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Emotional face expressions are differentiated with brain oscillations

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Abstract

The differentiation of "facial expressions" is a process of higher mental activity, which has considerable applications in "psychology of moods and emotions".

We applied the approach of event-related oscillations (EROs) to investigate the modulation of electrical manifestations related to emotional expression in EEG recordings of 20 healthy subjects. EROs of "neutral, angry and happy" faces in 13 electrical recordings sites (F_3, F_4, C_z, C_3, C_4, T_3, T_4, T_5, T_6, P_3, P_4, O_1, O_2) were analyzed. Following the recording session, the subjects were asked to express the degree of their emotional involvement (valence and arousal) using the Self-Assessment Manikin ratings. Amplitude frequency characteristics (AFCs) were used to determine the frequencies of interest and the ranges for digital pass-band filtering applied accordingly. Consecutively, peak to peak amplitude measures of oscillatory responses were computed for the selected frequency bands and for the differentiation of the different stimuli.

A differentiation between angry and happy facial expressions was observed especially in the alpha (9–13 Hz) and beta (15–24 Hz) frequencies, however, only when selecting stimuli with high mood involvement. Therefore, these frequency bands are the main focus of this report. The amplitudes of the alpha responses upon angry face stimulation were significantly higher than upon presentation of the happy faces at posterior locations. At F_3, C_z and C_3, beta responses upon angry face stimulation were significantly higher in amplitude compared with the happy face stimulation. It is discussed that the frontal theta response is highly increased in comparison to all theta responses also encountered in studies of face recognition: During observation of facial expression, the occipital theta is much higher.

We conclude and emphasize that the analysis of brain oscillatory responses distributed over the scalp in combination with subjective ratings of emotional impact of stimuli provide a good basis for analysing the influence of emotional information processing in the brain. In congruence with others, the results support the phylogenetical viewpoint suggesting that angry face stimulations are faster and more ample in responding. Furthermore, frontal, temporal, parietal and occipital lobes seem to be involved in processing of facial expressions, as reflected in an ensemble of different frequency brain oscillatory responses distributed over the scalp.

Keywords: Face expression; Brain oscillations; Emotion; Alpha; Beta; Theta

1. Introduction

The present report describes selectively distributed oscillations upon presentation of different facial expressions. Face processing involves different interwoven aspects, such as "emotions", "memory", "emotional memory" and "affections". It follows that the neuronal correlates associated with processing of faces processing are suggested to be modulated by differences in emotional expression, in valence as well as in familiarity and in affectionate involvement with the person behind the face (e.g. Basar et al., 2007-b). Accordingly, the differentiation of facial expressions is one of the most complex processes in integrative neurophysiology.

The number of reports is increasing in this field. However, most of the methodological approaches are based on conventional evoked potential analyses and applications of fMRI data analysis. In our study, we introduce the approach of multiple oscillations together with the application of a subjective rating scale named Self-Assessment Manikin (SAM), to analyse the impact of emotional expression on the processing of facial stimuli (Lang, 1980). By means of the SAM, the subjects give

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report about their subjective valence (i.e. degree of attractiveness) and arousal states following presentation of faces varying in expression. By joint application of both approaches, the present study gives an advanced description within a framework of dynamic analysis of facial expressions. Further, the existence of selectively distributed multiple oscillations presents an efficient way to analyze functional correlates of perceptual and cognitive brain processes (Basar, 2006). Accordingly, the ensemble of methods used in the present study has a broader spectrum in comparison to previous studies that analyzed face expressions by describing manifestations of brain oscillations (Balconi and Lucchiari, 2006; Schutter et al., 2001; Fink, 2005).

In the analysis of electrophysiology of facial percepts, the experimenter is confronted with face processing, which comprises (i) perceptual and memory processes required for the recognition of complex stimulation as a face, (ii) the identification of the particular face in view and (iii) the analysis of its facial expression (McCarthy, 2000). In addition to the processes pointed out, the valence and the arousal dimensions that the subjects express are the prominent features of facial expression analyses.

According to Solms and Turnbull (2002), emotion is akin to a sensory modality that provides information about the current state of body self, as opposed to the state of the object world. "Emotion" is the aspect of consciousness that is left if all externally derived contents are removed. The authors stated: "If you were deprived of all sensory images (drawn from present and past perception), you will still be conscious". What emotion one perceives is subjective too. What one perceives when you feel an emotion, is your own subjective response to an event itself. "Emotion is a perception of the state of the subject, not the object world" (Solms and Turnbull, 2002).

Le Doux (1999) proposed that emotions or feelings are consciousness of unconscious processes. However, he states that, despite millennia of preoccupation with every facet of human emotion, we are still far from explaining in a rigorous physiological sense this part of our mental experience.

Recognition of known and unknown faces, i.e. differentiation between episodic and semantic events, was also investigated in the last years by our group by means of oscillatory analysis. Basar et al. present the concluding results in a separate study within this issue. The comparative analysis of face expressions and face recognition reveals completely different results. Accordingly, it seems that fine adjustment of the brain to differentiate expressions in faces puts the brain into a completely different processing strategy. Because of this fact, the results related to face recognition can be recommended as prerequisite or complementary knowledge to analyze facial expressions.

Stimulation with different facial expressions is a common strategy for understanding emotional states. However, it is clear that emotional states cannot be manifested only by face expressions. We focused our descriptions to the study of facial expressions by emphasizing the importance of using the scope of event-related oscillations. As we repeatedly state, it is necessary to take precautions by application of the oscillatory approach (Basar, 2006; Basar et al., in press-a).

The results of this study indicate that angry faces evoke higher amplitude alpha responses in the posterior cortical areas, whereas increased beta responses were observed in anterior areas in comparison to happy face stimulation.

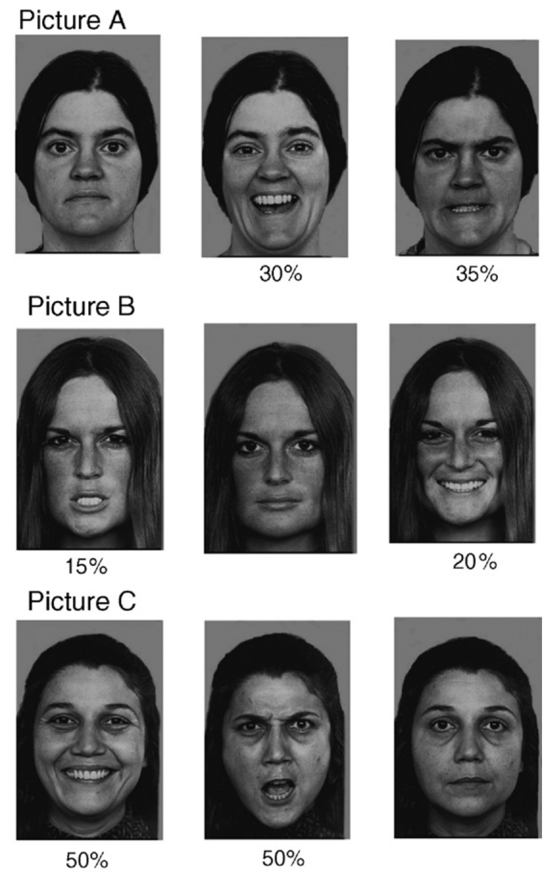

Fig. 1. The three sets of pictures (A, B and C) of angry, happy and neutral face expressions in the presented order.

2. Methods

2.1. Stimuli and experimental procedure

As stimulation we used an ensemble of the photographs presented by Ekman and Friesen (1976). We selected 9 out of 110 photographs, specifically, 3 different females with 3 different facial expressions (angry, happy and neutral). The pictures were presented black and white (17 × 17 cm) and displayed on a screen at a distance of 120 cm from the subjects. Stimulus duration was set to 1000 ms with intervals randomly varying between 3 and 7 s. The subjects were instructed to minimize blinking and eye movements, and they sat in a soundproof and dimly illuminated echo-free room.

The Stimuli and experimental procedure included five recording sessions, whereby the number of face and light stimulations were 60 in every section: (1) spontaneous EEG of the subjects. (2) First person's three different pictures with different facial expressions in the following[1] order: (a) neutral

[1] Pictures of three different persons were presented in order to classify pictures according to the rating of the subject related to the highest affect as "angry" or "happy". Changes in the sequence of pictures were applied in order to reduce effects of interactions between learning, habituation and fatigue.