Available online at www.sciencedirect.com
ScienceDirect
International Journal of Psychophysiology 67 (2008) 41–46
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

Consciousness and arousal effects on emotional face processing as revealed by brain oscillations. A gamma band analysis

Michela Balconi [a,*], Claudio Lucchiari [b]

[a] *Laboratory of Cognitive Psychology, Department of Psychology, Catholic University of Milan, Largo Gemelli, 1 20123 Milan, Italy*
[b] *Neurological National Hospital C. Besta, Milan, Italy*

Received 4 May 2005; received in revised form 29 August 2007; accepted 8 October 2007
Available online 13 October 2007

Abstract

It remains an open question whether it is possible to assign a single brain operation or psychological function for facial emotion decoding to a certain type of oscillatory activity. Gamma band activity (GBA) offers an adequate tool for studying cortical activation patterns during emotional face information processing. In the present study brain oscillations were analyzed in response to facial expression of emotions. Specifically, GBA modulation was measured when twenty subjects looked at emotional (angry, fearful, happy, and sad faces) or neutral faces in two different conditions: supraliminal (10 ms) vs subliminal (150 ms) stimulation (100 target-mask pairs for each condition). The results showed that both consciousness and significance of the stimulus in terms of arousal can modulate the power synchronization (ERD decrease) during 150–350 time range: an early oscillatory event showed its peak at about 200 ms post-stimulus. GBA was enhanced by supraliminal more than subliminal elaboration, as well as more by high arousal (anger and fear) than low arousal (happiness and sadness) emotions. Finally a left-posterior dominance for conscious elaboration was found, whereas right hemisphere was discriminant in emotional processing of face in comparison with neutral face.

Keywords: Facial expression; EEG; Gamma band; Arousal; Consciousness

1. Introduction

Correlates of affective face processing have been investigated using a variety of recording techniques. On one side, some authors studied ERP correlates associated with face comprehension. It has been argued that emotional face processing arises after 200 ms, and that differences between ERPs elicited by emotional faces and neutral faces were observable specifically between 250 and 550 ms after stimulus onset (Krolak-Salmon et al., 2001). An early negative deflection (N2) of higher amplitude was revealed for arousing facial stimuli (Balconi and Pozzoli, 2003; Sato et al., 2000; Streit et al., 2000) in comparison with neutral stimuli. Moreover, there is evidence that emotion processing is initiated and can proceed without conscious awareness (Bunce et al., 1999; LeDoux, 1998). An obvious and well-known example of unconscious perception of emotion is subliminal stimulation effect. This phenomenon was studied in a limited number of cases (Wong et al., 1994). Animal studies suggest that fear-related response are by a direct subcortical pathway from the thalamus direct to the amygdala, allowing emotional (and specifically threat) to be processed automatically and outside awareness. In humans, evidence for the unconscious perception of masked face has been revealed in terms of subjective reports (Esteves et al., 1994) autonomic reaction (Morris et al., 2001), brain imaging measures (Whalen et al., 1998), as well as ERPs (Kiefer and Spitzer, 2000). In addition, unconscious stimulation showed to be sensitive to the emotional content of the stimuli, as revealed by different behavioural and physiological measures (Lang et al., 1998).

On the other side, brain oscillations were found to be a powerful tool to analyze the cognitive processes related to emotion comprehension in general (Başar et al., 1999; Krause, 2003), and, even if less studied, to unconscious perception

* Corresponding author. Tel.: +39 2 72342600; fax: +39 2 72342769.
E-mail address: michela.balconi@unicatt.it (M. Balconi).

0167-8760/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.ijpsycho.2007.10.002

(Summerfield et al., 2002). Few previous studies on ERD/ERS responses to emotion-related stimuli have examined the narrow frequency bands (Aftanas et al., 2001, 2002). Recent researches showed the event-related theta band power responds specifically to prolonged visual emotional stimulation (Krause et al., 2000), and a synchronization was revealed in case of coordinated response indicating readiness to process information (Başar, 1999). Thus, theta EEG power typically increases with increasing attentional demands and/or task difficulty. Also the effect of valence in affective picture processing was studied, showing that valence discrimination is associated with the early time-locked synchronized theta activity (Aftanas et al., 2001). Moreover, recent research have demonstrated that the modulation of gamma band activity (GBA) in time windows between 200 and 400 ms following the onset of a stimulus is associated with perception of coherent visual objects (Müller et al., 1996), and may be a signature of active memory. In parallel, GBA was found sensitive to emotional vs nonemotional stimuli and more specifically it was related to the arousal effect: early GBA was enhanced in response to aversive or highly arousing stimuli compared to neutral picture (Balconi and Pozzoli, 2007). This result was revealed in accordance with previous research that employed ERP measures for arousing pictures (Schupp et al., 2000) or emotional face (Balconi and Pozzoli, 2003; Sato et al., 2000), since these studies found a modulation of the increased arousal on ERP. Interestingly, previous research has found that gamma frequency band could also be considered a marker of degree of consciousness during elaboration of a stimulus: synchronous oscillations in the gamma frequency range may be necessary for the entry of information into conscious awareness (Crick and Koch, 1998). Specifically, Summerfield et al. (2002) have found that gamma activity increases after subjects had been made aware of the stimulus, and, therefore, synchronous gamma oscillations occurred in association with awareness processes.

Therefore, gamma band is to be considered of main interest in exploring the effect of arousal as well as the consciousness in emotional face elaboration. The present study aims at studying the brain mechanisms underlying human emotional processing by measuring GBA changes in response to emotional faces presented visually in both supraliminal and subliminal stimulation. No previous study has widely explored the effect of consciousness on the processing of emotional faces, in conjunction with different types of stimulus (low or high arousing faces). Actually, although brain oscillations have been investigated in various sensory modalities, their role for brain functioning for emotion elaboration remains unclear. Secondly, it remains an open question whether it is possible to assign a single brain operation or psychological function for emotion decoding to a certain type of oscillatory activity. Thus, we intend to explore functional correlates of brain oscillations with regard to emotional face processing in supraliminal and subliminal condition and emphasize the importance of distributed oscillatory networks in gamma frequency band. We attended that emotional content may be indexed by oscillatory activity of the brain that was directly related to awareness or unawareness of the stimulus. Specifically, we hypothesized that conscious elaboration of emotional stimuli will be indexed by GBA synchronization, whereas unconscious condition will be related to a decreased power intensity of this frequency band. Secondly, we expected that affective significance of a facial stimulus may result in changes of subjects' EEG responses (Lang et al., 1993). Emotion evaluated as highly arousing should be indexed by an enhanced power of gamma band in conscious condition. Finally, brain lateralization was found significant for emotional elaboration. As previously shown, right dominance was revealed for emotional stimuli compared to neutral ones, and specifically for face. On the contrary, left hemisphere was found to be more activated by conscious elaboration than unconscious. The present experiment based on ERD measure examined whether emotions would be associated with band modulation as regard as interhemispheric asymmetries in the right direction, whereas left hemisphere is expected to be discriminant for conscious processing if compared to unconscious.

2. Method

2.1. Subjects

Twenty healthy volunteers took part in the study (eleven women, age range19–25, mean=23.37, SD=2.13). They were all right-handed and with normal or corrected-to-normal visual acuity. Exclusion criteria were history of psychopathology for the subjects or immediate family. They gave informed written consent for participating in the study.

2.2. Stimulus material

Stimulus materials were taken from the set of pictures of Ekman and Friesen (1976). They were black and white pictures of male and female actors, presenting respectively a happy, sad, angry, fearful, or neutral face.

2.3. Supraliminal/subliminal stimulation

A previous study was conducted in which the duration of target facial stimulus was varied in order to establish threshold condition (Liddell et al., 2004). In the current study we employed both an objective threshold, defined as the stimulus duration where the stimulus is perceived by the subject in 50% of the cases (Merikle et al., 2001); and a subjective threshold, defined as the overt lacking of discrimination of the stimulus and its emotional content. The pre-experimental study and post-hoc briefing confirmed that subjects were unable to detect target stimulus in the subliminal condition.

During the experiment we used a masking procedure. Each facial stimulus (target) was presented for either 10 (subliminal) or 150 (supraliminal) ms, followed by a neutral face presented for 150 ms (interstimulus interval 1.5 s) (Bernat et al., 2001; Brázdil et al., 1998; Liddell et al., 2004). The short stimulus presentation in subliminal condition prevents the subjects to have a clear cognition of the stimulus, but it allows for a semantic elaboration of the emotional faces. No target and mask pair