NeuroImage 163 (2017) 276–285

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/neuroimage

# No differential effects to facial expressions under continuous flash suppression: An event-related potentials study

Insa Schlossmacher [a], Markus Junghöfer [b], Thomas Straube [a], Maximilian Bruchmann [a,*]

[a] Institute of Medical Psychology and Systems Neuroscience, Germany
[b] Institute for Biomagnetism and Biosignal Analysis, Germany

ARTICLE INFO

*Keywords:*
Nonconscious processing
Emotion
Faces
Continuous flash suppression
Bayesian statistics
Event-related potentials

ABSTRACT

In recent years continuous flash suppression (CFS) has become a popular "blinding" technique for the investigation of nonconscious affective processing since it elicits potent and long-lasting suppression of conscious visual perception. While the majority of studies provides some positive evidence for nonconscious affective processing, there are also studies reporting their absence. Several methodological variations may give rise to this discrepancy: with respect to the experimental paradigm these variations pertain to the likelihood of residual stimulus visibility on the level of individual participants and single trials. Concerning the statistical analysis they relate to the procedures applied to assess whether detection performance is at chance level and whether the outcome measure does or does not depend on the affective stimulus category. In the present study we determined individual eye dominance and individual stimulus contrast in pretests, measured objective and subjective awareness online and applied Bayesian statistics to estimate the likelihood for the null hypothesis. Event-related potentials (ERPs) were measured while participants were subjected to fearful, happy, and neutral faces in a conscious as well as in a nonconscious CFS condition. In the conscious condition, expected emotion effects were observed in the ERP components N170/EPN and LPP. However, despite high statistical power, no effects of emotional expression were found in the nonconscious condition and the absence of nonconscious affective processing under the tested conditions was substantially more likely than its presence. We discuss whether CFS disrupts affective processing completely if thoroughly applied or whether positive and negative findings should be integrated under a two-threshold framework of nonconscious processing.

## 1. Introduction

In the past, it has been repeatedly demonstrated that emotional stimuli trigger neuronal activity even if they are held back from conscious perception by some experimental technique. In this field of research, studies make use of a great variety of outcome measures of nonconscious emotional processing from electrodermal, electro- and magnetoencephalographic to neuroimaging measures using various "blinding" methods, such as visual backward masking, binocular rivalry, or attentional blink (for reviews see e.g. Axelrod et al., 2015; Tamietto and de Gelder, 2010).

Numerous studies discussed in these reviews provide evidence for differential effects of emotional stimuli under suppression of conscious visibility. However, several studies found no evidence for nonconscious affective processing – at least in healthy participants – when controlling for several methodological confounds (e.g. Hedger et al., 2015, 2016, Hoffmann et al., 2012, 2015; Mayer et al., 1999; Pessoa, 2005; Pessoa et al., 2005; Straube et al., 2010).

Obviously, these contrary studies are relatively small in number in contrast to the countless studies which collected positive findings. However, several reasons for a scarcity of null-reports may exist: Apart from general reasons, such as the classical publication bias (Sterling, 1959), it should be taken into account that research of nonconscious effects requires adopting rigorous criteria in order to conclude that differential emotion processing exists independent of consciousness. These criteria regard, firstly, the way conscious visibility is measured. While some researchers advocate objective performance measures based on signal detection theory (SDT), others claim that only subjective measures adequately reflect the degree of consciousness, as it is inherently a subjective state (Cheesman and Merikle, 1984, 1986). Each measure has its weaknesses: objective above-chance level performance may be achieved through nonconscious stimulus-response-associations. Subjective

* Corresponding author. Institute of Medical Psychology and Systems Neuroscience, University of Münster, Von-Esmarch-Strasse 52, 48149 Münster, Germany.
*E-mail address:* Maximilian.Bruchmann@uni-muenster.de (M. Bruchmann).

https://doi.org/10.1016/j.neuroimage.2017.09.034
Received 3 August 2017; Received in revised form 11 September 2017; Accepted 18 September 2017
Available online 20 September 2017

measures do not allow to asses individual response criteria. Thus, several researchers have agreed on the view that a combination of objective and subjective measures may be the optimal solution (Hedger et al., 2016; Sterzer et al., 2014; Wiens, 2006).

Irrespective of the type of measure, the second criterion in studies on nonconscious processing is of statistical nature: the classically applied null hypothesis-significance-testing (NHST) method creates limitations as most studies rely on a condition where stimulus visibility is assumed to be fully suppressed. The typical manipulation check is testing whether some performance is not different from chance level (e.g. a sensitivity index $d' = 0$). However, with any variable containing a non-zero measurement error the NHST-problem comes into play (Schmidt and Vorberg, 2006), creating a situation best summarized by the phrase “absence of evidence is not evidence of absence” (Sagan, 1995).

Optimizing nonconscious stimulus presentation in order to fulfill these criteria is thus a methodological challenge. “Blinding” methods differ with respect to their reliability with which conscious perception is prevented (Kim and Blake, 2005). The relatively novel technique of continuous flash suppression (CFS; Tsuchiya and Koch, 2005) is one of the most potent suppression techniques, allowing the presentation of target images for up to several minutes without being consciously perceived (Tsuchiya et al., 2006). Under CFS the two eyes are presented with separate images, one being the to-be-suppressed static often low contrast target image, the other being a dynamically changing sequence of high-contrast often colorful random patterns, henceforth called “Mondrian images” (Piet Mondrian, Dutch artist, 1872–1944).

In spite of its strength compared to other “blinding” methods, CFS is not immune to occasional or partial breakthrough of target information. In fact, the likelihood of a breakthrough or the time span until it occurs is the critical outcome measure in so called breaking CFS (b-CFS) paradigms. It has been shown that the suppression duration is a function of various physical stimulus parameters, such as luminance contrast, the spatial frequency spectrum or presence of cardinal orientations (Yang et al., 2014; Yang and Blake, 2012) and depends on whether the target is being presented to the dominant or nondominant eye (Yang et al., 2010a). Furthermore, breakthroughs have been shown to depend on semantic and affective stimulus parameters (e.g. Gayet et al., 2016; Stein et al., 2011, 2016; Sterzer et al., 2014; Tsuchiya et al., 2009; Yang et al., 2007).

The b-CFS paradigm is suitable for uncovering stimulus effects at the behavioral level. Whereas these behavioral studies examine the conditions for a gradual progression from a nonconscious to a conscious condition, uncovering the neural correlates of these processes requires clear-cut conscious and nonconscious conditions. This is a methodological challenge since a high variation in the suppression strength across participants is to be expected if parameters determining the effectiveness of CFS (e.g. stimulus contrast) are not adjusted individually (Yamashiro et al., 2014). Furthermore, studies with incomplete suppression require post hoc-data selection (either of trials or of subjects) which could potentially give rise to statistical artifacts (Shanks, 2016). Thus, precise control of physical stimulus parameters – most importantly, stimulus contrast – and the assessment of eye dominance add to the methodological challenges whenever consciousness is to be prevented by CFS without exception.

Several EEG studies employing CFS have provided evidence for nonconscious processing of faces (Geng et al., 2012; Sterzer et al., 2009; Suzuki and Noguchi, 2013; Willenbockel et al., 2012; Yokoyama et al., 2013). Regarding emotional faces, Jiang et al. (2009) showed differential processing for neutral and fearful faces during CFS. More specifically, their study revealed a medium sized effect (Cohen's $d = 0.5$, see Methods) between 220 and 400 ms after face onset at bilateral lateral superior temporal electrodes with more negative ERPs for fearful compared to neutral faces presented under CFS.

Most of the methodological challenges for studies on nonconscious processing were addressed by the above mentioned researchers, e.g. by applying both subjective and objective measures of target visibility. The subjective measure was achieved by instructing participants during the recording session to report whether they saw any faces or any parts of faces. The objective measure, however, was obtained in a session different from the EEG-recording session, with a subset of participants and also with a task that was slightly different from the EEG-recording session. It is therefore possible that the different task demands (e.g. attentional requirements or response criteria) differed between the recording session and the awareness assessment (Sterzer et al., 2014). Similar offline procedures have been reported by several authors (Doi and Shinohara, 2016; Geng et al., 2012; Jiang and He, 2006; Lapate et al., 2016; Lufityanto et al., 2016; Vizueta et al., 2012; Willenbockel et al., 2012; Yuval-Greenberg and Heeger, 2013).

In many studies on nonconscious processing the statistical assessment whether performance is at chance level relies on the absence of a significant difference between performance and chance level (Adams et al., 2010; Doi and Shinohara, 2016; Jiang et al., 2009; Jiang and He, 2006; Schmack et al., 2016; Vizueta et al., 2012; Yang et al., 2010b; Ye et al., 2014). This way, the probability of a Type II error (assuming chancel level performance when it is in fact above chance level) remained uncontrolled.

Regarding stimulus contrast, some authors report that adjustments were made for each participant but do not specify any criteria for the adjustments of contrast (Jiang et al., 2009). In other studies contrast specifications are lacking (Jiang and He, 2006; Vizueta et al., 2012; Willenbockel et al., 2012) and some apply a fixed contrast for all participants (Adams et al., 2010; Almeida et al., 2013; Doi and Shinohara, 2016; Faivre et al., 2012; Madipakkam et al., 2015; Rothkirch et al., 2015; Schmack et al., 2016; Suzuki and Noguchi, 2013; Yang et al., 2010b; Ye et al., 2014; Yokoyama et al., 2013).

In the present study we sought to address the above mentioned challenges of statistical precision, optimal assessment of chance level performance, and control of breakthroughs more rigorously: first, we obtained a quantitative measure of eye dominance in a more reliable fashion than the typically used Porta-test (Porta, 1593) to present target stimuli to the nondominant eye. Second, we based the contrast adjustment on individual psychometric curves and chose a contrast that allowed a good but not optimal discrimination of emotional expressions (97.5% hits) for faces presented without CFS. We chose this method in order to ensure suppression was as strong as possible minimizing the risk of breakthroughs and thus of the exclusion of participants and/or trials which proves problematic in the investigation of nonconscious processing (Shanks, 2016). An alternative adjustment procedure would have been based on faces presented under CFS, yielding a contrast somewhere below the breakthrough threshold (Ludwig et al., 2013, 2015). Advantages and disadvantages of either method will be discussed below. Third, we simultaneously obtained both subjective and objective performance (i.e. during the EEG-recording session) and let participants judge the stimuli on the same dimension that was used for ERP comparisons, namely the emotional facial expression. Fourth, all statistical procedures were supported by calculations of the Bayes factor (BF) quantifying how much more likely the null hypothesis is compared to the alternative hypothesis. This statistical procedure was applied to check whether behavioral measures deviated from chance level, as well as whether ERPs differed between emotional categories. A large number of participants (52) was tested to ensure sufficient statistical power and reliability.

We included positive, negative and neutral faces to test for conscious and nonconscious effects of hedonic valence (negative vs. positive) and of emotional arousal (negative + positive vs. neutral), as previous research (Faivre et al., 2012; Jiang et al., 2009; Jiang and He, 2006) did not yet aim at separating valence from arousal effects under CFS. In the conscious condition we hypothesized components such as N170, EPN and LPP to be modulated by emotional facial expression (Hajcak et al., 2012). In the nonconscious condition we expected that if either valence or arousal of faces influenced nonconscious processing, then this should be mirrored in the related ERP components.