were the same 128 normal faces (7.95cm x 6.28cm) used in Experiment 1 and were also standardised to greyscale on a black background. The new contour manipulation was designed with the aim of preserving the image quality, retaining a sense of objecthood, and preserving some of the information from the original outline that could be used to help differentiate between stimuli. The distance was measured from the centre of the face to 8 points along the outline of the face, these distances were then used to create 8 "spikes" from the outline of the face outwards, the spikes were the joined to form a star shaped outline around the face and the colour of the face was blended to create a seamless image (Figure 2a). This gave the faces solid outlines which were as distinctive as the original outlines due to the measurements of the original outline being used to construct them but did not have the conventional outline of a face that George et al (1999) posit should elicit the use of holistic processing. As in the previous experiment, stimuli were counterbalanced across 8 participant groups such that a particular face is seen in a different orientation and with a different contour by different participants.

The behavioural task

The same old/new recognition task and number of stimuli as for Experiment 1, however this time instead of normal and no-contour faces, participants were presented with normal and new-contour faces.

Results

Accuracy data from each condition was used to calculate *d'*. We assessed performance against chance and for each condition we found a $p < .001$. A 2 x 2 within-subjects ANOVA using as factors *Face Type* (normal contour, new-contour) x *Orientation* (upright, inverted) revealed a significant main effect of Face Type, $F(1, 73) = 7.84$, $p = .007$, $\eta^2_p = .09$, with overall performance for normal faces being larger (M = .56, SD=.48) than that for new-outline ones (M=.40, SD=.40). A significant main effect of Orientation, $F(1, 73) = 29.48$, $p < .001$, $\eta^2_p = .28$, was found. No interaction (Face Type x Orientation) was found, $F(1, 73) = .46$, $p = .49$, $\eta^2_p < .01$. A significant inversion effect was found for both normal faces, $t(73) = 4.45$, $p < .001$, $\eta^2_p = .21$, and new-contour faces, $t(73) = 3.96$, $p < .001$, $\eta^2_p = .17$. A further analysis revealed that accuracy for upright normal faces (M=.79, SD=.71) was significantly larger than that for new-outline faces (M=.59, SD=.55), $t(73) = 2.43$, $p = .017$, $\eta^2_p = .07$. Only a numerical difference was found between inverted normal (M=.34, SD=.57) vs new-outline (M=.22, SD=.57) faces, $t(73) = 1.42$, $p = .157$, $\eta^2_p = .02$ (Figure 2b).

Analysis across experiments

We conducted an overall analysis using the within-subjects factors *Face Type* (normal, manipulated [no-contour, new-contour]), *Orientation* (upright, inverted), and the between-subjects factor *Experiment* (Experiment 1, Experiment 2). The results from the 2 x 2 x 2 ANOVA (*Face Type* x *Orientation* x *Experiment)* revealed a significant main effect of Face Type, $F(1, 216) = 11.70$, $p < .001$, $\eta^2_p = .05$ with overall performance for normal faces being larger (M = .51, SD=.47) than that for manipulated ones (M=.39, SD=.43). A significant main effect of Orientation, $F(1, 216) = 74.83$, $p < .001$, $\eta^2_p = .25$, was found. No main effect of Experiment was found, $F(1, 216) = .616$, $p = .433$, $\eta^2_p < .01$. The factor Experiment did not interact significantly with Face Type, $F(1, 216) = .752$, $p = .387$, $\eta^2_p < .01$, nor with Orientation, $F(1, 216) = .734$, $p = .392$, $\eta^2_p < .01$. The overall three-way interaction (Face Type x Orientation x Experiment) was not significant, $F(1, 216) = .002$, $p = .962$, $\eta^2_p < .01$. No significant interaction, Face Type x Orientation, was found, $F(1, 216) = 1.26$, $p = .263$, $\eta^2_p < .01$. Hence, a robust inversion effect was found for both normal faces, $t(217) = 7.44$, $p < .001$, $\eta^2_p = .20$, and manipulated faces, $t(217) = 6.16$, $p < .001$, $\eta^2_p = .15$. Accuracy for upright normal faces (M=.71, SD=.66) was significantly larger than that for manipulated faces (M=.55, SD=.58), $t(217) = 3.05$, $p = .002$, $\eta^2_p = .04$. A trend towards a significant difference was found between inverted normal (M=.32, SD=.55) vs manipulated (M=.24, SD=.57) faces, $t(217) = 1.73$, $p = .084$, $\eta^2_p = .01$.

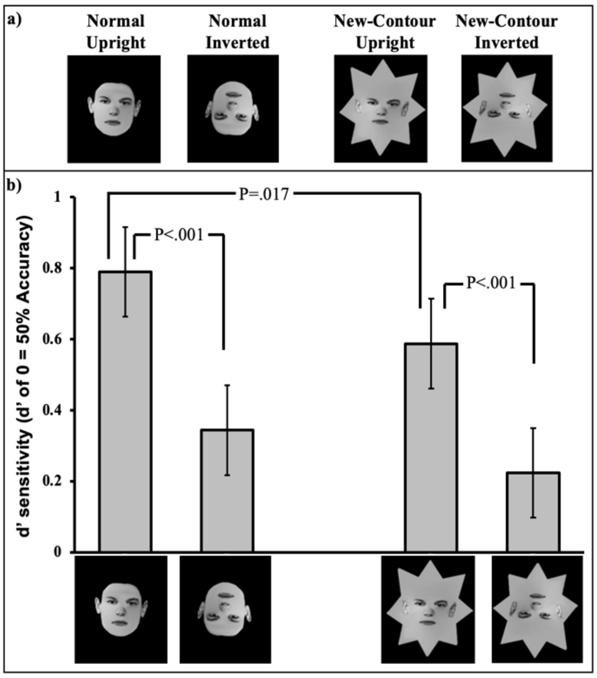

Figure 2a shows some examples of stimuli used in Experiment 2. **Figure 2b** reports the results from the old/new recognition task. The x-axis refers to the four different stimulus categories. The y-axis shows the mean *d'* accuracy for each condition. Error bars are s.e.m.

Discussion

Experiment 2 aimed to address the issue of whether the results obtained in Experiment 1 could have been explained by degradation of the overall quality of the images due to the blurring manipulation used to eliminate the face contour. This time instead of removing the contour we replaced it. The results are in line with what previously found in Experiment 1. Hence, manipulating the face contour did not affect the inversion effect, even though overall recognition performance was significantly reduced compared to that for normal faces. This reduction was due to upright new-contour faces being recognised significantly worse than normal upright ones and inverted new-contour faces being numerically recognised worse than normal inverted ones. The overall analysis across experiments confirmed this pattern of results and also provides evidence for a trend towards reduced performance for inverted ones with a changed contour.

General Discussion

Both experiments presented in this paper investigated the perceptual processes that underpin the FIE. As a follow up from previous work that looked at the role of both configural and holistic information (Civile, McLaren et al., 2014, 2016; McCourt et al., 2021), here we focused on the impact of manipulating holistic information while single feature orientation information and configural information are maintained. In both experiments we manipulated the contour of normal face stimuli aiming to examine the effects on the FIE. The key finding from the two experiments is that altering the face contour of a normal face (not scrambled) either by removing or replacing it, does not influence the size of the inversion effect. Hence, both normal faces, and normal faces with a manipulated contour showed a robust inversion effect. However, overall recognition performance was significantly reduced. The means of the upright manipulated contour faces were significantly lower than normal contour faces. This effect on upright faces was significant in both experiments. Furthermore, a trend towards a similar effect is also found for inverted faces, with manipulated contour faces being recognized less well than the normal contour ones. However, this trend towards significance only emerged from the analysis across experiments. Overall, our results suggest that manipulating the face contour of a set of normal faces does not strongly influence the inversion effect, although it does affect significantly face recognition performance in general.

Our findings extend McCourt et al (2021)'s findings. Specifically, the authors found that removing the face contour by adopting the same blurring manipulation as the one we used here, affects the size of the inversion effect for sets of scrambled faces via reduced performance for upright faces. Taken all together, our findings and those from McCourt et al (2021) suggest that disruption of holistic processing indexed by the manipulated face contour, is only effective on the inversion effect when in combination with disrupted configural information by scrambling the main features within a face. But when the face contour is manipulated on a set of normal faces no reliable effect is found on inversion. This suggests that holistic information has a role in determining the inversion effect only when combined with disruption of configural information as for the case of McCourt et al (2021)'s studies, or when performance is low enough.

One may argue that McCourt et al (2021) and our findings reported here contradict the results previously found by Civile, McLaren et al (2014). Specifically, the authors demonstrated how scrambling the configural information among the main features within a face by maintaining the single feature orientation information unaltered, does not affect the inversion effect which was found to be as robust as that for normal faces. Hence, the authors suggested how configural information may not be necessary in determining the inversion effect. However, based on McCourt et al (2021) and our experiments reported here, we are suggesting how it is the combination of configural, and holistic information that, in addition to single feature orientation information, determines the inversion effect. At this point, a more nuanced analysis is needed to disentangle the overall effects showed across the key studies mentioned here.

In a further study, Civile et al (2016) first replicated Civile, McLaren et al (2014)'s findings and then investigated the specific role that first and second-order configural relations have in the inversion effect. Using a set of faces (new Thatcherized faces) that had the single feature orientation controlled for (i.e., 50% upright and 50% inverted features) and the second-order relations disrupted by maintaining the first-order relations unaltered, the authors found a robust inversion effect. Civile et al (2016) suggested how first-order rather than second-order relations would seem to have a key role in determining the inversion effect. Importantly, in addition to the first-order relations also the contour of the new Thatcherized faces was for the most part unaltered (despite one ear was always inverted) in Civile et al (2016)'s studies. Thus, it could be that the combination of both first-order configural information, and holistic information (indexed by the face contour) contributed to the robust inversion effect for new Thatcherized faces demonstrated by Civile et al (2016).

We could operationalize the inversion effect obtained across all the studies here mentioned based on the presence of single feature orientation information, first-order configural information and/or holistic information. This would imply that the robust inversion effect for scrambled faces (Civile, McLaren et al., 2014, 2016) is led by holistic information (indexed by the face contour) and single feature orientation information. The reduced inversion effect for scrambled faces found in McCourt et al (2021) would be due to the disruption of holistic information by removal of the face contour. Importantly, despite being significantly reduced the inversion effect for no-contour scrambled faces in McCourt et al (2021)'s study was not eliminated, and this could be since the single feature orientation information was unaltered (i.e., all the features within the upright scrambled faces were presented upright). The robust inversion effect found for the new Thatcherized faces (Civile et al 2016) would be due to the combination of first-order configural information and holistic information. Finally, the robust inversion effect for manipulated contour normal faces found in the experiments reported here, would be due to first-order configural and single feature orientation information being unaltered. Future studies should investigate the link between first-order configural and holistic information directly, perhaps by applying the contour manipulation to the new Thatcherized stimuli created by Civile et al (2016).

A further consideration regards the effect of manipulating the face contour on overall face recognition performance. Our experiments already demonstrate how manipulating the contour of normal faces significantly affects recognition performance of upright faces. After conducting an across experiments analysis, we found a trend towards significance for inverted manipulated faces being recognized worse than those with normal contour. This would suggest that a decremental effect on performance is induced in both upright and inverted manipulated faces, however it may be smaller for inverted faces because they are closer to chance and there is less performance to be lost. Future work should investigate this issue directly by using a behavioural paradigm that could ensure a high level of performance also for the inverted faces like a delayed matching task of the kind used to investigate the inversion effect in individuals with face blindness (Farah et al., 1995).

A final consideration regards the extension of our findings to a recent line of research that uses transcranial Direct Current Stimulation (tDCS) to investigate the mechanisms of the inversion effect. Civile, Verbruggen et al (2016) showed that anodal tDCS (for 10 mins at 1.5mA) delivered over the Fp3 during the same old/new recognition task used by Civile, Zhao et al (2014) reduced the checkerboard inversion effect. This was mainly due to reduced performance for upright familiar checkerboards compared to sham tDCS (control). Importantly, Civile et al (2018), extended the tDCS procedure to the inversion effect for normal faces. A reduction (compared to sham) of the inversion effect was found after anodal tDCS, in this case also due to an impaired recognition performance for upright faces. These results have been replicated in multiple studies and it is now an established finding (Civile, Obhi et al., 2019; Civile, Cooke et al., 2020; Civile, McLaren et al., 2020; Civile, Waguri et al., 2020; Civile, Quaglia et al., 2021; Civile, McLaren et al., 2021). Interestingly, whereas the same tDCS procedure eliminated the checkerboard inversion effect, the FIE despite being significantly reduced compared to sham, was still significant. The authors suggested that the remaining FIE could be an index of face specificity mechanisms. Civile, McLaren et al (2021) applied the tDCS procedure to the composite face effect (CFE) which constitutes better recognition of the top half of an upright face when conjoined with a congruent rather than incongruent bottom half. This effect has often been used in the literature as index of holistic processing (Murphy et al., 2017). Civile, McLaren et al (2021) found no effect of tDCS on the CFE suggesting that holistic processing may be the type of information specific to faces and at the basis of the remaining FIE after anodal tDCS.

The results from our studies reported here add to this literature by suggesting that the face contour may not be the type of holistic information that leads to the remaining FIE in Civile et al (2018). Future work should investigate this directly by using our contour manipulations to the normal faces used in Civile et al (2018) and examine whether the tDCS procedure would in that case further reduce the FIE.

Acknowledgements

This project has received funding from the Economic and Social Research Council *New Investigator Grant (Ref.ES/R005532)* awarded to Ciro Civile (PI) and I.P.L. McLaren (Co-I) and from the UKRI Covid-19 Grant Allocation awarded to Ciro Civile.

References

Civile, C., McLaren, R., and McLaren, I.P.L. (2011). Perceptual learning and face recognition: Disruption of second-order relational information reduces the face inversion effect. In L. Carlson, C. Hoelscher, & T.F. Shipley (Eds.), *Proceedings of the 33rd Annual Conference of the Cognitive Science Society,* (pp. 2083-88). Austin, TX: Cognitive Science Society.

Civile, C., McLaren, R., & McLaren, I.P.L. (2014). The face Inversion Effect-Parts and wholes: Individual features and their configurations. *Quarterly Journal of Experimental Psychology, 67, 728-746*.

Civile, C., Zhao, D., Ku, Y., Elchlepp, H., Lavric, A., & McLaren, I. (2014). Perceptual learning and inversion effect: Recognition of prototype-defined familiar checkerboards. *Journal of Experimental Psychology: Animal Learning and Cognition,40,144-161*.

Civile, C., McLaren, R., and McLaren, I.P.L. (2016). The face inversion effect: Roles of first and second-order relational information. *The American Journal of Psychology*, *129, 23-35*.

Civile, C., Verbruggen, F., McLaren, R., Zhao, D., Ku, Y., & McLaren, I.P.L. (2016). Switching off perceptual learning: Anodal transcranial direct current stimulation (tDCS) at Fp3 eliminates perceptual learning in humans. *Journal of Experimental Psychology:Animal Learning and Cognition*, *290-296*.

Civile, C., McLaren, R., & McLaren, I.P.L. (2018). How we can change your mind: Anodal tDCS to Fp3 alters human stimulus representation and learning. *Neuropsychologia*, *119, 241-246*.

Civile, C., Obhi, S.S., and McLaren, I.P.L. (2019). The role of experience-based perceptual learning in the Face Inversion Effect. *Vision Research*, *157, 84-88*.

Civile, C., Cooke, A., Liu, X., McLaren, R., Elchlepp, H., Lavric, A., Milton, F., and I.P.L. McLaren. (2020). The effect of tDCS on recognition depends on stimulus generalization: Neuro-stimulation can predictably enhance or reduce the face inversion effect. *Journal of Experimental Psychology: Animal Learning and Cognition*, *46, 83-98*.

Civile, C., Waguri, E., Quaglia, S., Wooster, B., Curtis, A., McLaren, R., Lavric, A., and McLaren, I.P.L. (2020). Testing the effects of transcranial Direct Current Stimulation (tDCS) on the Face Inversion Effect and the N170 Event-Related Potentials (ERPs) component. *Neuropsychologia*, *143, 107470*.

Civile, C., McLaren, R., Milton, F., and McLaren, I.P.L. (2021). The Effects of transcranial Direct Current Stimulation on Perceptual Learning for Upright Faces and its Role in the Composite Face Effect. *Journal of Experimental Psychology: Animal Learning and Cognition*.

Civile, C., Quaglia, S., Waguri, E., Ward, W., McLaren, R., and McLaren, I.P.L. (2021). Using transcranial Direct Current Stimulation (tDCS) to investigate why Faces are and are Not Special. *Scientific Reports*, *11, 4380*.

Diamond, R. & Carey, S. (1986). Why faces are and are not special: An effect of expertise. *Journal of Experimental Psychology: General, 115, 107-117.*

Farah, M., Wilson, K., Drain, H. & Tanaka, J. (1995) The inverted face Inversion effect in prosopagnosia: evidence for mandatory, face- specific perceptual mechanisms. *Vision Research* 35, 2089–2093.

Hole, G., George, P. A., & Dunsmore, V. (1999). Evidence for holistic processing of faces viewed as photographic negatives. *Perception*, 28, 341–359.

Leder, H., & Bruce, V. (1998). Feature processing from upright and inverted faces. In Face Recognition (pp. 547-555). Springer, Berlin.

McLaren, I.P.L (1997). Categorization and perceptual learning: An analogue of the face inversion effect. *Quarterly Journal of Experimental Psychology 50, 257-273.*

McLaren, I.P.L., and Civile, C. (2011). Perceptual learning for a familiar category under inversion: An analogue of face inversion? In L. Carlson, C. Hoelscher, & T.F. Shipley (Eds.), *Proceedings of the 33rd Annual Conference of the Cognitive Science Society*, (pp. 3320-25). Austin, TX: Cognitive Science Society.

Maurer, D., Le Grand, R., and Mondloch, C. (2002). The many faces of configural processing. *Trends in Cognitive Science, 6, 255–260*.

McCourt, S., McLaren, I. P. L., & Civile, C. (2021). Perceptual Processes of Face Recognition: Single feature orientation and holistic information contribute to the face inversion effect. In Proceedings of the Cognitive Science Society (Vol. 43, No. 43).

Murphy, J., Gray, K. L. H., and Cook, R. (2017). The composite face illusion. *Psychonomic Bulletin & Review*, 24, 245-261.

Stanislaw H, & Todorov N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods Instruments & Computers* 31, 137-149.

James W. Tanaka & Martha J. Farah (1993) Parts and wholes in face recognition, The Quarterly Journal of Experimental Psychology, 46:2, 225-245.

Tanaka, J. W., & Sengco, J. A. (1997). Features and their configuration in face recognition. *Memory & Cognition*, 25, 583–592.

Valentine, T., & Bruce, V. (1986). The effects of race, inversion and encoding activity upon face recognition. *Acta Psychologica,* 61, 259–273.

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

Yovel G., & Kanwisher N. (2005). The neural basis of the behavioral face-inversion effect *Current Biology,*15,2256- 62.