Unconscious fearful body expression perception enhances discrimination of conscious anger expressions under continuous flash suppression

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Abstract

The continuous flash suppression (CFS) paradigm has been increasingly used to study unconscious visual perception. To compare to lesion and backward masking studies, we bilaterally presented whole-body postures expressing fear or anger in an emotion discrimination task, and rendered the stimuli invisible in one of the visual fields. We found that the CFS paradigm did not sustain the classical redundant target effect that would facilitate responses when the unconscious emotional bodies had congruent emotions; instead we found a facilitation effect on reaction times induced by the body stimuli of incongruent emotions, especially by the unconscious fearful body on the discrimination of conscious angry body. Our result with healthy participants showed similarities to hemianopia patients without blindsight, but not to blindsight or neglect patients, indicating that unconscious visual processing is not a single phenomenon, but is likely to involve multiple processes and brain regions. Further studies are necessary to validate the facilitation effect of fearful bodies on other tasks, and to study the neural substrates of this effect.

Keywords

Continuous flash suppression, emotion, body perception, redundant target effect, visual awareness

Introduction

Unconscious visual perception is a topic that has long fascinated researchers. The dissociations between behavior and subjective awareness seen in studies of patients with brain lesions contribute to our understanding of unconscious processes in the intact brain. Patients lose conscious visual perception due to variable lesions in different locations of the brain, and the residual visual behavior may be different or not always have the same neural basis. Blindsight patients with V1 lesions could not report the presence of a visual target in the contralesional visual field, but could still react to the visual target above chance level (Danckert & Rossetti, 2005; Weiskrantz, 1986). Patients with neglect usually due to parietal lesions would not consciously perceive a contralesional stimulus when another salient target was present in the ipsilesional visual field, unless explicitly asked to direct their attention to the contralesional side (Corbetta & Shulman, 2011; Driver & Vuilleumier, 2001). This makes the phenomenon of vision without awareness much more complex that assumed in the distinction between conscious and non-conscious perception.

The redundant target effect has been established in healthy participants under conscious viewing conditions, that bilaterally presenting two targets would facilitate the reaction times (RTs) comparing to one-target conditions (Miller, 1982; Raab, 1962). Since loss of visual awareness for these patients is visual field-specific, many patient studies have presented a redundant stimulus in the blind visual field, in addition to a stimulus in the intact visual field, as a means of testing residual vision in an indirect fashion. An effect of the redundant emotional target has been found in both blindsight patients and neglect patients. With blindsight patients, previous studies found that the RTs for detecting the emotional faces (fear and sad) in the intact visual field were shortened when faces with congruent expressions were shown in the blind field (de Gelder, Morris, & Dolan, 2005; de Gelder, Pourtois, van Raamsdonk, Vroomen, & Weiskrantz, 2001). With neglect patients, emotional faces were extinguished less than neutral faces (Vuilleumier & Schwartz, 2001). When extinguished, fearful faces activated the amygdala similar to when they were visible (Vuilleumier, et al., 2002). When priming a visible target face (happy, sad) with extinguished emotional faces, primes with congruent emotion to the target elicited faster RT than incongruent emotions (Williams & Mattingley, 2004). However, with hemianopia patients that had unilateral lesions but did not show any classical blindsight effects, studies did not find a redundant target effect, instead found a facilitation effect of fearful faces in the blind visual field, for detecting happy faces in the intact visual field and enhancing its N170 component of ERP (Bertini, Cecere, & Ladavas, 2013; Cecere, Bertini, Maier, & Ladavas, 2014). They found that this facilitation effect was even present for non-emotional tasks, including gender discrimination and orientation discrimination of Gabor patches in the intact visual field (Bertini, et al., 2013; Bertini, Cecere, & Ladavas, 2017). In two of the three studies, the facilitation was found only for patients with left hemispheric lesions (Bertini, et al., 2017; Cecere, et al., 2014).

Because patients with lesions are rare, several methodological paradigms have been applied to study unconscious processes in healthy participants, including masking and binocular rivalry.

Masking has been applied to induce blindsight-like effects. When fearful and happy faces were bilaterally presented, with one visual field masked to emulate the blind visual field, the masked faces with congruent emotion to the visible faces showed a redundant target effect: a shortening of the reaction time (RT) (M. Tamietto & de Gelder, 2008). When the stimuli were bilaterally presented and consciously perceived by healthy participants, a facilitation effect for congruent emotional face stimuli was also observed (M. Tamietto, Latini Corazzini, de Gelder, & Geminiani, 2006).

However, the strength of masking has the risk of not fully rendering stimuli subliminal (Kouider & Dehaene, 2007), and the duration of the stimulus dominance in binocular rivalry was not stable, and not freely controllable by the participant (Tong, Meng, & Blake, 2006). Another recently developed method is continuous flash suppression (CFS). Utilizing interocular competitions similar to binocular rivalry, the subjective percept of a low-contrast target stimulus in one eye could be suppressed by a high-contrast and dynamic noise pattern in the other eye. Compared to backward masking and binocular rivalry, CFS has stronger suppression strength, and could reliably render a stimulus invisible for a few seconds (Tsuchiya & Koch, 2005; Tsuchiya, Koch, Gilroy, & Blake, 2006). With the CFS paradigm, blindsight-like percepts, and dissociations between neural activity and percept have been found for emotional stimuli with healthy participants. For example, fearful faces have been found to break from CF-suppression (b-CFS) and enter into awareness faster than neutral and happy faces (Yang, Zald, & Blake, 2007), and could induce amygdala activation when suppressed under CFS (Jiang & He, 2006).

Similar to faces, the human body is also a category conveying information of identity and emotion. Because of the behavioral relevance, body stimuli have also been used as an effective tool to probe unconscious visual processing. For blindsight patients, both neutral body and face stimuli induced BOLD activation in the superior temporal sulcus and the amygdala (J. Van den Stock, et al., 2014). When presented to the blind field, happy and fearful bodies and faces could both trigger fast facial muscle and pupillary reactions (M. Tamietto, et al., 2009); angry dynamic body expressions could activate not only primary somatosensory, motor and premotor areas, but also in bilateral superior colliculi, pulvinar, amygdala and the right fusiform gyrus (Jan Van den Stock, et al., 2011). In neglect patients, when two stimuli were presented simultaneously in the two visual fields, bodies expressing fear were less extinguished than bodies expressing happiness, when presented to the contralesional visual field, showing an attention-grabbing effect (Marco Tamietto, Geminiani, Genero, & de Gelder, 2007). Extinguished fearful bodies also induced activation in extrastriate body areas and the left amygdala (M. Tamietto, et al., 2015). When investigating this in healthy participants, we also observed under the b-CFS paradigm that fearful bodies showed a longer suppression time than neutral bodies, while angry bodies were suppressed shorter, indicating different unconscious/preconscious processing of these two bodily emotions (Zhan, Hortensius, & de Gelder, 2015).

To further study the unconscious emotional body processing, and to compare to both previous patient studies and masking study of healthy participants, here we used the redundant target paradigm together with CFS. Wee bilaterally presented fearful and angry bodies under CFS in an emotion discrimination task, and suppressed one of the visual fields to emulate the effect of a blind visual field. We observed a facilitation effect of RT for unconscious emotional bodies incongruent to the emotion of the conscious targets, and this facilitation effect was present especially when the conscious targets were angry and the unconscious stimuli were fearful bodies.

Materials and method

Participants

Forty-one participants took part in the study. Forty participants had normal stereo and color vision, and normal or corrected-to-normal visual acuity. None of the participant had a history of neurological disorders. The participants provided written consents, and received either monetary or course credit rewards after participation. The experimental procedures were approved by the ethics committee of Maastricht University, and the experiments were carried out in accordance to the declaration of Helsinki. The following participants' data were excluded from the analyses: one participant had a lazy eye; two participants saw the stimuli in the noise; another two participants did not see any suppressed stimuli but saw two boxes once and twice respectively during the experiment, indicating imperfect merging; another participant had only 5 trials of correct responses. In total 35 participants' data were included in subsequent analysis (mean age=21.97, range 18-27 years, 4 males, 3 left-handed). These participants were not aware of the presence of suppressed stimuli.

Stimuli

The images of body stimuli consisted of 6 fearful and 6 angry postures, performed by 6 actors (3 males). The stimuli were adapted from Stienen and de Gelder (2011), with facial information removed, aligned with each other at the feet level, and were all positioned at the center of a gray rectangle (160 x 240 pixels, RGB value=128,128,128). The bodies occupied a region within 131 x 193 pixels.

Procedure

The experiment was presented with Psychtoolbox 3 (Brainard, 1997; Pelli, 1997) in MATLAB (version 2012b, the MathWorks, Natick, MA, USA). For stable refresh rates and precise timing of the stimuli presentation, the experiment was presented with a 3D-capable LCD screen (Acer VG248, resolution=1920×1080, refresh rate=60 Hz). The dichoptic display of stimuli was achieved by presenting stimuli in two rectangular regions (320 x 240 pixels) side-by-side at the center of the screen, while the participants viewed the screen through a pair of prism glasses (diopter=12), which bent the light from the screen and projected the ipsilateral image to the center of the view of each eye. The background of the screen was set to gray (RGB value=128,128,128). To aid fusing of the stimuli for participants, two rectangular frames (thickness=10 pixels) were placed around the stimuli presentation regions, and two fixation crosses were placed at the center of each region. To prevent crosstalk of the two images, a cardboard was placed between the screen and the participant, which separated the screen in two equal halves. Participants rested their head on a chin rest 59 cm from the screen. Under this setup, each eye of the participant saw the content within one rectangle, and the participant's left and right visual fields corresponded to the left and right side of the fixation cross for both eyes. Upon a stable fusion of the two rectangles, participants saw one single rectangle, and one single fixation cross at the center of the screen.

To indicate the start of each trial, the fixation cross would change to white color one second before the trail, and remain white throughout the trial. Participants were instructed to keep their heads as still as possible, remain fixated on the fixation cross, and not to blink within a trial if possible.

In each trial, the same target stimulus was presented in one visual field of both rectangles. In the other visual field of one rectangle, either no stimulus (blank, baseline conditions), or a stimulus with congruent or incongruent emotion was presented. In the corresponding visual field of the other rectangle, a dynamic and colorful noise pattern (flash rate = 10Hz) was presented. The noise pattern suppressed the perception of the other stimulus in the corresponding visual field, which rendered a percept of only one stimulus presented side by side with a noise pattern. The noise pattern consisted of overlapping small rectangles of different colors (height and width within 20x15 pixels). Six hundred unique noise images were created, and were randomly selected for each individual trial.

To decrease the possibility that the target stimulus escape suppression, the target stimulus was faded in from 0% to 50% contrast in 0.5 s, and then faded out to 0% contrast in 0.5 s. Participants performed the 2AFC task, where they reported the emotion they saw in the non-noise side as quickly but as accurately as possible during stimulus presentation, by pressing one of the two buttons (numpad button 1 and 2). If the participant didn't make a response, the noise would continue to flash for 2 more seconds after the target stimulus faded out. Thus the response window was 3 s upon stimulus onset. To eliminate the possibility of seeing afterimages in the suppressed visual field, the noise pattern would be presented in both eyes for 1 more second immediately following the participant's response, or after the response window closed. The inter-stimulus interval was jittered amongst 3.5, 4, 4.5, 5, 5.5 seconds.

There were 6 conditions of suppressed stimuli and a total of 192 trials: fear-congruent, fear-incongruent, fear-blank, anger-congruent, anger-incongruent, anger-blank. To balance the number of times that a certain stimulus was seen, the congruent and incongruent conditions had 24 trials each, and the blank conditions had 48 trials each. For the same reason, the noise pattern was presented in the right eye for congruent and incongruent trials, and was presented in the left eyes for blank trials. The visual field that the noise pattern was project into was balanced across trials, and later served as a factor in the analysis. See **Figure 1** for stimuli and conditions.

For the conditions where two bodies were presented in the same rectangle, the identities of the bodies were always different from each other, although both were from the same gender.

Before the actual experiment, participants underwent a short practice of 12 trials, where fearful and angry bodies different from the actual experiment were presented unilaterally (the side suppressed by the noise pattern was blank).

In the actual experiment, the button assignments (button 1 and 2) corresponding to the fear and anger responses were balanced across participants.

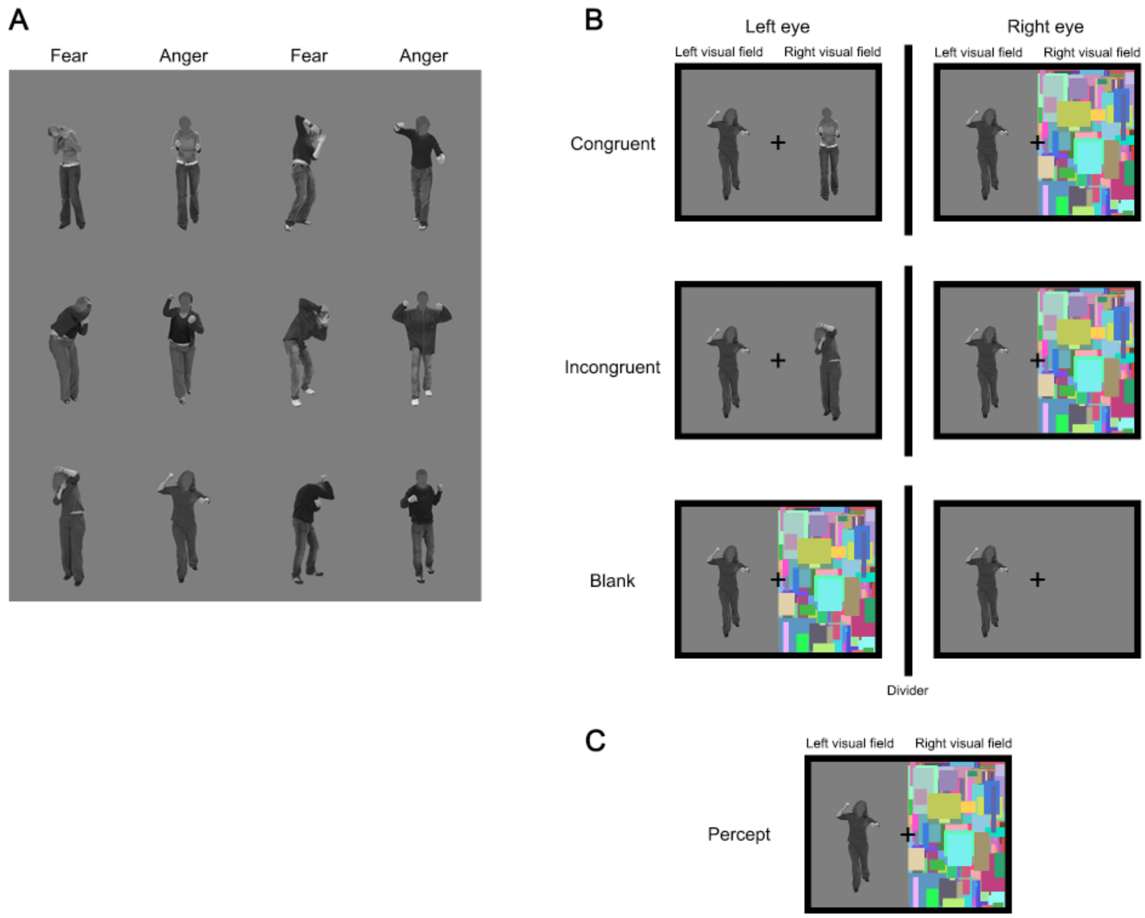

Figure 1. A. All body stimuli used in this experiment, performed by 6 actors. **B and C.** Stimuli presentation, with examples showing an angry body in the left visual field as the target, while the noise pattern suppressing stimuli in the right visual field. **B.** Conditions of angry-congruent, angry-incongruent, and angry blank. **C.** The 3 conditions in **B** all resulted in the same percept. The fearful conditions were constructed in the same way. In the experiment the visual field that the noise patterns were projected into for each trial was randomized. This figure shows right-visual-field projection of noise patterns.

Data analysis

Trials not responded (0.36% of all trials) and trials with a wrong response (5.22%) were excluded from subsequent analysis. The numbers of correct trials per condition were counted. Since the total number of trials for blank conditions and for the congruent/incongruent conditions were not the same, and the trial counts in most of the conditions were not normally distributed, two Friedman tests were performed respectively for the 4 blank conditions (fear/happy, L/R visual field that the target was projected into), and for the 8 congruent/incongruent conditions.

The average reaction times (RT) for each condition of suppressed stimuli were calculated for each visual field of each participant (LVF, RVF). For this analysis, independent of the correctness of the responses, the trials that had an RT outside 1.96 standard deviations of the average RT within each participant were also excluded (4.91% of all trials). A total of 10.49% trials were excluded for the RT analysis. The 12 conditions were then entered into a repeated-measures ANOVA with factors of conscious emotion (fear/anger), congruency (blank/congruent/incongruent), and visual field (L/R). We also performed an ANOVA by using the same inputs but coding the conditions differently, with factors of conscious emotion, unconscious emotion (blank/fear/anger), and visual field. Multiple comparisons were adjusted with the Sidak method in post-hoc simple effect analysis.

In addition, we also checked whether a Simon effect was present in the data, between the situations that the side of the button assignment was congruent with the stimulus presentation side, versus those incongruent ones (e.g. if the participant was assigned the buttons of 1=fear and 2=anger, a trial where fear was presented at the left visual field would be a congruent trial). The Simon effect on accuracy showed a trend to significance in the two-sided Wilcoxon signed ranks test, Z=-1.928, p=.054, where the accuracy for the congruent side was slightly higher. In the ANOVA conscious emotion (fear/anger) * congruency (blank /congruent/incongruent) * button congruency (congruent/incongruent), the congruent button condition showed faster RTs with a trend to significance (mean difference =0.010 s, F(1,34)=4.083, p=.051, η_p^2=.107), but did not have interactions to the other two main effects (F(1,34)=0.617, F(1,34)=0.022 respectively), thus the Simon effect was not included as a factor in the main analysis.

Results

The numbers of correct trials did not differ among the 4 blank conditions (Fblank_Lfield, Fblank_Rfield, Ablank_Lfield, Ablank_Rfield), $\chi^2(3)$=3.137, p=.371. The numbers of correct trials among 8 congruent and incongruent conditions were also not different, $\chi^2(7)$=2.294, p=.942.

The repeated measures ANOVA (conscious emotion × congruency × visual fields) for the RTs showed a main effect of congruency, F(2,68)=9.535, p=.00022, η_p^2=.219, where the incongruent conditions had a shorter RT than both the blank and the congruent ones (RT mean difference=0.014 s, p=.020, and RT mean difference=0.020 s, p=.00081, respectively). Examining fear and anger separately with post-hoc simple effect analysis, the RT of conscious angry body together with an incongruent fearful body was significantly shorter than with a congruent angry body (mean difference=0.031 s, p=.00074), and also shorter than presenting the conscious angry body alone (mean difference=0.021 s, p=.011). See **Figure 2**.

There was also a trend to significance for the interaction of conscious emotion × visual fields, $F(1,34)=3.956$, $p=.055$, $\eta_p^2=.104$. Post-hoc simple effects analysis showed that, in the right visual field, the conscious angry bodies across 3 congruency conditions in general had a longer RT than the conscious fearful bodies (RT mean difference=0.019 s, p=.023).

None of the other main effects or interactions was significant.

In the ANOVA of conscious emotion × unconscious emotion × visual fields, where the conditions were coded differently, we found a significant interaction of conscious and unconscious emotions, $F(2,68)=8.982$, $p=.00035$, $\eta_p^2=.209$. There was a trend to significance for conscious emotion × visual field, $F(1,34)=3.956$, $p=.055$, $\eta_p^2=.104$, the same to the ANOVA above. There was also a trend to significance for unconscious emotion, $F(2,68)=2.863$, $p=.064$, $\eta_p^2=.078$, where the unconscious fearful bodies had a slightly shorter RT, although pairwise comparisons were not significant.

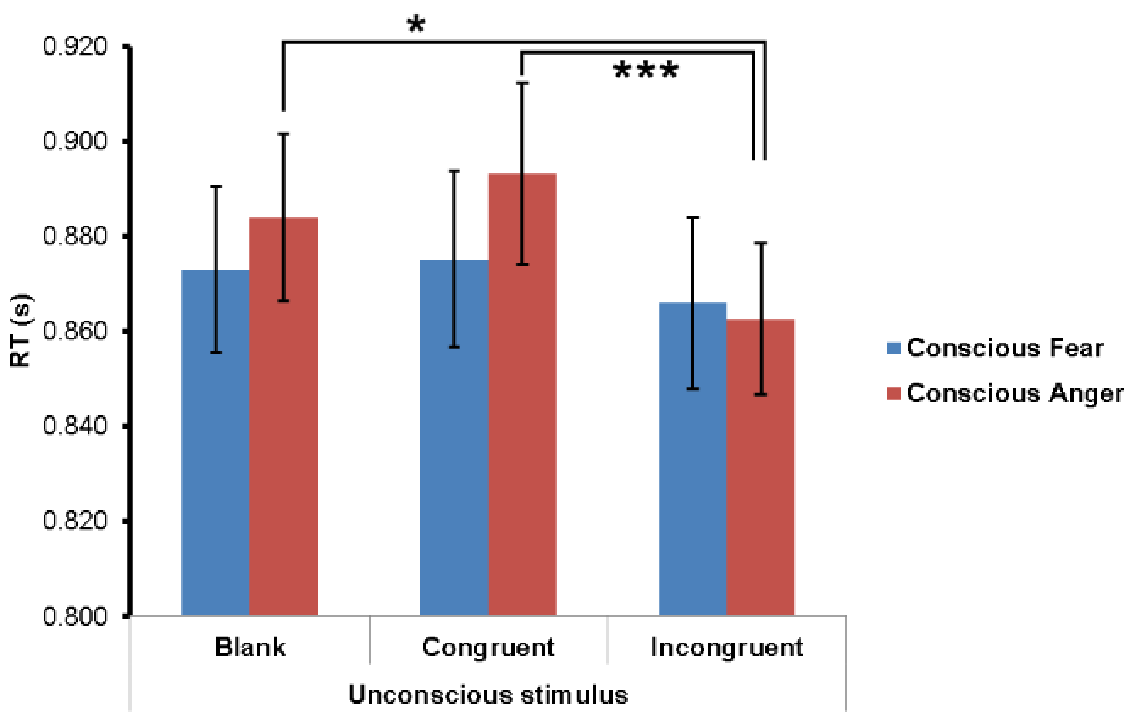

Figure 2. Reaction times (RTs) of conscious fear and anger, presented together with an unconscious stimulus, which was a blank stimulus, a congruent stimulus, or an incongruent stimulus (n=35. Error bars denote SEM. *: p<.05, ***: p<.001.

Discussion

Our goal was to find evidence for perception of emotional body expressions outside visual awareness in healthy participants by using the redundant target effect and the CFS paradigm, and to compare to patient studies. We found an interaction between the body expressions of the consciously and the unconsciously seen stimuli. We expected that here the RT would typically be shorter when comparing the congruent condition to the single-stimulus condition, in line with the traditional redundant target effect observed with stimuli under both fully visible conditions and backward-masked conditions. However, we did not find a facilitation effect by the congruent conditions, but instead found a faster RT for the incongruent conditions. This indicates that the unconscious process during CFS measured here may be sustained by different mechanisms at stake in backward masking, and under conditions of full visibility. Under CFS, the unconscious bodies were processed to some extent, but the processing was not at a level that would allow a redundant target effect to appear, unlike the findings for healthy participants with conscious perception or under masking conditions, and for blindsight patients.

The congruency effect we found appears to have a level of emotion specificity: it was more strongly shown when the consciously perceived bodies were angry ones. Unconscious fearful bodies facilitated the conscious perception of angry bodies, but unconscious angry bodies did not. Previously we found that angry bodies were suppressed for a shorter time span than the fearful bodies (Zhan, et al., 2015), which may in part explain the differential effects between the unconscious emotions observed here: the unconscious angry bodies may be more salient and therefore may act like distractors, thus slowing down the RT comparing to unconscious fearful bodies. Compared to patient studies, the facilitation effect of unconscious fearful bodies was previously found in neglect patients, where the fearful bodies in the contra-lesional side were extinguished less (Marco Tamietto, et al., 2007). However, this attention-grabbing effect of fearful bodies would indicate a slower RT for the consciously perceived emotion in our study, which we did not find. Thus, it seems that the CFS disrupts the conscious percept by a different mechanism than neglect.

On the other hand, our results showed similarities to results obtained with the hemianopia patients without blindsight. These studies found a facilitation effect for unconscious fearful faces, on both emotional and non-emotion-related tasks (Bertini, et al., 2013, 2017). In one of the studies, the fearful faces presented to the blind visual field did not show a facilitation effect when the intact field also perceived a conscious fearful face (Bertini, et al., 2013), which was similar to what we found for congruent fearful bodies. The authors postulated that the conscious presentation of fearful faces may have inhibited the unconscious processing of fear through subcortical routes (Bertini, et al., 2013). Future fMRI studies are necessary to validate this assumption. Interestingly, a follow-up study applied inhibitory transcranial direct current stimulation (tDCS) on either the vertex or the left occipital cortex (corresponding to O1 of the EEG 10/20 system) of healthy participants, both controlled with sham stimulations. Participants performed a go/no-go task to bilaterally presented emotional faces (fear, happy), masked by a neutral face. The study found that both under the sham condition and when inhibiting the vertex, the RTs for happy and fearful target faces were facilitated when the masked face had congruent emotions, a redundant target effect similar to those found in other masking and blindsight studies. However, inhibiting the occipital cortex showed a facilitation effect of masked fearful faces on target happy faces, similar to hemianopia patients without blindsight (Cecere, Bertini, & Ladavas, 2013). Given that the interocular competition utilized by the CFS paradigm is thought to occur in V1 or LGN (Tong, et al., 2006), this tDCS study presented particularly intriguing similarities to CFS.

With the CFS paradigm, two recent studies used a similar bilateral presentation design. One presented one arrow and 4 flanker arrows dichoptically, with the flanker arrows either masked with CFS or not masked. They found that the non-masked flanker arrows with direction incongruent to the target arrow slowed down the RT for the target, but this effect was abolished when the flanker arrows were suppressed, where no difference was found comparing to the conditions without flankers (Wu, et al., 2015). Another study used faded-in fearful and happy faces under CF-suppression 600 ms before presenting the target (thus was a much longer prime), while participants categorized the emotion of a visible target face presented for 200 ms. The study found a facilitation effect on RT for the unconscious faces with congruent emotions (Ye, He, Hu, Yu, & Wang, 2014). The difference between the results of these two studies may therefore be related to the different levels of their suppression under CFS, that one of them showed very strong suppression, and the other used priming effects beside the bilateral presentation.

In our case, since the traditional redundant target gain effect shown with backward-masking was not seen here under CFS, residual vision under CFS suppression is likely to be abolished more thoroughly than that with backward-masking. However, as the unconscious fearful bodies facilitate the processing of conscious angry bodies, does the amount of information transmitted under CFS allow integration between the two emotions? Because the angry and fearful bodies together have not been tested behaviorally under either conscious or masking conditions, future behavioral experiments with healthy participants would shed light on the level of integrations between these two emotions, and behavioral CFS studies with bilateral presentation are needed to see whether unconscious fearful bodies would also facilitate non-emotion-related tasks in a manner similar to fearful faces for hemianopia patients. When brain activity of healthy participants were observed under fMRI, consciously seeing two incongruent body expressions (fear and happy) induced weaker activity across the brain than seeing two congruent body expressions, indicating interference between the incongruent emotions (de Borst & de Gelder, 2016). Our results suggest that unconscious perception of bodies under CFS is very different from perception that is fully conscious.

A range of different methods have been used in the consciousness literature to render stimulus unconscious, and several studies had made efforts to compare them. Almeida et al. observed an influence of happy faces on the likability rating for neutral stimuli (Chinese characters) under backward masking, but did not observe this effect under CFS (Almeida, Pajtas, Mahon, Nakayama, & Caramazza, 2013). Faivre et al. compared CFS with conscious viewing and several other non-conscious paradigms, including gaze-contingent crowding and masking. They found that the preference bias for angry, neutral, happy emotional faces was different across these methods, but the stimuli rendered unconscious by masking and CFS did not influence subsequent preference judgments (Faivre, Berthet, & Kouider, 2012). Another recent fMRI study further compared the brain responses between CFS and chromatic flicker fusion, and found the categorical information of stimuli could be decoded from temporal and frontal areas under chromatic flicker fusion, but not with CFS (Fogelson, Kohler, Miller, Granger, & Tse, 2014). We observed in our current study that the facilitation of incongruent emotions was also different from the traditional redundant target effect under backward masking. The evidence all points to a difference in the mechanisms rendering stimulus unconscious, thus the phenomenon of being visually unconscious of a stimulus is likely to involve multiple stages and processes.

For the same reason, the blindsight, hemianopia without blindsight, and neglect phenomena are also likely to involve different lesion-induced and compensatory mechanisms, and the links of them to CFS and other methods rendering stimuli unconscious are yet to be fully established. We observed similarity of CFS to hemianopia patients without blindsight, but not to blindsight patients or neglect patients. Similar to hemianopia patients not displaying above-chance performance for a range of visual stimuli, it is also possible for the methods applied to healthy participants, where the stimulus information was processed in some way in the brain, but did not induce dissociation or was not captured in either behavioral measures or brain signal measures. Apart from finding a more sensitive behavioral measure with participants, future fMRI and EEG/MEG research with more sensitive measures or neural signatures for unconscious processing would be necessary to better understand unconscious processes.

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