Development of a System to Measure Visual Functions of the Brain for Assessment of Entertainment

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Abstract. The unique event related brain potential (ERP) called the eye fixation related potential (EFRP) is obtained with averaging EEGs at terminations of saccadic eye movements. Firstly, authors reviewed some studies on EFRP in games and in ergonomics and, secondly introduced a new system for assessment of visual entertainments by using EFRP. The distinctive feature of the system is that we can measure the ERP under the conditions where a subject moves eyes. This system can analyze EEG data from many sites on the head and can display in real time the topographical maps related to the brain activities. EFRP is classified into several components at latent periods. We developed a new system to display topographical maps at three latent regions in order to analyze in more detail psychological and neural activities in the brain. This system will be useful for assessment of the visual entertainment.

Key words: ERP, eye movement, attention, game, movie

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1. Introduction

Entertainment computing brings great benefits to the people. Recently, however, ill effects on the brain by playing a game are reported sensationally by journalisms in Japan. Of course, playing a simple game for a long time is not good for healthy development of the child's brain and mind. On the other hand, some of the games and new medias have possibilities to activate and recover an aged brain function in an old person. And new types of digital contents are developed to activate cognitive activities for an adult person [1].

Positive psychology is becoming a big topic in the field of clinical psychology [2]. The positive psychology deals with the well-being in the human life. Many researchers who study positive psychology are interesting in the creation of the good relation between people. They study positive emotion and motivation related to cognitive factors. Not only a good human relation, but also a new relation between the human and such artifacts as games, robots and digital contents bring great benefits for high quality of life. Therefore, scientific assessment of the entertainment is required in many fields; e.g. psychology, medicine, education, information science and engineering.

When a person watches a display, movies or something, psychological and physiological changes occur in the brain and the body. Psychological phenomena; e.g. perception, cognition, emotion and motivation are studied as indices by using performance, verbal responses and physiological responses.

The author found the specific brain potential associated with eye movements [3]. The potential varies with visual functions [4]. We developed a system to measure cognitive phenomena with the brain potential. The system is applicable to assess the visual function. In this paper, firstly we reviewed some studies of the brain potentials and, secondly introduced a new system to measure the brain potential for assessment of the visual entertainment.

2. ERP and EFRP

Brain potentials (e.g. EEG; the spontaneous brain wave and ERP; the event related brain potential) can be measured from electrodes placed on the scalp. ERP is a sequence of electrical changes elicited by sensory or perceptual stimuli, and cognitive events. ERP is a very small change in electrical activity of the brain. The direct observation of ERP is very difficult, because ERP is intermingled with EEG. In order to obtain an ERP, successive stimuli or events have to be presented to a subject. The EEG is triggered by the onset of a stimulus or event and EEG epochs associated with the onsets are averaged. Because the spontaneous EEG is assumed to be a random process, the averaged value of EEG gradually approaches to zero. On the other hand, ERP linked to the events becomes increasingly clear as the number of trials averaged increases. Therefore, in order to obtain ERP, signals associated with repeatable stimuli, responses or events are required to trigger EEGs for averaging. A researcher must prepare intermittent visual stimuli with a fixation point on the display to obtain the visual ERP. The researcher asks to a subject to watch the fixation point and not to move eyes. Therefore, it is very hard to apply the visual ERP to situations where eyes move.

When a subject looks at something, the eye movement record shows step-like pattern consists of saccadic eye movements (saccade) and eye fixation pauses. Since saccadic suppression occurs during the saccade, information concerning the nature of the visual object is sent from the retina to the brain during the fixation pause. When EEGs are averaged time-locked to fixation pause onset; i.e. offset of saccades, a unique ERP is obtained. The author found the potential and named it the eye fixation related potential (EFRP). EFRP is a kind of ERPs measurable in situations requiring eye movements. EFRP like the ERP consists of some components that are classified with the latent time (latency) and the distribution on the scalp of the brain (Fig.1). The most prominent component with latency of about 80-100 ms is called the lambda response. Some components of EFRP change as a function of stimulus properties as well as subjective factors [5]. The late component with long latency (300 ms) appears at around the central region on the scalp, when the subject detects a given target at visual search tasks. The component is identical the so-called P3 (P300) component.

3. Application of EFRP to entertainment

The technology of EFRP is applied to assessment of attention in ergonomics. For instance, assessment of lighting environments [6], a visual display [7], a computer graphic (CG) task [8] and so on [9, 10, 11]. Further, the technology is also applied to assessment of the visual fatigue [12] or attention in computer games [13]. In ERP studies, many intermittent stimuli are repeatedly presented at the same point. The ERP gradually decreases by habituation, if a response to the stimulus is not assigned in the experiment. However, EFRP showed very small decrement during the CG task and a playing game. We observed increment of the EFRP in amplitude during a computer graphic task [8]. The subjects who were novices of a CG task reported that they were interested in the task and enjoyed the painting task. They felt that the task was a kind of games rather than the work.

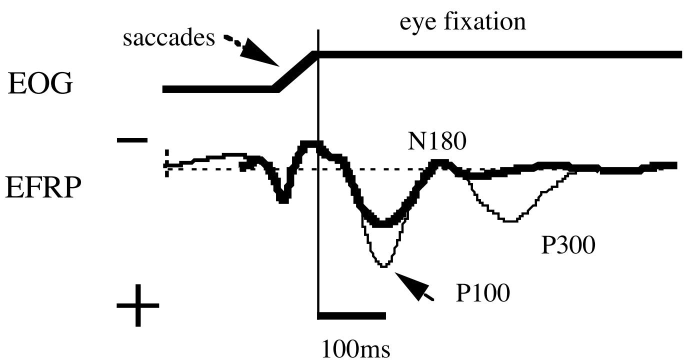

Fig. 1 Model of EFRP. EFRP consists of several components, (upward negativity) EOG shows Eye movement.

In the studies on games, a real time analyzer is required to develop to assess temporal variation of the EFRP. And topography of EFRP also is useful to observe the regional activities of the brain associated with cognitive phenomena. We developed a system to make a real time topographical map of EFRP [14]. In the system, amplitudes of only one component (P80) of the EFRP from 32 sites on the scalp can be displayed in real time. Recently, we developed a new system to display in real time the topographical maps of three components; for instance P80, N150 and P200 (these parameters are optionally changeable).

4. Out line of the system

4-1. Detection of onset of an eye fixation pause (offset of a saccade)

EOG data for the eye movements are digitized with a given sampling time by an A-D converter. The waveform of EOG consists of saccades (big deflections), slow drift and small noises. There are small noises by EMG (muscle potential) even during eye fixation pauses. At the first stage, a saccade is discriminated from the noise. And at the second stage, the point where a big deflection changes into flat is defined as onset of the eye fixation pause. The vector value is computed form the horizontal EOG and the vertical EOG to detect the absolute value of the saccade.

4-2. Averaging EEGs

In the detection of the regular ERP, EEG epochs time-locked to the stimulus onset are averaged several ten times to increase the ratio of the signal to noise. In EFRP detection, EEG epochs time locked to onset of the eye fixation pause are averaged several ten times. One EFRP can be obtained by this procedure similar to the regular ERP. When an eye blink (spike) occurs, the trigger signal is canceled from the subsequent analysis.

Further, when EMG or an irregular eye movement occurs, the EEG sample is canceled. Therefore, EEGs without artifact and noise are averaged automatically at offset of saccades in real time.

4-3. Sliding average

As mentioned above, suppose EEGs are averaged 30 times to obtain one ERP. 30 EEG epochs for the first array are collected and averaged from the first epoch for the first stimulus to the 30th. This is a regular method to obtain the ERP. For the second array, the data in the top epoch is deleted and the data in the 31st epoch is added. A series of EFRPs in time course can be obtained successively by continuing the procedure.

4-4. Monitor screen of low data

Fig.2 shows windows of real time monitors of low data. The upper left shows the current waveform of EFRP at the occipital region. The upper right shows the current saccade offset. The trigger point indicates by a vertical line. EEG and EOG data are shown in the lowest window. We can check the trigger point and the effect of noise and artifact.

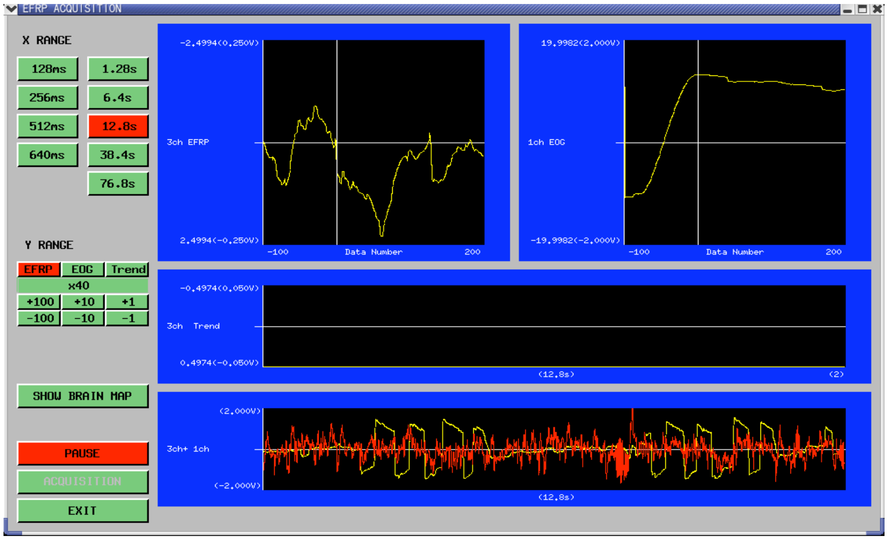

Fig.2 Monitor screen. A waveform in the upper left shows typical EFRP. The upper right shows a current saccade. A vertical line indicates the point of saccade offset: i.e., onset of an eye fixation. The lowest window shows EEG and EOG.

4-5. Display of the EPRPs

When a series of topographies of EFRPs can be displayed continuously, we can observe the dynamic changes of EFRPs like an animation. Fig. 3 shows the topographical maps in three time zones of EFRPs. Each topographical map indicates the distribution of potentials on the brain. The upper side of each topography is the frontal region and the bottom side is the occipital region.

Three bigger maps at the left side show the current topographical maps at three time regions; an early component, a middle component and a late component. Since each topographical map is displayed at the same position, the maps show dynamic changes of EFRP on the scalp. We can observe in real-time the dynamic movement of the EFRP. The dynamic movement was like an animation movie.

Smaller maps at the right side presented one by one at each time region. Therefore, the final map is the same as the right big one. We can observe the trend of the maps at three time regions. The map with the number of 1 indicates the earliest map in each component.

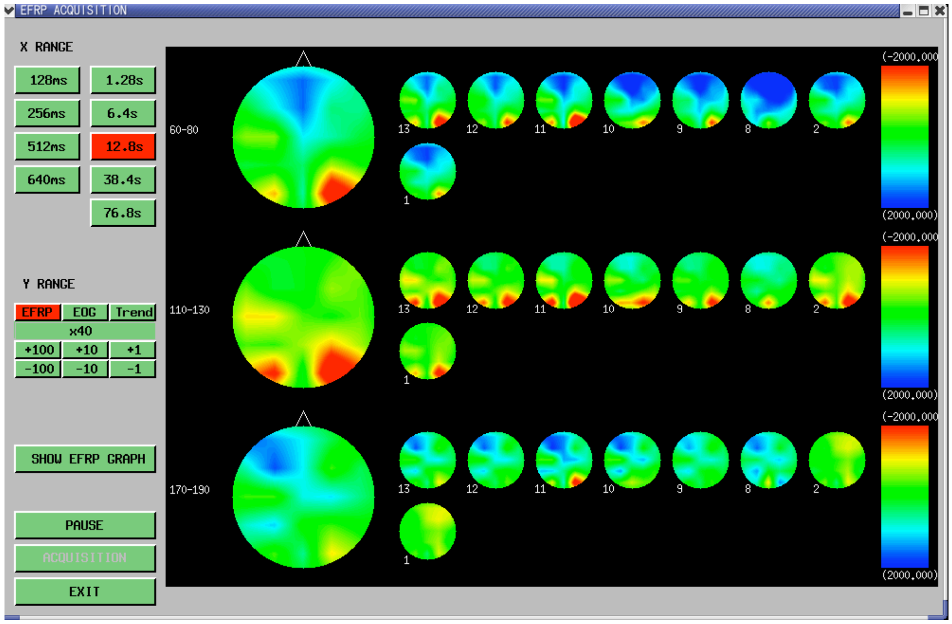

Fig.3 shows topographies of EFRP in three latent periods. The left three are current topographies. Red means high positive potential and blue means negative potential.

5. Test of the system

In the test of the system, EEGs were measured from 14 sites. The horizontal and the vertical EOG were measured and amplified. EEGs were averaged 30 times to observe variation in the amplitude of EFRP in neatly real time. The amplitudes of three components; i.e. the positive component (70 ms), the negative (120ms) and he positive (180ms) after an eye fixation were measured and made maps by the analyzing system. In this test, the subject, who was a student, was asked to move eyes between two targets on the strips every 1sec. The distance between two targets was 20 deg. The task was very simple. Topographical maps show dynamic variations of EFRP in time course.

Fig. 3 shows an example of the topographical changes of EFRP. We can observe the temporal changes of EFRP.

6. Conclusion

In this paper, we reviewed some studies on EFRP and introduced the new system that was developed very recently. In the most of the past studies on the brain function, mass data in a session for a long time have been analyzed while subjects are playing games. However, the new system is useful to analyze in real time the functions of the brain. The main part of the system consists of a very high speed computer with four CPUs that is very expensive. However, we also developed a more economical system that works with a personal computer of Window-XP. We can analyze EFRP and can obtain a topography of EFRP in offline [15]. The system is already on sale. It will be useful for a convenient analysis of EFRP. The authors believe those two systems will be useful for assessment of such visual entertainment as game, movies and so on.

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