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Steady-State Visually Evoked Fields (SSVEF) Associated with Affective Emotions

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Abstract—**The aim of this study was to examine the SSVEFs associated with the processing of positive and negative impression images. We used the International Affective Picture System (IAPS) which is increasingly used in brain imaging studies to examine emotional processes. Their images also allow valence to be systematically investigated. All 200 images were categorized into three categories of "negative", "positive" and "neutral" individually according to valence assessed by each subject after the MEG measurement. The peripheral square, i.e., frame, of the image was flickered black and white at 15 Hz while the image was kept stationary. Those images were randomly presented for 2.0 s on screen set at 120 cm in front of the subject. Ten healthy subjects participated. MEG recordings were made with a 122-channel whole-head MEG system in a magnetically shielded room. We made two-dipoles estimation of the averaged MEG signals and obtained the amplitude of souse waveform in 15Hz component (using a band-pass filter at 14 - 16Hz) of SSVEF in occipital area. The amplitude of the SSVEF source in the occipital area was larger for the negative impression images than the positive impression images ($p<0.05$). This result suggests that the amplitude of SSVEF that originated from the surrounding field of visual object was modulated by the emotional object and that the SSVEF could be a measure of emotion of subjects.**

I. Introduction

Recent theoretical approaches to emotional perception have proposed that the affective relevance of a visual stimulus may result in changes of sensory processing [1]. Therefore, neural correlates (cortical and subcortical activity) of affective picture processing have been investigated in neurophysiological approaches [2-6]. Several studies have described event-related potentials (ERP) in electro-encephalogram (EEG) associated with affective picture viewing [2-6]. These ERP studies have consistently demonstrated a sustained late positive wave (>300 ms latency) in response to emotional stimuli, which was decreased when subjects viewed neutral pictures [5]. In fMRI study, Lang et al. examined the hypothesis that intensity of neuronal activity in the visual cortex is enhanced with increasing motivational significance of visual stimulus [6]. They found that the functional activation in visual areas of the occipital cortex varied as a function of affective arousal.

The aim of our study was to assess emotional picture-processing using Steady-State Visually Evoked Fields (SSVEFs). The SSVEF is the oscillatory field (and potential for SSVEP) generated in the visual cortex in response to a flicking stimulus which indexes neural activity related to stimulus processing, and is able to track rapid changes occurring in the neural activity during the ongoing processing [7]. Given the connection between affective aspects of stimulus and processes of motivated attention, we expected that the SSVEF amplitude is associated with variation of affective arousal.

In this study, we examined spatial and temporal characteristics of SSVEF using magnetoencephalogram (MEG), in addition to the amplitude of SSVEF occurring in the visual cortex in response to positive and negative impression images.

II. Methods

A. Subjects

Ten subjects (nine male and one female, 21-25 years), nine of them right-handed (one left-handed), having no previous history of neurological or psychiatric diseases and free of any medication participated in the experiment. All the participants had normal vision or corrected-to-normal vision. Informed

Fig. 1. An example of the images (International Affective Picture System) used in this study. In general, Picture (a) and (c) are neutral, (b) is negative, (d) is positive impression images.

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consent was obtained from all participants, and the experimental procedures were conducted in accordance with the guideline provided by the Ethics Commission of Tokyo Denki University and with the Declaration of Helsinki.

B. *Visual stimuli*

We used the International Affective Picture System (IAPS) as visual stimuli in this study [8]. The IAPS includes standard ratings for each image as to its emotional valence and arousal obtained from a normative sample of subjects. It is based on a dimensional approach of emotion, allowing for systematic variations of stimuli along the dimensions of emotional valence and arousal [9].

Figure 1 show an example of the images used in the experiment. To examine the effect of varying emotion valence, 200 images were selected only arousal scale range from 4.32 to 5.32 assessed by IAPS (the emotion valence including from 0 to 9).

We investigated brightness of original images in IAPS in our previous study [10] (Fig.2). From this result, the brightness was lower for negative than positive or neutral images. Therefore, we adjusted the brightness of all 200 images to the same level (100) by image processing software (Adobe Photoshop 11).

Using a video projector (KG-PS120X, TAXAN, Japan), the images were projected on a screen which was set at 1.2 m in front of the subject in the magnetically shielded room. The images size was a horizontal angle of 10.8 ° and a vertical angle of 7.6 °.

Single trial began with a fixation on the '+' symbol. The image was then randomly presented for 2.0 s, followed by a 1.0 s interval. During the one trial, the peripheral square, i.e., frame, of the image was flickered black and white at 15Hz, while the image was kept stationary (Fig.3).

C. *Procedure*

First, we measured MEG from subject while presenting all 200 IAPS images. In order to keep their attention to the screen, subjects were instructed to respond by lifting the right-hand index finger every time when 'neutral image' appeared. Here, decision of the neutral image was based on the subjects' own judgment.

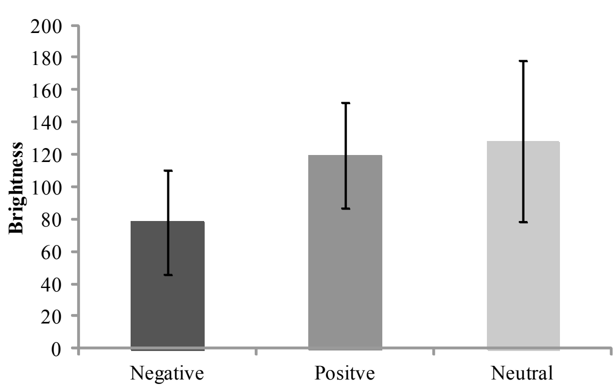

Fig. 2. Average of brightness of original pictures in negative, positive and neutral images.

There were differences in affective valence to IAPS images in individual subjects. Therefore, after the MEG measurement, subject viewed again all 200 IAPS images. They assessed the images as to its affective valence with positive, neutral and negative impressions. We then categorized all the images into three categories of "negative", "positive" and "neutral" individually according to the valence assessed by each subject.

D. *MEG data acquisition and analysis*

MEG recordings were made with a 122-channel whole-head MEG system (Neuromag-122™, Elekta Neuromag, Helsinki, Finland) in a magnetically shielded room at the Research Center for Science and Technology, Tokyo Denki University. The MEG signals were band-pass filtered from 0.03 to 100 Hz and sampled at 1000 Hz. Trials with error response or those contaminated with body movements (MEG amplitude > 3000 fT/cm) were excluded from averaging. A total of at least 50 epochs were recorded for averaging.

MEG data were averaged off-line for the each condition of negative, positive, and neutral according to the categorization in each subject. The averaged data were digitally band-pass filtered 14 to 16 Hz during from 0 - 2.0 s period after stimulus presentation. To obtain the source activity of the SSVEFs, we performed two-dipole estimation to the averaged MEG signals. We then calculated the souse waveforms in 15Hz component of SSVEFs in the left and right occipital regions. We compared the amplitude of left and right dipoles and used the dipole of the larger one. In this estimation, location of sources with goodness-of-fit values exceeding 80% was used. Finally, we obtained strength of SSVEF from Hilbert-transform of the source waveforms under the three conditions of negative, positive and neutral.

III. Results

Figure 4 shows representative distribution of magnetic fields of SSVEF in the occipital region of one subject for negative (a), positive (b) and neutral (c) conditions at about 1500 ms from stimulus onset. The red area indicates magnetic

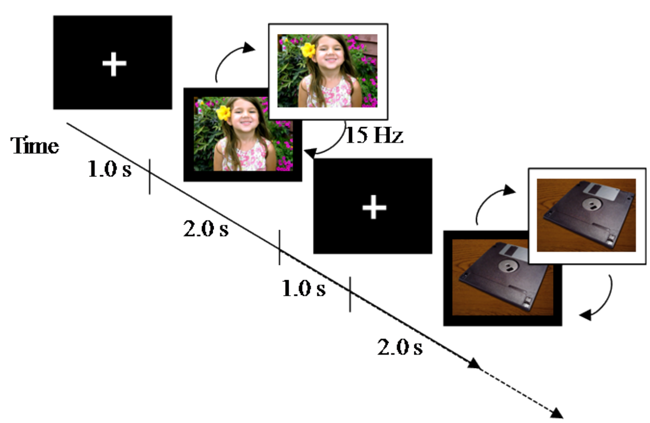

Fig. 3. Time sequence of visual stimuli.

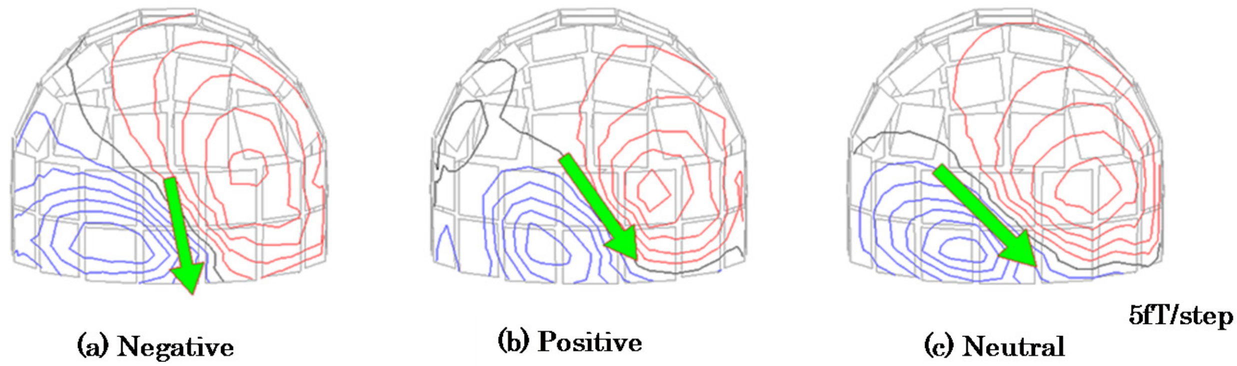

Fig. 4. Distribution of magnetic fields in the occipital area at about 1500 ms from stimulus onset. The red area indicates magnetic field emerging from brain, and blue area the reentering field. Electric current flows in the middle along the zero line (black curve).

field emerging from the brain, and blue area the reentering field. Electric current of the source flows in the middle along the zero line (black curve).

Figure 5 shows the location of three sources for negative, positive and neutral images, superimposed on the structural MRI of one subject. These source locations are in the occipital visual area. From the results of Figures 4 and 5, no difference was observed in the location of the SSVEF sources (modeled as equivalent current dipoles) among the three conditions.

Figure 6 shows the time-course of group average of ten subjects for the amplitudes of SSVEF. These waveforms were obtained from Hilbert-transform of 15Hz component in the averaged response in 'negative', 'positive' and 'neutral' conditions. It was observed that the amplitude of SSVEF increased during the period of flicking stimulation, and that the amplitude was stronger for negative condition than positive or neutral condition.

Figure 7 shows the mean amplitude during 0 to 2.0 s period of dipole strength in Fig.6. It was found that the dipole strength in the negative condition was significantly stronger than in the positive condition ($t(9)=3.91$, $p<0.05$). Meanwhile,

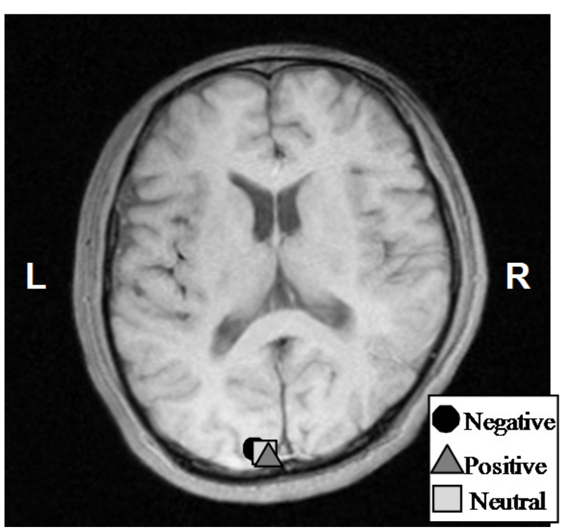

Fig. 5. Locations of SSVEFs (15-Hz) sources estimated from the responses to negative (circle), positive (triangle) and neutral (square) images, superimposed on the structural MRI of one subject at about 1500 ms from stimulus onset.

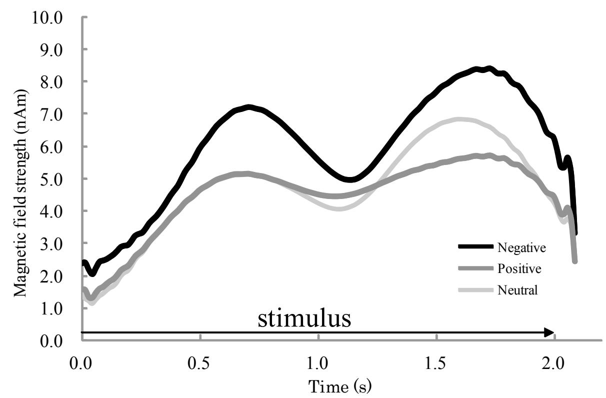

Fig. 6. Time-course of the group average of the amplitudes resulting from Hilbert-transform of its 15Hz component in the averaged response waveforms in 'negative', 'positive' and 'neutral' conditions.

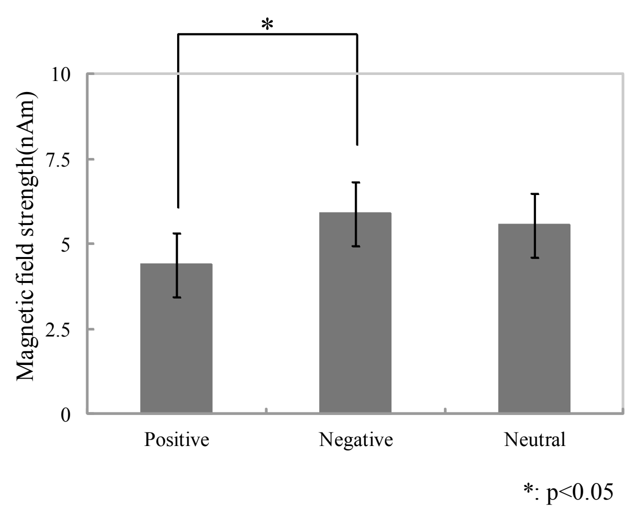

Fig. 7. The mean amplitude obtained from the Hilbert transforms of dipole wave forms of SSVEFs in positive and negative conditions.

no significant differences in the strength were observed between negative or positive conditions and neutral condition.

IV. Discussions

In previous study, IAPS pictures were presented in a flickering at 10 Hz in order to elicit SSVEPs [11]. Because of picture itself flickers, the flicker in the stimulation cannot reject to affect emotion of subjects. Therefore, in this study, we used the stimulation which the peripheral of the IAPS pictures was flickered at 15Hz.

The source location in the occipital visual cortex in Fig.5 suggests that the flickering stimuli activated primary visual areas directly through thalamocortical inputs. It has been reported that the SSVEF source localization in visual cortex depends on flicking frequency [12]. In this study, flicking frequency was used at 15 Hz in all three conditions. Therefore, such frequency dependence may not have been observed. Indeed, the difference of source location was not observed among three conditions (Fig.4, 5).

The amplitude of SSVEF source in the occipital region was significantly stronger in the negative impression images than the positive impression images ($p<0.05$, Fig.7). From the indistinguishable location of the sources of the different images, the differences in the activity of SSVEF seem to be ascribed to the condition difference, which was reflected in the subjective ratings on the arousal dimension. We infer that the images rated as negative by subjects were more atttentional than positive images and such attentional images induced higher brain response amplitudes. In this regard, the SSVEP in the visual modality have been shown to be sensitive to visual spatial selective attention [13]. The amplitude of SSVEP recorded at the sites contralateral to attended location in separated hemi-visual fields was enhanced compared to non-attended condition [14]. Here, the latter report has some relevance to the experimental condition of the present study, in which the response-eliciting visual object, i.e., flicking frame, was in the peripheral visual field apart from the central visual stimulus of the image. It is suggested that even such a case, the attention to the image might induce enhancement of SSVEP. In transient response of ERP, it has also been reported that P200 component shows higher amplitudes and shorter latencies in response to negative stimuli than in response to positive stimuli, where the P200 component was also related to attention [15].

V. Conclusion

We measured the SSVEF in MEG while viewing the positive and negative impression images. The cortical activation in relation to affective emotion was observed in the occipital region. The result suggests that the activity of SSVEF was modulated by negatively emotional images associated with subject's attention and that the SSVEF may be used as a measure of emotion of subjects.

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