Neuropsychological Trends

1
April 2007

Emotional face recognition and EEG measures

Walter Mahler & Sandra Reder

Department of Applied Science, University of British Columbia

w.mahler@inside.co.uk

ABSTRACT

Twenty one adults looked at emotional (sad, happy, fearful) or neutral faces. EEG measures showed that emotional significance of face (stimulus type) modulated the amplitude of EEG, especially for theta and delta frequency band power. Also, emotional discrimination by theta was more distributed on the posterior sites of the scalp for the emotional stimuli. Thus, this frequency band variation could represent a complex set of cognitive processes whereby selective attention becomes focused on an emotional-relevant stimulus.

Key-words: event-related oscillations; EEG; Face processing; facial affect; emotion

1. INTRODUCTION

Recent electroencephalographic studies have supported the hypothesis that the process of emotional facial-expression recognition starts very early in the brain after stimulus onset by approximately 180 ms (Maurer et al., 2002). On one hand, some authors studied ERP correlates associated with face processing. It has been argued that emotional face processing arises after 200 ms, and that differences between ERPs elicited by emotional face and neutral faces were observable specifically between 200 and 550 ms after stimulus onset. An early negative deflection (N2) of higher amplitude was revealed for arousing facial stimuli (Krolak- Salmon et al., 2001; Sato et al., 2001; Streit et al., 2000) in comparison with neutral facial stimuli. On the other hand, emotive significance of a facial expression may result in phasic changes of motivated attention, indexed by frequency band variations. Thus, brain oscillations were found a powerful tool to analyze the cognitive processes related to emotion comprehension (Aftanas et al., 2002; Başar et al., 1999; Keil et al., 2001; Krause et al., 2000). Specifically, recent researches showed the event-related theta band power responds to prolonged visual emotional stimulation. Theta frequency range has been associated with attention and cognitive processes, and brain oscillations around 4 Hz respond to the relevance of the material being processed. More generally, it was observed an "orienting" function of this frequency band, since a synchronization was revealed in case of coordinated response indicating alertness, arousal and readiness to process information (Aftanas et al., 2001). On the contrary, at present no specific data exist on modulation of delta band by emotional significance of the stimulus. The amplitude of delta response is considerably increased during oddball experiments (Karakaş et al., 2000; Iragui et al., 1993) and it varies as a function of the necessity of stimulus evaluation and memory updating. Accordingly, it was concluded the delta response is related to signal detection and decision making. Some other studies have examined the alpha frequency band of the EEG and have revealed that this band can uncover the cortical correlates of relatively small differences in emotion processing (Klimesch, 1997). Nevertheless, it was found an anterior asymmetries in alpha reduction, that was explained as correlates of changes on individual affective state (Davidson, 1998; Klimesch et al., 1999). To summarize, visually evoked brain oscillations in the alpha frequency range seem to be closely related to visual attention-involving and memory processes, and not merely to visual stimulus processing per se, as well as it may be directly related to alert response of the subject (Başar et al., 2000). On the contrary, theta frequency range has been associated with attention and cognitive processes, and brain oscillations around 4 Hz respond to the relevance of the material being processed and to degree of attention in visual stimuli. Finally, delta band should be mainly related to decision-processes, and updating functions. Nevertheless, actually it remains an open question whether it is possible to assign a single brain operation or a psychological function for emotion decoding to a certain type of oscillatory activity.

1.1. Objectives and hypotheses

In the present study we intend to explore functional correlates of brain oscillations with regard to emotional face processing and to emphasize the importance of distributed oscillatory networks in a specific frequency range (between 1 and 12 Hz). A critical issue of the present research is to analyze the variability of frequency bands inside a known time interval, the temporal window around 200 ms latency. In other words, according to the theory that postulates that each oscillation represents multiple functions and, therefore, that they are selectively distributed in the brain as parallel processing systems, we explored the hypothesis of oscillatory neural assemblies on a well-known ERP component, the N200 effect (Krause, 2003). An important and currently questioned issue is, therefore, the possible effect of brain oscillation synchronous activity on the ERP correlates. We supposed that oscillatory activity of the brain is a valid index of brain's cognitive processing and that there is a multivariate relation between different sets of phenomena such as ERO (event-related oscillation) and ERP. Finally, among other issues, one question that has been raised in terms of the central nervous mechanisms mediating emotional facial stimulus concerns their cortical localization in the scalp. A specific neural mechanism can be supposed to be dedicated to emotion comprehension, since previous studies have supported the view that a posterior cortical site is activated during emotional face comprehension (Lang et al., 1998; Sato et al., 2001). Specifically, ERP studies have showed a more posterior-distributed peak for the emotional expressions than neutral expressions. Thus, the cortical distributions of brain oscillations are explored, in order to test their resemblance with ERP localization.

2. METHOD

Participants

Twenty one healthy volunteers took part in the study (19-25, M = 23.75; SD = 1.76). They were all right-handed and with normal or corrected-to-normal visual acuity. We did not instruct the subjects to evaluate the emotionality of the stimulus, in order not to cause him/her to be more attentive to the emotional stimuli than the neutral stimuli.

Procedure

Stimulus materials were taken from the set of pictures of Ekman and Friesen (1976), presenting respectively a happy, sad, fearful, or neutral face. The subjects were asked to analyze the stimuli viewed after the experimental section. Each facial expression was presented twenty times, in a randomised order in the center of a computer monitor, with a horizontal angle of 4° and a vertical angle of 6°. The inter-stimulus fixation point was projected at the center of the screen (a white point on a black background). The stimulus was presented for 500 ms on the monitor with an interstimulus interval parameter (ISI) of 2000 ms. The subjects were told to observe the faces carefully. Subjects were seated in a sound-attenuated, electrically shielded room and were asked not to blink during the task. Prior to recording ERPs, the subject was familiarized with the overall procedure (training session). Finally, in a post-experimental phase the correct identification of facial expressions was tested.

EEG recording

The EEG was recorded with a 62-channel DC amplifer (SYNAMPS system) and acquisition software (NEUROSCAN 4.2). An ElectroCap with Ag/AgCl electrodes were used to record EEG from 62 active scalp sites referred to ear-lobe (10/20 system of electrode placement). Additionally two EOG electrodes were sited on the outer side of the eyes. The data were recorded using sampling rate of 256 HZ, with a frequency band of 0.1 to 50 Hz. The impedance of recording electrodes was monitored for each subject prior to data collection and it was always below 5 kΩ. After EOG correction and visual inspection only artefact-free trials were considered. An averaged waveform (off-line) was obtained (trials exceeding 50 mV in amplitude were excluded from the averaging process). Peak amplitude measurement was quantified relative to 100 ms prestimulus. To evaluate differences in ERPs response for emotional/neutral stimuli we focused data analysis within a time window between 180-250 ms and four central, Fz, Cz, Pz, Oz. Successively, the digital EEG data were bandpass filtered in the following frequency bands: 0.5-4, 4-8, and 8-12 Hz (fast-Fourier transform) (Cooper et al., 2003). The data were epoched, triggered each second, using a time windows of 180-250 ms. To obtain a mean amplitude of each EEG frequency band, an average absolute amplitude value for each electrode for each condition (emotional/neutral type) was calculated separately for each frequency band.

3. ERPs Results

The effects of the variables on the ERP waveforms were studied using a 4 (electrode) x 2 (type) repeated measure analysis of variance (degrees of freedom were Greenhouse-Geisser corrected where appropriate). For the peak measurement the ANOVA showed a significant main effect for type (F [1,20] = 8.71, $p < 0.001$), and for electrode (F [3,20] = 11.03, $p < 0.001$). An interaction type x electrode was found (F [3,20] = 7.83, $p < 0.001$). A peak approximately 230 ms is revealed by the emotional expressions in the posterior scalp sites. On the contrary, the neutral stimuli showed an ERP profile different from the emotional ones, with a less negative peak. It was revealed a more posterior- (Pz) than anterior- (Fz F[1,20] = 8.47, $p < 0.001$) and central-distributed (Cz F[1,20] = 7.82, $p < 0.001$) peak for the emotional type. Finally contrast effects showed a more posterior negative deflection for emotional vs neutral stimuli (F [1,20] = 9.61, p < 0.001). No other post hoc comparison was statistically significant.

Successively, the EEG data were entered into three repeated measures analyses of variance (ANOVA), one for each frequency band, with two repeated factors: type (2), and electrodes (4). We reported distinctly the results for each frequency band. Delta frequency band showed sensitivity to type (F [1,20] = 7.07, p < 0.001), but not to electrode (F [3,20] = 1.72, p = 0.47). Specifically it was revealed a significant larger amplitude of delta within 150-280 ms, and, as shown, this increasing is related to the emotional content of the stimulus. Nevertheless, as revealed by the ANOVA, in this time interval delta band power synchronization was not differentiated by the location, but it was equally distributed on the anterio- posterior-site of the scalp. For theta band power it was observed a significant effect for type (F [1,20] = 10.52, p <0.010), and for the interaction type x electrodes (F [3,20] = 6.12, p = 0.001), it being associated with a selective larger delta amplitude within 180-250 time window, with a peak at about 240 ms. Synchronous activity of theta band was present mainly for emotional compared with neutral stimuli. Moreover, as revealed by post-hoc comparisons, the scalp distribution of the band frequency power revealed a more posterior (Pz (F [1,20] = 6.90, p = 0.001) and Oz (F [1,20] = 11.05, p < 0.001) than anterior (Fz) theta synchronization in emotional type. In alpha band only the electrodes were statistically significant (F [3,20] = 10.08, p < 0.001). Contrast analysis showed a significant increasing of alpha power for Fz than Cz (F [1,20] = 7.71, p < 0.001) and Pz (F [1,20] = 8.93, p < 0.001). No other effect resulted statistically significant.

4. Discussion

The findings of the present research can be summarized into three main points. First, a specific ERP variation (N230) was found for emotional vs neutral facial stimuli. Secondly, some frequency band oscillations (delta and mainly theta) appear to be responsive of emotional stimuli more than of neutral stimuli. Third, ERO amplitude variations can be considered predictive of ERP amplitude variations as a function of type of stimuli and cortical localization. Finally, an emotion-specific cortical distribution of ERP/ERO was found, mainly on the posterior site of the scalp. For the first result, a negative deflection, peaked at about 230 ms, was found for the emotional stimuli compared to neutral stimuli. We hypothesize that this deflection is strictly related to decoding of emotion facial-expressions, as revealed in previous ERP research. Interestingly, we observed a more posterior distribution of the peak for the emotional faces, in line with previous results, which have found that emotional visual area activation covers a broad range of the parieto-temporal cortices (Marinkovic et al., 2000; Sato et al., 2001).

For the second result, theta and delta oscillations respond to the variations in type conditions by variation in amplitude. On the contrary no significant variations were found for alpha power as a function of emotional/neutral stimuli. Thus, not all the frequency band are sensitive to emotional content of face, since only delta and theta showed a significant larger amplitude for the emotional stimuli, whereas alpha was not modulated by the stimulus type. Nevertheless, only theta response appears to be related to a specific scalp localization, that is posterior (Pz) sites, whereas the delta effect is obtained diffusely over the scalp. On one hand, being recorded from various locations of the scalp, the delta response is a product of the distributed response system of the brain. Potentially, it could be viewed such as an attentional selective mechanism that responds to more salient (emotional) than not salient (neutral) stimuli (Aftanas et al., 2001). On the other, findings of the present study demonstrated that the theta response contributes to a main degree to the amplitude at the N2 latency. Specifically theta oscillations represent a complex set of cognitive response selective attention whereby becomes focused on emotional-relevant stimulus. It was found that theta band was related to the function of orienting and attention for emotional significance of the stimulus, representing the first stage of conceptual stimulus processing of a short-term conceptual memory-system, in which stimuli reach meaningful representation rapidly. This theta response could represent a process that involve encoding of emotional information, and this effect of theta is obtained from the posterior location. Since a general posterior dominance theta band was found, this modulation could be involved in the modulation of emotion-related evaluation. This effect regarding cortical sites is in line with previous study, that underlined the posterior-localization of emotional face processing (Sato et al., 2001).

Third, oscillations respond to variations in processing stage of emotional face by variations in amplitude. As we have stated it appears to be likely that the content sensitivity (emotional vs neutral content) of theta and delta is related (or contribute to) the correspondent N2 phenomenon. Specifically, theta oscillations effects as oscillation activity at the N2 latency. This frequency band variation could represent a complex set of cognitive processes whereby selective attention becomes focused on an emotional-relevant stimulus that is maintained in short-term memory (N2). In addition, we can suppose an explanation for the genesis of ERP variation through the principle of superimposition. According to Başar (1999), a compound waveform can be generated by the superimposition of different oscillatory responses. Nevertheless, future research should test in more systematic manner the likely effect of specific emotional content on frequency band oscillations, especially as a function of high/low arousing emotional stimuli. Indeed it was found that recognition of specific emotions would depend on the existence of partially distinct systems. Moreover, ERP responses showed a significant difference as a function of degree of arousal and valence (negative vs positive) of facial stimuli. Therefore, the effect of this variable on the attentional and motivational significance of the stimulus, and on the brain oscillation variations must be considered.

REFERENCES

Aftanas, L.I., Varlamon, A.A., Pavlov, S.V., Makhnev, V.P., Reva, N.V. (2001). Affective picture processing: event-related synchronization within individually defined human theta band is modulated by valence dimension. *Neuroscience Letters*, *303*, 115-118.

Aftanas, L.I., Varlamon, A.A., Pavlov, S.V., Makhnev, V.P., Reva, N.V. (2002). Time-dependent cortical asymmetries induced by emotional arousal: EEG analysis of event-related synchronization and desynchronization in individually defined frequency bands. *International Journal of Psychophysiology*, *44*, 67-82.

Başar, E. (1999). *Brain function and oscillations. II. Integrative brain function. Neurophysiology and cognitive processes.* Heidelberg: Springer

Başar, E., Başar-Eroğlu, C., Karakaş, S., Schürman, M. (1999). Are cognitive processes manifested in event-related gamma, alpha, theta and delta oscillations in the EEG?. *Neuroscience Letters*, *259*, 165-168.

Başar, E., Başar-Eroğlu, C., Karakaş, S., Schürman, M. (2000). Brain oscillations in perception and memory. *International Journal of Psychophysiology*, *35*, 95-124.

Cooper, N.R., Croft, R.J., Dominey, S.J.J., Burgess, A.P., Gruzelier, J.H. (2003). Paradox lost? Explorjng the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypothesis. *International Journal of Psychophysiology*, *47*, 65-74.

Davidson, R.J. (1998). Affective style and affective disorders: perspectives from affective neuroscience. *Cognition and Emotion*, *12*, 307-330.

Ekman, P., Friesen, W.V. (1976). *Pictures of facial affect.* Palo Alto: Consulting Psychologist Press

Iragui, V.J., Kutas, M., Mitchiner, M.R., Hillyard, S.A. (1993). Effect of aging on event-related brain potentials and reaction times in an auditory oddball task. *Psychophysiology*, *30*, 10-22.

Karakaş, S., Erzengin, Ö. U., Başar, E. (2000). The genesis of human event-related responses explained through the theory of oscillatory neural assemblies. *Neuroscience Letters*, *285*, 45-48.

Keil, A., Müller, M.M., Gruber, T., Wienbruch, C., Stolarova, M., Elbert, T. (2001).

Effects of emotional arousal in the cerebral hemispheres: a study of oscillatory brain activity and event-related potentials. *Clinical Neuropsychology*, *112*, 2057-2068.

Klimesch, W. (1997). EEG alpha and theta oscillations reflect cognitive and memory performance: a review and analysis. *Brain Research Review*, *29*, 169-195.

Klimesch, W., Doppelmayr, M., Schwaiger, J., Auinmger, P., Winkler, T. (1999). Paradoxical' alpha syncronization in a memory task. *Cognitive Brain Research*, *7*, 493-501.

Krause, C.M. (2003). Brain electric oscillations and cognitive processes. In K. Hugdahl (Ed.), *Experimental methods in neuropsychology* (pp. 11-130). New York: Kluwer

Krause, C.M., Viemerö, V., Rosenqvist, A., Sillanmäki, L., Åström, T. (2000). Relative electroencephalographic desyncronization and syncronization in humans to emotional film content: an analysis of the 4-6, 6-8, 8-10 and 10-12 Hz frequency bands. *Neuroscience Letters*, *286*, 9-12.

Krolak-Salmon, P., Fischer, C., Vighetto, A., Mauguière, F. (2001). Processing of facial emotional expression: spatio-temporal data as assessed by scalp event-related potentials. *European Journal of Neuroscience*, *13*, 987-994.

Lang, P.J., Bradley, M.M., Fitzsimmons, J.R., Cuthbert, B.N., Scott, J.D., Moulder, B., Nangia, B. (1998). Emotional arousal and activation of the visual cortex: an fMRI analysis. *Psychophysiology*, *35*, 199-210.

Marinkovic, K., Trebon, P., Chauvel, P., Halgren, E. (2000). Localized face processing by the human prefrontal cortex : face-selective intracerebral potentials and post-lesion decificts. *Cognitive Neuropsychology*, *17*, 187-199.

Maurer, D., Le Grand, R., Mondloch, J. (2002). The many faces of configural processing. *Trends*, *6*, 255-260.

Sato, W., Takanori, K., Sakiko, Y., Michikazu, M. (2001). Emotional expression boosts early visual processing of the face: ERP recording and its decomposition by independent component analysis. *Neuroreport*, *12*, 709-714.

Streit, M., Wölwer, W., Brinkmeyer, J., Ihl, R., Gaebel, W. (2000). Electrophysiological correlates of emotional and structural face processing in humans. *Neuroscience Letters*, *278*, 13-16.