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Fast Track Report

Emotional expressions modulate low α and β oscillations in a cortically blind patient ☆

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ABSTRACT

Studies of cortical blindness have suggested that some residual visual function may persist without perceptual awareness, a condition known as blindsight. To investigate electrophysiological evidence of unconscious processing of emotional stimuli, we examined the event-related oscillations (EROs) in a 62 year-old male patient (TN) with affective blindsight during random stimulation of three facial expressions (fearful, happy and neutral). Spectral power analysis in response to the different emotions revealed significant differences between fearful and happy faces over the right frontal regions at 7–8 Hz (low α), and between emotional and neutral faces over the left frontal sites at 12–13 Hz (low β) in a time period between 100–400 ms after visual stimulus onset.
These results demonstrate that emotional face processing occurs very early in time in the absence of any functional striate cortex, and further reveals the existence of specific oscillatory frequencies that reflect unconscious processing of facial expressions in affective blindsight.

1. Introduction

The capacity to discriminate visual stimuli without any perceptual awareness following lesions in the primary visual cortex (V1) has been called "blindsight" (for overviews Kentridge et al., 1999; Weiskrantz, 1986, 1996, 1997, 2001, 2003). Previous experiments with a hemianopic blindsight patient described a specific phenomenon called affective blindsight, in which patients retain the capacity to correctly guess the expression on a face presented to their blind field (De Gelder et al., 1999, 2001). An ERP study in a blindsight patient, GY, revealed that P1 and N1 components for emotional faces were smaller and delayed on mesial-occipital electrodes placed over the impaired hemisphere, compared to those placed over the healthy hemisphere (De Gelder et al., 1999). However, no difference was reported for emotional expressions presented to the blind visual half field.

By contrast, the first fMRI investigation of a bilateral blindsight patient (TN) showed that, despite the absence of any conscious visual processing by the patient, a strong right amygdala activation occurred in response to emotional compared to neutral faces (Pegna et al., 2005). This finding was in line with the study of patient GY (Morris et al., 2001), although in this case, the patient suffered from a hemianopic defect, and bilateral amygdala activation was observed for fearful faces presented in his blind field.

Electrophysiological data was subsequently recorded in patient TN and multivariate pattern analysis was applied to the source-localisation algorithms computed from these data (Gonzalez Andino et al., 2009). This investigation, using passive viewing of different emotional faces, suggested the possibility of an emotion-specific response (fear vs. neutral, happy and angry face) beginning at 120 ms after stimulus onset in the right anterior cerebral areas which was followed by right amygdala activation at around 200 ms in response to emotional faces (e.g. happy, angry, fearful vs. neutral faces). To date, this is the only published study on a patient with complete cortical blindness that specifically compared categories of emotional faces.

Recently, electrophysiological findings in healthy controls (Smith, 2011) showed that emotional faces produce an early modulation at around 170 ms. Combining event-related potential analysis (ERPs) with time-frequency analysis of event-related oscillations (EROs), Zhang et al. (2012) also found a greater N170 for fearful compared to neutral faces that increased with awareness of the stimuli. This effect was significantly correlated with a theta power (4–8 Hz) increase within 250 ms of stimulus presentation. They claimed that the parallel modulation of the N170 component and theta synchronization over occipital parietal areas may reflect awareness of rapidly presented fearful faces.

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This report further showed a high interindividual variability for consciousness during backward masking and suggested a relatively early (<200 ms) neural response to unconscious emotional faces. By contrast, a similar study of Balconi and Mazza (2009) with seven facial expressions reported alpha (8–15 Hz) brain modulation in response to masked emotional facial expressions. Specifically, a decrease (desynchronization) in alpha activity was found in response to: i) negative (angry and surprised) facial expressions over the right-frontal region; ii) facial stimuli over anterior frontal compared with central and posterior sites; and iii) positive emotions (happiness) over the left hemisphere. These findings were interpreted as reflecting the interplay between inhibition and activation brain responses in the context of approach vs. withdrawal behaviour towards emotional stimuli.

EEG rhythms are therefore clearly modulated by the presentation of emotional stimuli and alpha oscillatory activity appears to play a fundamental role in the cognitive processing during attentional as well as memory tasks (for a review see Başar and Güntekin, 2012). However, the EEG oscillatory response to emotional faces has not yet been studied in patients with affective blindsight.

Here we present an EEG study with patient TN, which aimed at establishing the electrophysiological oscillatory activity underlying the processing of three facial expressions (positive, negative and neutral faces) in blindsight using an active task. We aimed to investigate the time course of the ERO activity underlying non-conscious processing of facial expressions using high-density EEG recordings. Since gamma is linked to visual awareness according to several studies involving healthy controls (Tallon-Baudry et al., 1997; Zhang et al., 2012) and in patients with hemianopia (Schurger et al., 2006, 2008), our analysis focused on theta, alpha and beta frequencies.

2. Materials & methods

Patient TN is a 62 year old male who suffered two consecutive strokes at the age of 52, the first in the left parietal–temporal–occipital cerebral areas, and the second in the right occipital lobe producing a loss of the remaining left visual field (for anatomical details see paragraph 1 in "Supplementary Material" and Buetti et al., 2013). Clinically, TN was completely blind and unable to detect colours or geometric shapes or even the presence of light source at the time of testing. Interestingly, despite this lack of conscious vision, we observed that he could guess above chance the emotional expression on a face (Pegna et al., 2005), point to a visual stimulus with an above-chance probability (Buetti et al., 2013), guess whether a face was making eye-contact (Burra et al., 2013; De Gelder et al., 2008; Pegna et al., 2005) or even navigate down a path while avoiding obstacles (De Gelder et al., 2008). These residual capacities occurred without any awareness.

The current study was approved by our local Ethics Committee. Prior to testing, the consent form was read to the patient in the presence of his wife who verified its content before signature. A visual perimetry performed on the day of the experiment confirmed that TN was unable to report the presence of any visual stimulus confirming his cortical blindness. Clinically, no auditory deficit was observed, nor was any reported by the patient.

2.1. Stimuli and procedure

Visual cue-stimuli consisted of 60 pictures of emotional cropped faces divided into 3 categories: fear (F), happiness (H) and neutral (N), with 20 different models by category (half females). As the patient was unwilling to guess at the time of the test, we used an attentional visual cuing paradigm rather than a task requiring explicit guessing. In this paradigm, this emotional face was presented in the centre, left or right side of the screen for 1000 ms, followed by a random interval ranging between 100 and 400 ms. This was followed by a 500 Hz acoustic stimulus of 250 ms duration that was delivered to the left or right ear (50% on each side) by means of a pair of headphones, to which the patient had to respond (for details, see Fig. S1a in Supplementary Material). The following trial was initiated 1500 ms after the target. To monitor the gaze fixation of the patient, we used a webcam placed on the monitor in front of the participant. Additionally, an experimenter was located under the screen during all experimental session.

The investigation was performed according to the Declaration of Helsinki on Biomedical Research Involving Human Subjects. The protocol was approved by the local Ethics Committee and informed consent of the patient was obtained.

2.1.1. EEG recording parameter

Electroencephalogram (EEG) was continuously recorded during the entire experimental session using a 128 scalp electrodes cap at a sampling rate of 2048 Hz (BioSemi Active Two, Amsterdam, Netherlands; for more details see Supplementary Material, Fig. S1b).

2.2. Time frequency-domain analysis

EEG data analysis was performed using BrainVision Analyzer 2 software (Brain Products GmbH). Continuous EEG data were down sampled to 512 Hz and corrected for eye movement artefacts through an independent component analysis (ICA) (Jung et al., 2000). For EEG power analysis, data were segmented into cue-locked epochs of 4000 ms, starting 1000 ms before cue onset. The epochs were visually inspected for artefacts and only artefact-free EEG trials corresponding to correct responses were subsequently analysed, totalling 281 trials for fearful faces, 272 trials for happy faces, and 265 trials for neutral faces.

We performed a time-frequency (TF) analysis based on a continuous wavelet transform of the signal (complex Morlet's wavelets) between 4 and 30 Hz in 1 Hz step (e.g. Deiber et al., 2012; Tallon-Baudry et al., 1998), corresponding to theta, alpha and beta frequency bands. The mean power of the pre-cue stimulus interval (−650 ms to −150 ms before cue onset) was considered as a baseline level independently for each frequency (for details see "Methods" in "Supplementary Material").

2.3. Statistical analyses

2.3.1. EEG data

We performed an initial exploratory time-point by time-point *t*-test analysis, in order to determine the range of frequencies to be investigated (Michel et al., 2004). The EEG oscillatory power of each of the 3 emotional conditions was computed at every time point in the 3000 ms epochs of all trials, time-locked to stimulus onset. This was performed at every frequency from 4 to 30 Hz on all 128 electrodes. Facial expressions were then contrasted using the running *t*-test which compared the conditions 2 by 2 at every consecutive time-point. Using a threshold at $p = .01$ (uncorrected), 4 frequencies emerged as possible frequencies of interest: 7 Hz, 8 Hz, 12 Hz and 13 Hz (see Supplementary Figure S2).

In order to explore interactions across the different factors, we carried out an ANOVA analysis restricted to the four frequencies. We defined 9 regions of interest (ROIs) covering the main scalp regions (Fig. S1b in Supplementary data), and divided the epoch into six 50 ms-time-windows from 100 ms after cue onset (i.e., from 100 to 400 ms). The differences in oscillatory power across emotional conditions were established by entering the power of the four sensitive frequencies (7 Hz, 8 Hz, 12 Hz and 13 Hz) in every trial into a repeated measures ANOVA using $3 \times 6 \times 3 \times 3$ factors: 3 facial emotions (E), 6 time windows (T), 3 regions along the left-right axis (Hemisphere, H: right, central and left) and 3 regions along the antero-posterior axis (AP: frontal, central, and occipital). Thus, the number of repetitions in each category was determined by the number of trials retained. Greenhouse–Geisser corrections and post-hoc Tukey HSD comparisons, with a statistical threshold of $p < .05$, were used in both behavioural and electrophysiological analysis.