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Perceptual Processes of Face Recognition: Single feature orientation and holistic information contribute to the face inversion effect

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Abstract

In this study (n=144) we investigated the perceptual processes that are the basis of the face inversion effect (better recognition for upright vs inverted faces). We evaluated the effects of disrupting configural information (i.e., the spatial relationships among the main facial features) and disrupting holistic information indexed by the face outline. We used scrambled faces which are characterized by a disruption of configural information and scrambled no-contour faces which in addition to disrupted configural information they also suffered of disruption of the face outline. Using an old/new recognition task we obtained a robust inversion effect for scrambled faces. No significant inversion effect was found for scrambled no-contour faces. Our results provide direct evidence that holistic information plays a significant role in the inversion effect. We also confirmed that it is possible to obtain a robust inversion effect when configural information is disrupted.

Keywords: Face Recognition, Face Inversion Effect, Configural Processing

Introduction

The study of face recognition has led to a debate about the nature of the processing involved, which is generally divided into two camps. The first asserting that there are specialised mechanisms that are unique to the processing of faces, and the other that face recognition skills are based on general mechanisms that are also used for non-face stimuli. Key to this debate is the face inversion effect (FIE), which refers to a reduction in performance when we try to recognize upside-down faces (i.e., inverted) compared to when presented in their usual upright orientation (Yin, 1969; Civile, McLaren & McLaren, 2014; Civile, McLaren & McLaren, 2016; Civile, McLaren & McLaren 2011). When it was first discovered, this deficit to recognition for inverted stimuli was reported to be greater for faces than for non-face stimuli like for example images of houses, airplanes and cars (Yin, 1969; Valentine & Bruce, 1986; Yovel & Kanwisher, 2005). Thus, initially the FIE was attributed to some specific mechanism unique to face processing making their encoding highly reliant on orientation, thus causing them to be severely disadvantaged by inversion.

This interpretation was challenged by Diamond and Carey (1986) who found that an inversion effect equivalent to that for faces can be observed using dog images when presented to dog breeders (i.e., dog "experts"). Diamond and Carey (1986) posited that useful to recognition are three distinct types of information: isolated features e.g., the nose, first-order relational features e.g., the nose in relation to the mouth, and second-order relational features e.g., the variation in first-order relational features in comparison with the prototype of that stimuli set. They argued that isolated features and first-order information are used to distinguish a group of facial features as a face (and are largely consistent across all faces), but that second-order relational information is required to recognise faces as distinct from each other. Their results led to the proposition that expertise with a prototype-defined category, rather than face-specific processing, is what causes the FIE. In particular, it is our life-long expertise at exploiting the configural information in upright faces that enhances our ability to recognise them. Inversion disrupts our ability to exploit this configural information leading to poorer performance.

Gauthier and Tarr (1997) provided additional support for this account by generating a set of artificial novel stimuli named Greebles that were specifically designed to match as closely as possible the configural constraints of faces and offer comparable levels of visual homogeneity, difficulty in recognition and development of expertise. They demonstrated that for these stimuli, subjects who have been made experts through training were more greatly disadvantaged by inversion than were novices. McLaren (1997) and then McLaren and Civile (2011) and Civile, Zhao et al (2014) further developed the research on expertise and the inversion effect by showing that it is possible to obtain a robust inversion effect for prototype-defined categories of non-mono-orientated (they do not have a predefined orientation) checkerboards after subjects had been pre-exposed to that category. This strengthened the argument that expertise with stimuli that share a configuration is a key factor contributing to the inversion effect. As a consequence, researchers then set about investigating how specific manipulations aiming to alter configural processing and/or featural processing would influence the inversion effect for face and object stimuli.

Convincing evidence that disruption of configural information occurs during inversion is provided by Searcy and Bartlett (1996). They conducted an experiment in which they used stimuli that had been made grotesque by disrupting either the local features; (e.g., blackening and discolouring teeth, reddening the pupils of the eye), or the configuration of the facial features; (e.g., moving their eyes/mouth up or down). When asked to rate the grotesqueness of these sets of stimuli subjects deemed those with configural changes to be less grotesque (compared to normal) when inverted, whilst those with the local features distorted were rated as equally grotesque inverted as they were upright. This indicated that processing of the configural changes was more greatly disrupted by inversion than were local changes. Similarly, Leder and Bruce (1998) distorted either the local features or configural information of faces to make them more distinct. Perceptions of distinctness caused by distorted configural information disappeared when the faces were inverted relative to when they were upright or caused by distortion to local features. These results are consistent with the notion that configural information is a key component to the FIE.

Tanaka and Farah (1991) conducted a direct assessment of the specific roles of first and second-order relational information using prototype-defined categories of dot patterns. Hence, they generated dot patterns that differed in the extent to which their processing required second-order relational information, with some being created as variations of a prototype and some not prototypical. Subjects were trained to identify the first-order and second-order patterns by male or female names, and subsequently tested on their identification of these patterns. An inversion effect was found for both groups and did not differ between the first and second-order patterns, even when prototypical exemplars were altered to share a higher degree of configuration with one another. They interpreted this finding as in contrast of the Diamond and Carey (1986) theory that second-order relation information is that which becomes increasingly sensitive to inversion with experience and concluded that both first and second-order relational information may contribute to the FIE. Further support for this is provided by Tanaka and Sengco (1997), who theorised that when featural and configural information are combined and the stimuli is viewed as a *holistic* image, then disruption to configural information ought to impact recognition of individual features. To test this, subjects were trained with upright faces, some of which had the configural information altered by manipulating the distance between the eyes. It was found that disruption of configural information resulted in difficulty recognising individual features (even those which has not been subject to the disruption) and that this disadvantage was not present when the faces were inverted. The authors concluded that changes to second-order relational information affects recognition of individual features only in upright faces.

In 2014, Civile et al conducted an experiment to assess whether configural information is essential to the inversion effect and whether without it no inversion effect would exist. They created face stimuli with scrambled features such that the eyes, nose, mouth, and ears were rearranged into a different configuration than normal. In Experiment 1b the scrambled faces were designed to conform to one of four prototype categories each with a different configuration of facial features. They used an old/new recognition task, typically used to study the FIE. In a study phase, subjects were presented with a series of normal and scrambled faces to memorise and then, in a recognition phase, were presented with those same stimuli along with a new set not previously seen. They were asked to identify whether or not a stimulus had been seen in the study phase. They discovered that the disruption to all configural information through scrambling the faces was not sufficient to eliminate the FIE. The inversion effect for scrambled faces was as robust as that found for normal faces. Following from this, Civile et al (2014) created new stimuli named "50% Feature-Inverted and Scrambled faces" by inverting half of the facial features on the previously used scrambled faces. This meant that 50% of the features were upright no matter the overall orientation of the face which allowed for the assessment of the role of individual features in the inversion effect. If featural information plays a main role in determining the FIE then these new stimuli should result in an elimination of the inversion effect, as half of the features are always upright and half inverted. This result was found and importantly, recognition for these stimuli was significantly above chance. Thus, these stimuli served as a baseline for the inversion effect obtained for scrambled faces which was found to be significantly larger. Overall, Civile et al (2014) demonstrated that after disruption of the configural information the FIE still remains robust, it is only when the *single feature orientation* information is disrupted that the FIE is abolished.

Expanding on this work, Civile et al (2016) investigated whether or not configural information is at all essential to obtain the FIE. In order to control for the effect of single feature orientation information they created categories of "new Thatcherized" faces. The original Thatcher illusion manipulation involved rotating the mouth and each of the eyes (individually) by 180° (Thompson 1980; Civile et al., 2012). However, Civile et al (2016) introduced a new manipulation where they rotated (by 180°) one eye (including eyebrow), one ear, and either the nose or mouth of sets of normal faces. The features that had been rotated were counterbalanced so to create four different sets or categories of new Thatcherized faces, each represented by a prototype. Exemplar faces drawn from a particular category shared the same orientation of the features with the category prototype. This manipulation balances the number of features that are upright in a face (whether the face itself is inverted or not), thus controlling for the effect of individual features on inversion to an extent that has been shown to be effective in Civile et al (2014)'s experiments. Importantly, this manipulation affects second-order relational information by leaving the first-order relational information relatively unaltered. Direct comparison of the FIE for scrambled faces in Civile, et al. (2014) and that for new Thatcherized faces showed that, as previously seen, a robust inversion effect was found for scrambled faces and provided evidence for that claim that an inversion effect exists for new Thatcherized faces also. An additional experiment was conducted comparing the inversion effect for Civile et al. (2014)'s 50% Feature Inverted and Scrambled faces and new Thatcherized faces. These results confirmed that new Thatcherized faces do produce an inversion effect and that this is significantly greater than that for the baseline stimuli which did not produce an inversion effect. Taken together these results demonstrate that when local feature orientation is controlled for, but first-order relational information is unaltered a FIE is produced, indicating that first-order relational information has a causal role in the production of the FIE. Furthermore, they show that only when both configural and local feature information are manipulated is the inversion effect eliminated entirely. Civile et al (2016) proposed that first-order configural information is that which engages holistic processing for familiar (upright) faces, thus when new Thatcherized faces are upright they are processed holistically due to their first-order configural information remaining intact, giving them an advantage, but when inverted they are no longer processed holistically and the orientation of their individual features becomes more important to recognition, reducing performance. This interpretation is based on Hole, George, and Dunsmore's (1999) theory in support of two distinct types of relational processing that contribute to face recognition, one being holistic processing and the other configural. It is proposed that holistic processing occurs in response to stimuli that follow the rough plan of a face and is that which denotes them as being a face. Configural processing on the other hand relates to the specific position of individual facial features in relation to one another. As such, upright new Thatcherized faces may induce holistic processing as they still conform to the basic outline of a face. Importantly, Hole et al (1999)'s theory of holistic processing could be elicited also by scrambled faces as despite the features being shuffled, the outline (i.e., the contour) of the faces is relatively unaltered.

The current work aims to assess directly the impact that holistic information has on the FIE. In order to do so, we directly manipulated the outline of the same scrambled faces used in Civile et al (2014) and Civile et al (2016) by eliminating the face contour. We then compared the inversion effect for these scrambled no-contour faces vs that for "normal" scrambled faces.

Method

Subjects

Overall, 144 subjects (55 male, 89 female; Mean age = 21.7, age range = 16-57, *SD* = 6.39) took part in the study. 72 of these were students at the University of Exeter who were recruited through the university online recruitment SONA system and participated for course credit. Another 72 were recruited through the third-party recruitment service Prolific and received monetary compensation adhering to the fair pay policies of Prolific Academic. Analyses with *Recruitment* as a factor (SONA or Prolific) showed no main effect ($F[1, 142] = .262$, $p = .60$, $\eta^2_p < .01$) and it did not interact significantly with any other factors in the study (max. $F[1, 142] = 2.57$, $p = .11$, $\eta^2_p = .018$) uncorrected for multiple comparisons). The sample size was determined from earlier studies that used the same categories of scrambled faces, counterbalance of the stimuli, and behavioural paradigm (Civile et al., 2014; Civile et al., 2016). We also conducted a post-hoc power analysis for our sample size using G*Power software, based on the effect size (η^2_p=.030) recorded from the overall 2 x 2 interaction (*Face Type* x *Orientation*). This revealed a statistical power >.99 (Effect size $f = 0.65$, 1 group, 2 measurements [*Face Type*, *Orientation*]).

Materials

The study used the sets of scrambled faces adopted in Civile et al (2014), Civile et al (2016) and Civile, Elchlepp et al (2018). The original set consists of 128 male faces with neutral expression and the hair cropped, standardized to a greyscale colour on a black background. Four categories of scrambled faces were constructed so as to conform to a prototype—that is, a particular configuration, but not the normal one that subjects would be familiar with. Six facial features were used for creating the scrambled exemplars—that is, the mouth, nose, two ears, and two eyes (including eyebrows). Each of the four categories of scrambled faces was represented by a particular configuration. The scrambling manipulation consisted of selecting one of the six facial features at random, then moving it to the forehead chosen because this is the widest space inside the face that can accommodate any feature. After this, a second feature was selected and moved to the space left empty by the first feature, and so on until all six facial features had been moved, but their orientation remained the same (i.e., upright). Within an individual category, all the scrambled faces shared the arrangement of the features in common with the prototype. Using the four categories of scrambled faces we created the scrambled no-contour faces by blurring the outline of the faces (Figure 1). The faces were manipulated using Gimp 2.10 and all stimuli were 7.95cm x 6.28cm. Subjects were presented with stimuli drawn from only one category of scrambled faces (upright and inverted) and one different category of scrambled no-contour faces (upright and inverted). The four categories of scrambled and no-contour scrambled faces were counterbalanced across eight participant groups as in Civile et al (2014) and Civile et al (2016)'s studies. The study was run remotely using the online platform Gorilla.

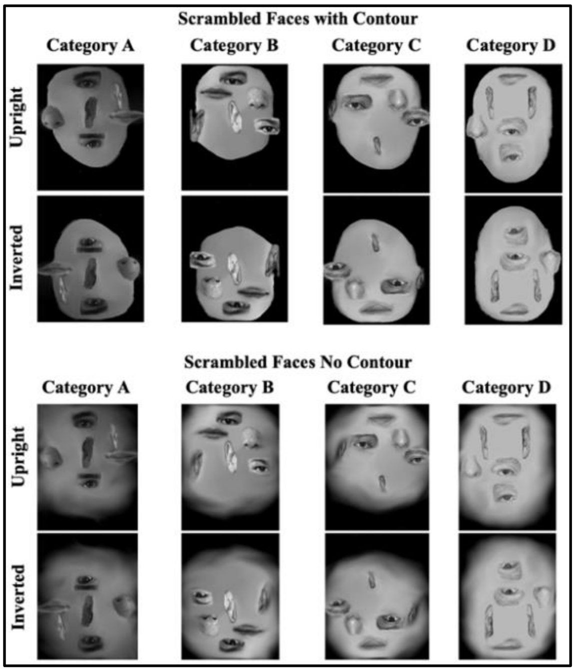

Figure 1. Examples of stimuli used in the study showing one stimulus from each category, upright and inverted. Each exemplar from a given category has the same featural configuration.

The Behavioral Task

We used the same old/new recognition task paradigm as that adopted in Civile et al (2014) and Civile et al (2016). This consisted of a study phase in which subjects were presented with 64 faces split by the four stimulus' conditions (16 upright scrambled, 16 inverted scrambled, 16 upright scrambled no-contour, 16 inverted scrambled no-contour) presented one at a time, in random order. Each trial consisted of a fixation cue presented in the centre of the screen (1s) followed by a face (3s). During the study phase subjects were instructed to try to memorise the faces and no response was required from them. After further instructions, subjects then began an old/new recognition phase. This consisted of 128 face stimuli, 64 were the faces previously shown in the study phase and 64 were novel stimuli, also evenly split between the four stimulus' conditions. During this phase faces were once again shown one at a time, in random order. Following a fixation cue (1s) a face was presented for 3 seconds, and subjects responded by pressing either "." or "x" (depending on the counterbalanced condition) to indicate whether or not they thought they had seen the face in the study phase. If subjects did not respond within 3 seconds, they were timed out with the feedback "too slow" and the next trial began.

Results

Our primary measure was performance accuracy. The data from all the subjects in a given experimental condition was used to compute 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. To calculate d', we used subjects' hit rate (proportion of YES trials to which the participant responded YES) and false alarm rate (proportion of NO trials to which the participant responded YES). Intuitively, the best performance would maximize H (and thus minimizes the miss rate) and minimizes FA (and thus maximizes the correct rejection rate); thus, the larger the difference between H and FA, the better is the subject's sensitivity. The statistic d' is a measure of this difference; it is the distance between the signal and the signal + noise distributions. However, d' is not simply H – FA; rather, it is the difference between the z transforms of these two rates: d' = z(H) – z(F) where neither H nor FA can be 0 or 1 (if so, they are adjusted slightly up or down).

Each p-value reported is two-tailed, and we report the F or t value along with measures of effect size (η^2_p). We assessed performance against chance (*d'* of 0) which showed that both types of upright faces (scrambled and scrambled no-contour) were recognized significantly above chance (for each condition we found a $p < .001$). Performance against chance for inverted no-contour scrambled faces showed a trend towards significance (p = .052) whereas just like in Civile et al (2014) and Civile et al (2016) inverted scrambled were not recognized significantly above chance (p = .45). We analyzed 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 *Face Type* (scrambled, scrambled no-contour) x *Orientation* (upright, inverted) as factors revealed a significant interaction, *F*(1, 143) = 4.41, p = .037, η^2_p = .030. A significant main effect of *Orientation* was found (upright better), *F*(1, 143) = 17.28, p < .001, η^2_p = .108. No significant main effect for *Face Type* was found, *F*(1, 143) = .63, p = .425, η^2_p < .01. As in Civile et al (2014) and Civile et al (2016) follow up, paired samples *t*-tests were conducted to compare performance on upright and inverted faces i.e., the face inversion effect, for each face type. We found a large inversion effect for scrambled faces with performance for upright (*M* =.31 *SD* =.48) significantly better than that for inverted scrambled faces (*M* = .04 *SD* = .53), *t*(143) = 4.71, p < .001, η^2_p = .036. Although performance for upright scrambled no-contour faces (*M* = .19 *SD* = .57) was numerically higher than that for inverted ones (*M* = .09 *SD* = .51) no significant inversion effect was found, *t*(143) = 1.62, p = .107, η^2_p = .239. The significant interaction can thus be interpreted as being due to a reduced inversion effect in the scrambled no-contour faces (Figure 2).

Importantly, in similar fashion to Civile et al (2014) and Civile et al (2016), we directly compared performance for upright scrambled faces vs that for upright scrambled no-contour faces and for inverted scrambled faces vs inverted scrambled no-contour faces. These comparisons are particularly appropriate because the same stimulus sets are rotated across participants in a counterbalanced manner; so that for each upright or inverted face seen in a scrambled condition for a given participant will equally often serve as an upright or inverted face in the scrambled no-contour condition. Performance for upright scrambled faces was significantly higher than that for scrambled no-contour faces, *t*(31) = 2.07, p = .040, η^2_p = .029. No significant difference was found between inverted scrambled and inverted scrambled no-contour faces, *t*(31) = .846, p = .399, η^2_p < .01.

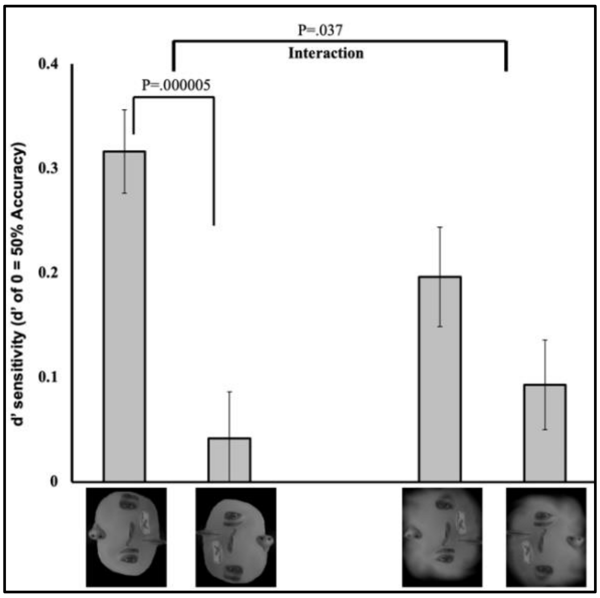

Figure 2. The x axis shows the four different stimulus categories. The y axis shows the mean d' for each of these four stimulus conditions in the recognition phase. Error bars show SE of the mean.

Discussion

In the current paper we report the results from a large behavioural study where we investigated the perceptual processes at the heart of one of the most robust phenomena in the face recognition literature i.e., the face inversion effect. Specifically, we measured the influence of configural and holistic processing in determining the inversion effect. Our work follows on from a series of previous studies conducted by Civile et al (2014) and Civile et al (2016) where clear evidence was found in support of an inversion effect for sets of faces that had their configural information disrupted through the scrambling manipulation. In our study we provided additional evidence for this effect, and so confirmed that it is possible to obtain a robust inversion effect for scrambled faces. This finding suggests that configural information is not necessary to obtain a significant inversion effect. The critical finding from our study is that when holistic information, indexed by the face contour, is removed, then the inversion effect for scrambled faces is no longer significant. Hence, we find a significant interaction between the inversion effect for scrambled vs that for scrambled no-contour faces. This finding suggests that holistic information plays an important role in determining the inversion effect.

Our results contribute directly to the face recognition literature in two main ways. Firstly, from Civile et al (2014) we know that single feature orientation information is important in the inversion effect. The authors showed that the robust inversion effect for scrambled faces was significantly reduced only when single *feature orientation information* was disrupted. Hence, three of the features within the scrambled faces were turned upside down, and three were presented upright. Thus, whether the scrambled faces were presented upright or inverted, half of the features would be always upright and half inverted. Our results introduce a new manipulation able to significantly reduce the robust inversion effect for scrambled faces i.e., disruption of the face outline. We now know that *single feature orientation* and *holistic information* indexed by the face contour, are both critically important in determining the face inversion effect.

Secondly, our results provide additional support to theories that distinguish between configural and holistic processing. Hence, some authors have taken configural and holistic processing as part of the perceptual process and used the two terms interchangeably, or as holistic processing specifically being an additional type of configural processing (for a review see Maurer, Le Grand, & Mondloch, 2002). A different approach was that proposed by Rossion (2008) which referred to configural processing as the physical information that can be manipulated by changing the spatial relationships among the main facial features (e.g., scrambling the face). Instead, with the term holistic processing, the author referred to the simultaneous integration of the several features of a face into a single perceptual representation. Thus, according to this proposition the facial features are interdependent, so the perceiver cannot focus on one feature only of the face without being influenced by the other features at the same time. In a similar vein, as mentioned in the introduction of this paper, Hole et al (1999) suggested configural and holistic processing as two distinct types of processes that both contribute to face recognition. Specifically, holistic processing is elicited by any source of the information that would conform to the basic outline of a face, and importantly it is holistic information that establishes that the stimulus is a face as opposed to other types of non-face stimuli. Configural processing, on the other hand, depends on the specific locations of the facial features relative to one another.

Our results support the view that has configural and holistic processing defined as different types of perceptual processes. Based on Hole et al (1999)'s theory, we find that the face contour is essential information that upright scrambled faces benefit from despite having their configural information disrupted. It would seem that it is the contour of the scrambled faces that elicits face-like perception leading to holistic processing that benefits discrimination of upright scrambled faces. This can be directly observed in the statistical analysis conducted here where we compared performance for upright scrambled vs upright no-contour scrambled faces. Removing the face contour significantly reduced performance for upright no-contour scrambled faces relative to upright scrambled faces. No difference was found when we compared performance for inverted scrambled faces to that for inverted no-contour scrambled faces.

Future studies should investigate the specific sources of information that elicit holistic processing. Civile et al (2016) for example, suggested that first-order configural information may elicit holistic processing which would then help recognition of upright new Thatcherized faces. The authors found no differences between the inversion effect for scrambled faces and that obtained for the new Thatcherized faces. Our results are consistent with that finding in showing that the inversion effect for scrambled faces is based on holistic information in addition to the single feature orientation information as demonstrated by Civile et al (2014). Our results also suggest that it may not just be the first-order configural information but also the contour of the faces that engages holistic processing for new Thatcherized faces (where single feature orientation information is controlled by having 3 upright and 3 inverted features) leading to the inversion effect that the authors have repeatedly found. Future work could investigate that directly, by removing the face contour of the new Thatcherized faces and see if a significant inversion effect is still obtained.

A final consideration regards the extension of our findings to a recent line of research that uses transcranial Direct Current Stimulation (tDCS) to study face recognition. In 2016, Civile, Verbruggen et al (2016) showed that anodal tDCS (for 10 mins at 1.5mA) delivered over the left dorsolateral prefrontal cortex at prefrontal area Fp3 during the same old/new recognition task used by Civile, Zhao et al (2014) reduced the checkerboard inversion effect. This was due to reduced recognition performance for upright checkerboards compared to sham (control) participants. The specific tDCS montage was selected based on previous studies that used this montage to modulate performance during a checkerboard category learning task (Ambrus et al., 2011; McLaren et al., 2016). Importantly, Civile et al (2018), Civile et al (2019), Civile, Cooke et al (2020), Civile, Waguri et al (2020), Civile, McLaren et al (2020) and Civile, Quaglia et al (2021) extended the tDCS procedure to an old/new recognition task this time testing the inversion effect for normal faces. The authors found a reduction (compared to sham) of the FIE after anodal stimulation, in this case also due to an impaired recognition performance for upright faces. These results provided evidence that the inversion effect for checkerboards and that for faces share at least some of the same causal mechanisms. Importantly, whereas the same tDCS procedure completely 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. In further work, Civile, McLaren et al (2021) extended the same tDCS procedure to examine the composite face effect 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 in face recognition (for a review see Murphy et al., 2017). Civile, McLaren et al (2021) found no effect of tDCS on the composite face effect 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 this study add to this literature by suggesting that holistic information is important in determining the FIE, and that it may be the holistic information engaged by the face contour that gives rise to the remaining inversion effect in Civile et al (2018). Future work should extend our contour removal manipulation to the normal faces used in Civile et al (2018) and examine whether the tDCS procedure would in that case further reduce the FIE.

In conclusion, we provided here some evidence in support of the importance of the face contour when individuals try to recognize a series of faces that do not share a familiar configuration. This suggests that configural information is not the only type of information we rely on when called upon to recognise others' faces.

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