



# The modulation of delta responses in the interaction of brightness and emotion



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## ABSTRACT

The modulation of delta oscillations (0.5–3.5 Hz) by emotional stimuli is reported. Physical attributes such as color, brightness and spatial frequency of emotional visual stimuli have crucial effect on the perception of complex scene. Brightness is intimately related with emotional valence. Here we explored the effect of brightness on delta oscillatory responses upon presentation of pleasant, unpleasant and neutral pictures. We found that bright unpleasant pictures elicited lower amplitude of delta response than original unpleasant pictures. The electrophysiological finding of the study was in accordance with behavioral data. These results denoted the importance of delta responses on the examination of the association between perceptual and conceptual processes while in the question of brightness and emotion.

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## 1. Introduction

Researches of emotional processes by means of brain oscillations gained increasing attention in the field of neuroscience. Neuroimaging and electrophysiological findings demonstrated that the neural organization of emotion is a result of parallel, complex and distributed network (Lane et al., 1997; Liotti and Tucker, 1995). The analysis of event-related oscillations [delta (0.5–3.5 Hz), theta (4–7 Hz), alpha (8–13 Hz), beta (15–30 Hz), gamma (28–48 Hz)] is essential to understand the underlying physiological mechanisms of cognitive and emotional processes (Başar, 1980). One common finding of the studies on brain oscillatory activity in emotional processing is that brain responds differently to unpleasant or pleasant stimuli compared to the neutral ones and this result is more or less valid for all frequency bands (Klados et al., 2009; Aftanas et al., 2002; Balconi et al., 2009b; Balconi et al., 2009a; Güntekin and Başar, 2010; Keil et al., 2001, 2007; Müller et al., 1999). In these studies evoked and induced activities in different frequency bands were evaluated. In general authors discuss that evoked responses might be related with top-down processes, whereas induced responses might be more associated with bottom-up processes. In the present study, we focused on delta (0.5–3.5 Hz) oscillations which have been considered as the main feature of P300 and late

positive potential that appear in response to cognitive and emotional tasks, respectively (Başar et al., 1984). It was noted that when cognitive tasks are performed delta responses are observed in the frontal and central regions whereas arousing emotional stimuli elicit delta responses over posterior electrode sites (Knyazev et al., 2009; Klados et al., 2009; Güntekin and Başar, 2009; Güntekin and Başar, 2014; Balconi and Lucchiari, 2006). Also, the mean amplitude of occipital delta responses to facial expressions show higher amplitudes in comparison to delta responses upon stimulations from simple light stimuli as well as known and unknown faces (Başar et al., 2006). Likewise, emotional stimuli generate stronger delta synchronization than neutral stimuli (Knyazev et al., 2009; Klados et al., 2009; Balconi et al., 2009a). These findings seem to be coherent with the results of ERP studies indicating prominent slow wave activity on emotional stimuli (Alorda et al., 2007; Codispoti et al., 2007; Olofsson et al., 2008).

Emotional visual stimuli have crucial effect on the perception of complex and potentially hostile environment which leads individual to develop successful behavior (Meier et al., 2004; Meier et al., 2007; Purves et al., 2004). Contribution of color on affective picture processing generates ERP amplitude and latency changes, most likely related to early visual processing (Kaya and Epps, 2004; Smith et al., 2003; Cano et al., 2009). Similarly, higher stimulus luminance resulted in higher ERP amplitudes for the posterior N95, occipital P1 and parietal N1 independent of the attention effect (Johannes et al., 1995). Also, by being independent of age, luminance effect had been observed in the N170 component of ERP (Bieniek et al., 2013).

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Since the brightness differences provide contrast which is essential for visual system, brightness is suggested to be one of the most important sources of perceptual processing (Valberg, 2005). Psychological studies revealed that high bright colors are evaluated more positively compared to low bright or dark colors whereas dark colors are evaluated more negatively, namely as “brightness bias” (Jiang and Bian, 2013; Valdez and Mehrabian, 1994; Lakens et al., 2013). This effect was also reported in a recent study, wherein the brightness value of IAPS pictures were found to be correlated with their valence rating (Lakens et al., 2013). These findings are consistent with the argument that there is an automatic association between brightness and affect (Meier et al., 2004; Meier et al., 2007). However, the idea that abstract thought are built on perceptual experiences is still under debate. Spatially rough information carried by luminance channels is suggested to be notably critical for the elicitation of emotional responses (Vuilleumier et al., 2003). One of the neuroanatomical hypothesis of the interaction between luminance and emotional processing relies on the extensive connectivity between magnocellular pathway and amygdaloid complex (Zeelenberg et al., 2006). It has been previously noted that cells which have been located in the magnocellular division of the amygdala send projections to occipital and temporal regions of the brain (Amaral et al., 2003).

Another issue which should be taken into consideration is spatial frequency and luminance discrepancies among International Affective Picture System (IAPS; Lang et al., 1997) pictures. In previous studies, the spatial frequency of the IAPS pictures and their brightness level were found to be shown diversity on emotional content which may manipulate emotional valence (Delplanque et al., 2007; Lakens et al., 2013). Therefore, it is crucial to explore if, and how, brightness modulates brain oscillatory activity in response to visual emotional stimuli.

Although previous studies converge to a general conclusion on the brain's delta oscillatory responses and luminance effect on emotional processing, the findings need to be integrated. Event-related delta response is participating in both, bottom-up and top-down processes (Başar and Düzgün, 2016). Thus, we may suppose that examination of delta responses to presented emotional stimuli in bright and original versions may contribute to understand the above mentioned association between perceptual (bottom-up) and conceptual (top-down) processes.

In the present study, we aimed to compare delta oscillatory responses to original and bright IAPS pictures. Our working hypothesis is that brightness might affect delta oscillatory responses to emotional stimuli in accordance with “brightness bias”. We expect that the mean amplitude of delta responses would be more pronounced for bright emotional pictures compared to those of original ones, but not for bright neutral pictures. Additionally, in order to replicate previous studies' findings, we aimed to analyze delta responses to original emotional and neutral stimuli along with the valence and arousal values of the pictures.

## 2. Method

### 2.1. Participants

Thirty-one subjects (17 females-14 males) participated in the study. The mean age of subjects was  $27.33 \pm 7.03$  years of whom 28 were right handed, and three were left handed. All subjects had completed at least 10 years of education. All subjects were interviewed with a questionnaire on their demographic and medical profiles and drinking habits. None of the subjects reported any current or past neurological or psychiatric illness and all participants had normal or corrected to normal vision. Prior to the experiment, the Beck Depression Inventory (BDI) and the Beck Anxiety Inventory (BAI) were applied to evaluate the participant's depression and anxiety level, respectively. Subjects scoring above 17 from BDI and/or above 14 from BAI were excluded from the study. All subjects signed an approved consent form.

### 2.2. Stimuli

Thirty pictures (10 pleasant, 10 unpleasant, 10 neutral) with similar luminance level (mean  $32.5 \pm 12.2$  cd/m<sup>2</sup>) were selected from the International Affective Picture System (IAPS), which were also used in another study (Güntekin and Başar, 2010). We changed the brightness of each image so that two different image sets, low and high brightness, were obtained with respect to their luminance values. First, the averaged power of each image was calculated, and then its brightness was increased by multiplying an appropriate positive constant. A constant greater than one was selected to increase the brightness. Next to that, the intensity values were normalized before saving the image in jpeg format to avoid saturation. If the normalization is not applied, saturation obscures the image and alters the contrast. Finally, the band-limited contrast value was computed for both images to ensure that the contrast remained constant. We used band-limited contrast definition (Hess and Plant, 1983; Peli, 1990),

$$C(u, v) = \frac{2A(u, v)}{DC}$$

where  $A(u, v)$  is the amplitude of the Fourier transformed image,  $u$  and  $v$  are the horizontal and vertical spatial frequency coordinates, respectively, and  $DC$  is the zero-frequency component.

The luminance of the pictures was measured by Delta OHMHD 2302.0 light meter and remeasured after increasing the luminance level. The luminance level of pleasant, unpleasant and neutral pictures were increased approximately 107% (min. 101%–max. 109%), 103% (min. 101%–max. 107%), and 108% (min. 100%–max. 133%), respectively. The code numbers of the selected pictures, their original and new luminance values and the percentage of augmentation of their luminance level were given in Table 1.

**Table 1**

The code numbers of the selected pictures, their original and new luminance values and the percentage of augmentation of their luminance level.

| Emotional Content | Code Number | Original Luminance Value cd/m <sup>2</sup> | Augmented Luminance Value cd/m <sup>2</sup> | Augmentation Percentage % |
|-------------------|-------------|--|---|---------------------------|
|                   | 1460        | 24.2                                       | 50.4  | 108                       |
|                   | 1500        | 16.9                                       | 34.4  | 104                       |
|                   | 1710        | 45.0                                       | 93.5  | 108                       |
|                   | 1722        | 26.7                                       | 55.7  | 109                       |
|                   | 1750        | 30.3                                       | 61.6  | 103                       |
|                   | 2058        | 49.5                                       | 99.4  | 101                       |
|                   | 2080        | 43.5                                       | 88.9  | 104                       |
|                   | 2165        | 40.6                                       | 84.4  | 108                       |
|                   | 2332        | 22.9                                       | 47.0  | 105                       |
| Positive          | 2340        | 25.0                                       | 51.3  | 105                       |
|                   | 1052        | 36.2                                       | 74.1  | 105                       |
|                   | 1114        | 25.8                                       | 52.0  | 102                       |
|                   | 1274        | 25.5                                       | 52.8  | 107                       |
|                   | 1930        | 20.5                                       | 41.2  | 101                       |
|                   | 1932        | 24.6                                       | 50.3  | 104                       |
|                   | 2205        | 43.8                                       | 88.5  | 102                       |
|                   | 2352        | 54.2                                       | 111.2                                       | 105                       |
|                   | 3400        | 30.3                                       | 61.2  | 102                       |
|                   | 6350        | 38.5                                       | 77.6  | 102                       |
| Negative          | 6550        | 25.1                                       | 51.8  | 106                       |
|                   | 2190        | 17.6                                       | 35.3  | 101                       |
|                   | 2210        | 30.7                                       | 64.4  | 110                       |
|                   | 2214        | 55.7                                       | 115.9                                       | 108                       |
|                   | 2480        | 17.2                                       | 34.4  | 100                       |
|                   | 2495        | 26.0                                       | 54.4  | 109                       |
|                   | 7010        | 25.6                                       | 51.2  | 100                       |
|                   | 7020        | 53.8                                       | 111.7                                       | 108                       |
|                   | 7030        | 37.4                                       | 76.6  | 104                       |
|                   | 7041        | 28.5                                       | 59.1  | 107                       |
| Neutral           | 7080        | 31.5                                       | 73.5  | 133                       |

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