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Emotion effects within frontal alpha oscillation in a picture oddball paradigm

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ABSTRACT

In the current study we measured frontal alpha band oscillation in an oddball paradigm with emotional pictures as target stimuli. Within these emotional target pictures we varied valence and arousal separately. Irrespective of this emotional connotation, participants were asked to respond to the occurrence of any picture that deviates from the standard picture (a checkerboard). All stimuli were presented briefly and target stimuli were easily distinguishable from the standard stimulus based on mere perceptive features. Thus, the procedure reduces the probability that participants intentionally process or evaluate the emotional content of the pictures. With these incidental procedural conditions we yet observed a relative shift of alpha power to the right frontal site with increasing pleasantness of the pictures. Furthermore, frontal alpha band oscillation decreased with increasing picture arousal. These patterns were also evident when we controlled for valence and arousal of the pictures at the individual level. The results suggest that changes in frontal alpha band oscillation reflect reliable emotion correlates of incidental picture processing in the oddball paradigm.

1. Introduction

Valence and arousal are fundamental psychological concepts. For example, the biphasic emotion framework (Bradley et al., 2001) posits that valence and arousal are estimates of the activation of underlying motivational systems. While valence indicates which motivational system is activated (unpleasant stimuli activate withdrawal, pleasant picture activate approach), arousal, in contrast, is assumed to indicate the extent of activation of the respective motivational system. In line with this distinction, it has been shown that valence and arousal parameters of incoming information differently modulate various aspects of a person's emotional experience (Bradley & Lang, 1994), attention, and overt behavior (Schimmack and Derryberry, 2005; Suri et al., 2013). Considering the separable roles of valence and arousal in cognition and behaviors, it is not surprising that many studies focus on the investigation of neurophysiologic correlates of these ubiquitous emotional concepts (e.g. Keil et al., 2002; Kissler et al., 2009; Van Strien et al., 2010).

When examining neurophysiologic correlates of valence and arousal, it is important to consider both, the stimulus material and the procedural conditions of the experimental paradigm. For example, in a recent study Rozenkrants and Polich (2008) found separable neurophysiologic correlates of valence and arousal even if the experimental procedure reduced the probability that participants intentionally processed or evaluated the stimuli's emotional connotation. In particular, the authors used the oddball paradigm to establish these incidental procedural conditions.

Originally, the oddball paradigm was designed to examine neurophysiologic correlates of stimulus discrimination (Squires et al., 1975). It involves the rapid repetitive presentation of a stimulus (the standard) that infrequently is interrupted by deviants (the targets). The timing of presentation is usually quite fast and the participant is required to respond to any of the targets. To date, there is a considerable history of neurophysiologic research that has been conducted with this paradigm (e.g., McDonald et al., 2010; Näätänen, Gaillard, & Mäntysalo, 1978).

Rozenkrants and Polich (2008) repeatedly presented an emotionally neutral checkerboard picture as the standard stimulus that was occasionally intermixed with pictures from the IAPS (the targets). All stimuli were presented briefly (1 s) and the authors varied valence and arousal of target pictures separately. Participants were asked to press a single key in response to any of these target pictures *regardless of their emotional connotation*. Targets were easily distinguishable from the standard picture based on mere perceptive features (e.g., structure, color) so that participants did NOT need to process or to evaluate the particular emotional content of the target pictures.

From a methodological point of view, the oddball paradigm offers elegant procedural conditions for the investigation of neurophysiologic effects of incidental emotion processing because the procedure minimizes processing variability while reducing the probability that the participants process or evaluate the emotional content of the presented pictures intentionally. Yet, Rozenkrants and Polich (2008) observed significant effects of arousal and valence on ERPs. Arousal effects were

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observed within the N2 (220–300 ms), P3 (300–450 ms), as well as in the early (550–700 ms) and the late Slow Wave (700–850 ms). All these components were larger for high- compared to low-arousal pictures. Valence effects occurred, in that P3 and Slow Wave were larger for unpleasant, when compared to pleasant pictures.

These findings are in line with the proposition that the brain processes the emotional quality of stimuli even under incidental procedural conditions (e.g., Pessoa, 2005). Furthermore, these findings suggest that incidental emotion processing is accompanied by separable neurophysiologic correlates of valence and arousal within ERPs. However, no oddball paradigm study to date reported of such incidental emotion effects within frontal alpha band oscillation.

This is surprising as a growing number of studies using time-frequency analysis of electroencephalography (EEG) over frontal areas, have reported a relative right-sided lateralization of frontal alpha band oscillation with increasing pleasantness of pictures (Balconi et al., 2009; Huster et al., 2009). Furthermore, Balconi et al. (2009) reported a non-lateralized decrease of frontal alpha oscillation with increasing picture arousal. Note that decreased alpha is indicative of increased cortical processing and can thus, be an estimate of changes in internal motivational/emotional states. These findings suggest that separable neurophysiologic correlates of valence and arousal can be observed within frontal alpha band oscillations.

Importantly, however, the particular procedural conditions of these studies (especially with respect to timing and task structure) may have facilitated the intentional processing and evaluation of the stimuli's emotional connotation. For example, Balconi et al. (2009) exposed participants to pictures for 6 s each, and the time interval between consecutive pictures amounted to 7 s. A similarly slow timing was applied by Huster et al. (2009); in each trial of their study, three pictures of the same valence (e.g., pleasant) were shown consecutively in a "mini-block". Each of these "mini-blocks" lasted several seconds and was divided by a 6 s inter-stimulus interval. This slow timing is probably a result of the authors' belief that it may take some longer time for the emotion effects to be evolving within frontal alpha oscillation. Unfortunately, it is likely that these procedural conditions (e.g., slow timing of presentation; repeated presentation of pictures from the same valence category; large inter-stimulus interval) have also "invited" participants to process or evaluate the emotional content of the pictures intentionally (indeed, participants in some of these studies (Balconi et al., 2009) were even asked to evaluate the emotional connotation of the pictures during measurement explicitly).

It is thus still open whether emotion effects within frontal alpha band oscillation generalize to incidental procedures like the oddball paradigm (e.g., Rozenkrants and Polich, 2008). A manifestation of such effects would offer important insights into the reliability of frontal alpha measures as neurophysiologic correlates of incidental emotion processing. Furthermore, such an examination links to a considerable history of (emotion-) research within the oddball paradigm and may thus be informative to related research domains.

While Rozenkrants and Polich (2008) focused on event related potentials (ERPs), therefore, in the current study we aimed at extending these findings by examining whether correlates of valence and arousal can be observed within frontal alpha oscillation (e.g., Harmon-Jones et al., 2010). In particular, we conducted an oddball paradigm similar to Rozenkrants and Polich (2008) while analysing frontal alpha band oscillation. The emotional target pictures were taken from the International Affective Picture System (IAPS, Lang et al., 2008). As the IAPS provides normative ratings with respect to valence (unpleasant to pleasant) and arousal (calm to exciting) for a large number of pictures, we controlled the target pictures for both, valence and arousal separately. In particular, we selected four categories of pictures: unpleasant, high arousing; unpleasant, low arousing; pleasant, low arousing; pleasant, high arousing. The selection ensured that pictures from the pleasant and unpleasant category were equally arousing. Furthermore, pictures from the high and low arousing category were equally pleasant.

Theoretically, such a controlled selection would allow for a separate and independent analysis of the effects valence and arousal on frontal alpha band oscillation. However, individuals (as samples too) may differ with respect to their emotional experience in response to one and the same stimulus. A stimulus selection based on normative ratings, therefore, may inhere sample-specific biases (i.e., confounds) that may undermine the clarity and conclusiveness of the findings. In order to detect and control for such biases, we additionally collected individual ratings on picture arousal and picture valence from each of our participants at the end of the experiment, and, in a second step, examined the association of these rating data with frontal alpha band oscillation in a regression analysis. To our knowledge this has not yet been done before. By taking into account individual emotion ratings too, we were able to more conclusively assess whether the incidental emotion effects within frontal alpha oscillations are specifically attributable to picture valence and/or picture arousal.

In accordance with the findings described above, we expected stronger right lateralized alpha band oscillation in frontal brain areas on target trials with pleasant compared to unpleasant pictures. Furthermore, we expected overall attenuated (non-lateralized) frontal alpha oscillation in trials with high compared to low arousal pictures.

2. Method

2.1. Participants

The sample consisted of 28 right-handed German participants (20 females) with normal or corrected to normal vision and an average age of 28.25 years. Participants were students at Humboldt-Universität zu Berlin. All participants gave informed written consent that included a statement that they would not be able to participate if they suffered from any known psychiatric disorders. However, we did not specifically ask for a known disorder on emotions recognition. When examining the data on subjective emotion ratings on valence and arousal, we could not observe any blatant deviations from the expected norms in any of the participants. This may be considered as evidence that emotion recognition was not impaired in our sample. All participants received either course credit or 16 € compensation.

2.2. Materials

Stimulus material was adapted from a previous study (Rozenkrants and Polich, 2008). For the oddball paradigm we used 64 pictures from the IAPS (Lang et al., 2008) as target stimuli. The target stimuli varied on the dimensions of valence and arousal, and could be classified into four categories with 16 pictures each: 1) pleasant and low arousal, 2) pleasant and high arousal, 3) unpleasant and low arousal, 4) unpleasant and high arousal (for specific numbers of the selected IAPS images see appendix). As a standard stimulus a red and white checked pattern was presented. This pattern was considered to be of neutral emotional content (Lang et al., 2008).

Separate analyses of variance (ANOVA) with the factor valence category (unpleasant, pleasant) and arousal category (low, high) were computed on the normative ratings of both valence and arousal, respectively. The first ANOVA revealed that pictures from the category with pleasant content were rated to be more pleasant than pictures from the category with unpleasant content ($F(1,60) = 4143.8$ $p < 0.00001$). Neither a main effect of arousal, nor an interaction of arousal and valence was observed. The second ANOVA revealed that pictures from the high arousal category were rated more arousing than pictures from the low arousal category ($F(1,60) = 924.2$ $p < 0.00001$). Neither a main effect of valence, nor an interaction of arousal and valence was observed. Thus in later analyses, effects of the factor "valence" can be interpreted independently from the factor "arousal", and vice versa.

Covering their original size, the color IAPS pictures were expressed in a resolution of 1024 by 768 pixels. In a next step, we took the mean and