Changes in Small Eye Movements in Response to Impressions of Emotion-Evoking Pictures

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Abstract—**The possibility of evaluating the emotional impressions of pictures was examined using the cross power spectrum density (CPSD) of small eye movements. Pictures were employed as a set of normative emotional stimuli and were presented to 7 male subjects in order to evoke emotional impressions. The eye movements resulting from each stimulus were measured using a video based eye tracker while the viewer's subjective impression for each picture was rated. The stimuli were then grouped as "Pleasant" or "Unpleasant". In comparing the CPSDs of eye movements between two groups, the powers of the CPSDs for the "Unpleasant" group were significantly higher, at 3.75-7.5Hz during the 400-1033.3ms after stimulus onset. This result confirms that eye movements reflect viewer's emotional impression.**

Keywords–eye movements; emotional assessment; subjective assessment; cross power spectrum

I. Introduction

Emotional impressions require the highest level of information processing, and emotions are an essential facet of human behavior. Therefore, this activity has been studied psychologically and clinically, and has often been referred to in the study of applied sciences, such as marketing. The emotional state which is created in some patients is often measured using eye oscillations such as small eye movements [1]–[3]. As the eye oscillations also reflect the mental workload in a specific task [4], a more detailed analysis is required.

However, as the definition of an emotional state remains ambiguous, facial expressions were used to evoke viewer's responses. During the experiment, the frequency power of small eye movements can indicate the degree of "Unpleasant" impressions of facial expressions [5]. Whether the phenomenon is maintained when various images are used should be confirmed. In addition to this, the observation procedure has not yet been established.

This paper confirmed the possibility of using a set of normative emotional stimuli of photos and a typical video based eye tracker to detect viewer's emotional responses using the responses of their eye movements. Also, a procedure for evaluating eye movement was established. This paper is organized as follows. Section II gives a brief description of previous works, and Section III presents the experimental method. In Section IV, the results of the experiment are shown, and the discussion is summarized in Section V. Section VI concludes the overall results.

II. Previous work

The relationships between facial expressions and the observer's eye movements has been studied previously [6]. An observer's emotional impressions are stimulated by the viewing of facial expressions, due to a kind of emotional synchronization [7]. The responses of both eye movements and event related potentials (ERPs), such as the observation of brain activity, were analyzed after pictures of facial emotions that had been prepared as the Japanese and Caucasian Facial Expression of Emotion (JACFEE) collection [8] were shown to participants. The individual impressions of the facial expressions in the pictures were evaluated using a scale called the "Affect Grid" [9]. The results of viewer's rating patterns were extracted using cluster analysis, and assigned to two clusters labeled "Pleasant" and "Unpleasant" [10]. Also, there were some significant differences in the waveforms of ERPs between the two clusters [10]. All of the differences suggest that the degree of two dimensional eye oscillation for "Unpleasant" facial images is significantly higher than for "Pleasant" images.

To extract perceptual differences between the two groups of emotional face images, ERP potentials were compared at three typical positions on the scalp, such as the Frontal (Fz), Central (Cz) and Occipital areas, according to the international 10-20 system. Significant differences in frontal electrode Fz from 142.5ms to 192.5 ms and central electrode Cz from 132.5ms to 195.0 ms were observed [10]. The difference was not detected in waveforms at the Oz (Occipital) electrode. Emotional recognition is a thought process at the highest level, and the differences appear on potentials at an early stage, from between 130 to 195 milliseconds after the introduction of the stimulus at the mid and frontal areas [10].

In regard to these results, as ERP responses to facial expressions occur earlier than the reactions to eye movements [11] [12], some specific area of brain activation may trigger these eye movements. As there are some latencies in eye movement after stimulus onset [13], eye movement may follow a rapid physiological response such as an ERP. In order to examine the phenomenon, the relationships between the two indices were analyzed for every 160msec. time interval. The results provide evidence that the activity of an electrode at the central area of the scalp affects eye movement between 220 and 540ms when "Unpleasant" images of facial expressions are displayed. This phenomenon is more highly emphasized during the viewing of "Unpleasant" facial expression images than it is during the viewing of "Pleasant" images [5].

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During the experiment, eye movement was measured using electro-oculograms (EOGs) at a sampling rate of 400Hz. Eye oscillation activity was calculated as a cross power spectrum density (CPSD) using the two dimensional positions of eye movement. The EOG observation requires four electrodes which are placed directly around the eyes of the subjects, so that viewing activities are restricted. In addition to this, the measuring technique did not focus on the frequency powers of lower frequency ranges where eye oscillations during fixation increase the power of CPSDs. While most eye trackers are designed for use during unrestricted viewing, observations were measured at a sampling rate of 60Hz. Therefore, the sampling rate and the period of observation used to detect eye oscillation should be considered carefully.

In order to determine the feasibility of observing eye oscillations at a lower sampling rate, the EOG data was re-sampled at 60Hz and analyzed using CPSD measurements and an observation interval set at 640 ms (256 data points). Frequency power can be calculated every 1.5625Hz. The frequency powers of the CPSDs of the two groups of emotions were compared across several periods of time. As a result, significant difference ($p < 0.05$) in two of the groups was detected at a frequency range between 3.125 and 6.25Hz in 650–1440ms. The result is a reasonable range of frequency and duration for eye oscillation.

The possibility of evaluating eye oscillations at lower frequency which would be comparable to the 60Hz rate was examined, and a procedure was developed [14].

III. Experimental Method

The stimulus and experimental design are organized as follows.

A. Stimulus

To evoke viewer's emotions, a set of pictures from the International Affective Picture System (IAPS) was employed [15]. According to the license, the images are not allowed to be presented in any format. This data set consists of scene images which produce specific impressions and is well known as a set of normative emotional stimuli for use in the experimental investigation of emotions. The contents of the photographs are completely different from the photographs of facial emotions mentioned above in Section II. Sixty seven pictures were selected that would produce the anticipated responses within a range of emotional impressions. Since the photos consisted of natural expressions, the level of brightness varied widely. The color range also varied widely. This is known as saliency, when the features of images presented affect a viewer's eye movement [16]. To reduce the effects of color, all pictures were converted into grayscale images. However, the brightness levels were not adjusted for presentation in this experiment.

B. Experimental design

The photos were displayed on a 19 inch LCD which was 60cm away from subjects. The eye tracker unit (nac:EMR-ACTUS) was set under the LCD monitor, and the observer did not wear any equipment. A presentation diagram is shown in Figure 1. Each photo was displayed for 3 seconds, followed by a blank image used to produce eye fixation. The stimulus presentation was controlled using the software of the eye tracker. Subjects were not asked to produce any responses before an image had been viewed. The eye movements of both eyes in response to every photo were recorded at 60Hz, and the data of the left eye was used in the analysis which follows.

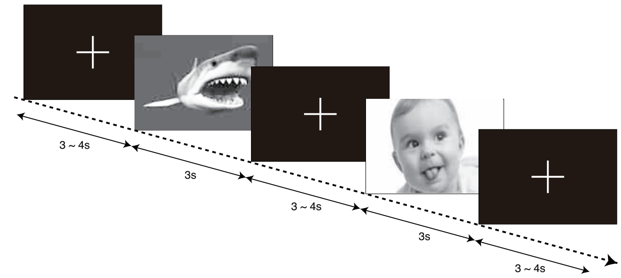

Figure 1. Diagram of stimuli shown.

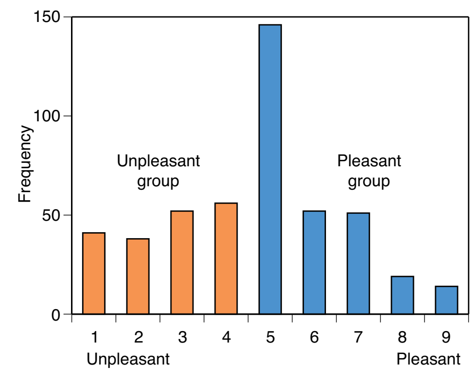

Figure 2. Results of viewer's ratings of photos using an "Unpleasant" – "Pleasant" scale.

Three trials were conducted during which the same set of images was shown to each subject, followed by a short break. All photos were evaluated by each participant following each of the sessions, using a 9 point scale which ranged between "Pleasant" and "Unpleasant". The numerical rating was used as one of the two dimensions of an Affect grid [9].

The subjects, who possessed sufficient visual acuity, were 7 male university students aged between 21 and 24 years old. The contents of the experiment were explained to all participants in advance, and informed consent was then obtained.

IV. Results

The rating responses for stimuli and the analyses of eye movements are summarized as follows.

A. Subjective evaluation

All photographs were rated by each subject using a 9-point scale. The overall frequencies of the scale are summarized in Figure 2. The frequency is the cumulative value of the responses of all participants to each photograph, since individual ratings are different and independent. The responses

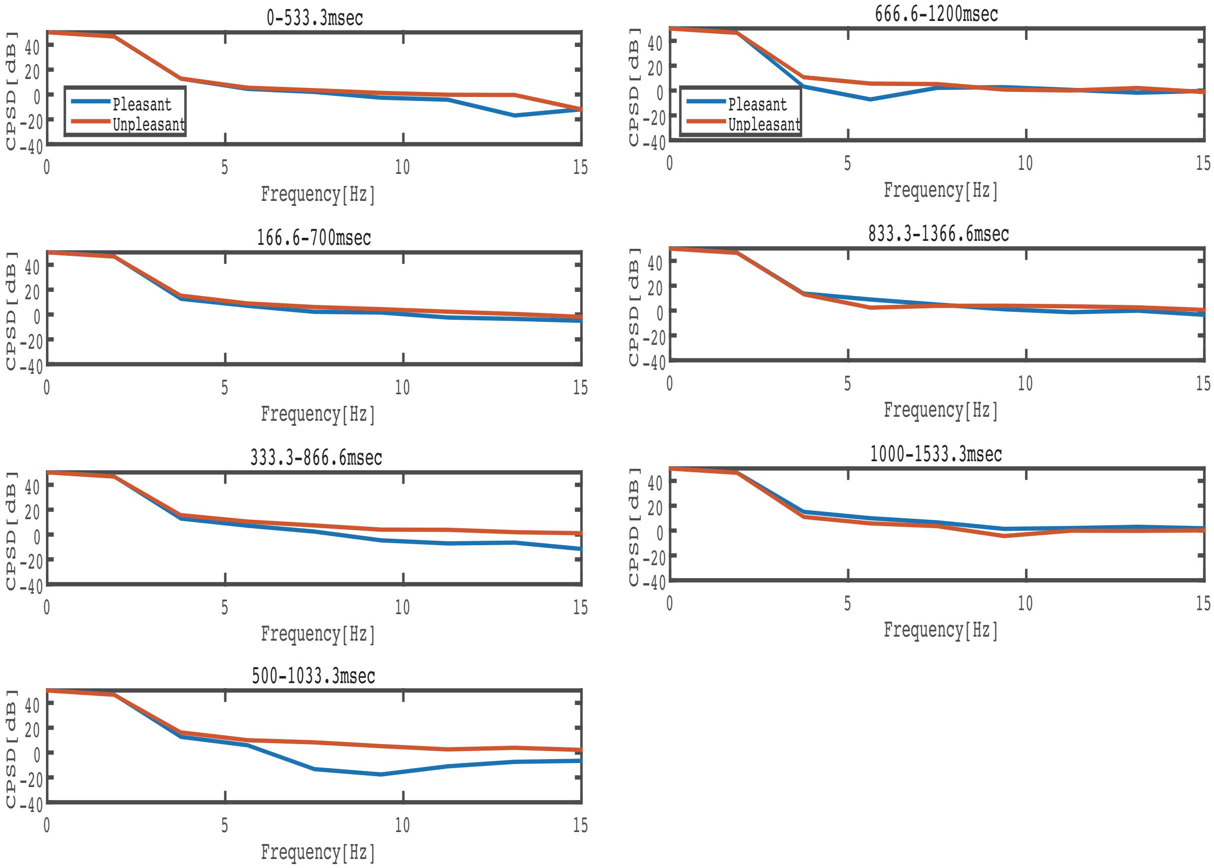

Figure 3. Comparison of cross power spectrum densities for every 533.3ms between 0 and 1533.3ms.

were widely distributed as was intended by the experimental design. The result suggests that some pictures are rated as the most "Pleasant" ones while others were rated as the most "Unpleasant". The most common responses to pictures were in the neutral category "5". Therefore, the photographs have been divided into two groups using the rating scale. The responses between two groups were compared, in order to rate them according to the factor of their emotional impressions. In the following analysis, ratings less than 5 are classified as "Unpleasant" (N_u = 187) and the remainder of the ratings are classified as "Pleasant" (N_p =282). As the responses consist of individual impressions of each photo, the grouping patterns between individuals are different.

B. Cross power spectra of eye movements

To detect evoked eye movements during picture observation, frequency analysis was conducted using the two dimensions of eye movement. Cross power spectrum densities (CPSDs) were calculated for every 533.3ms (32 data points at a 60Hz sampling rate). As the frequency power of the CPSD is generated every 1.875Hz, it is comparable to the calculations used for the condition mentioned above in Section II. When eye blinks occurred during observations, the trials were omitted. Since the eye tracker measures pupil diameters simultaneously, eye blinks can be used to detect the sudden drop in the diameter of the eye.

To examine the emotional difference factor of the pictures, frequency powers of CPSDs of eye movements were calculated for 7 periods: 0–533.3ms, 166.6-700ms, 333.3-866.6ms, 500-1033.3ms, 666.6-1200ms, 833.3-1366.6ms, and 1000-1533.3ms. The duration was shifted every 166.6ms. The power spectra of CPSDs of eye movements are summarized in Figure 3. In the figures, the blue line indicates the powers of the "Pleasant" group, and the red line indicates the powers of the "Unpleasant" group. The powers are at almost the same levels at 0–533.3ms and 166.6–700ms. For the periods 333.3-866.6ms, 500-1033.3ms and 666.6-1200ms, the powers of the "Unpleasant" group gradually become greater than the ones for the "Pleasant" group, and the frequency range of the difference becomes lower.

In examining the significant differences in frequency powers between the two emotional groups, some significant differences exist. The results are summarized as a 3D graph in Figure 4. The horizontal axes represents the frequencies and duration analyzed, and the vertical axis represents the levels of significance. A cuboid indicates that there is a significant difference between the two groups. As the figure shows, significant differences appear, depending on frequency and duration. At an early stage, a significant difference between 333.3 and 866.6ms at 5.625Hz was observed. Some additional differences which were significant followed at an early stage. In addition, the possibility of detecting the differences occurred between 400 and 1033.3ms at 3.75–7.5Hz. The duration of

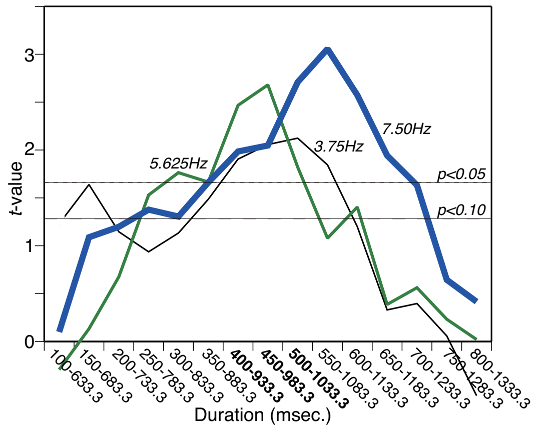

Figure 4. Results of t-tests which confirm significant differences in cross power spectrum densities of eye movements between two emotional groups.

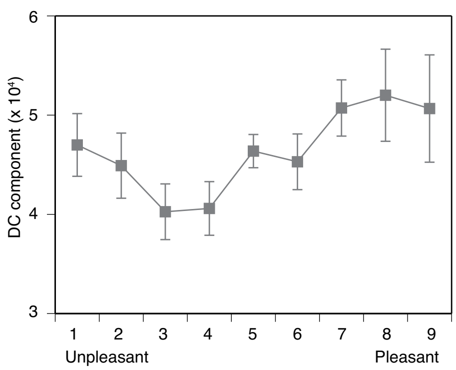

Figure 5. Relationship between viewer's rates and the brightness of photographs presented (Error bars indicate STD Errors)

observation time is shown as red cuboids in Figure 4. When this condition was analyzed, it was confirmed that the difference in the frequency power of eye movement CPSDs for the "Unpleasant" group is significantly higher than the CPSDs for the "Pleasant" group across all periods of time.

V. Discussion

The activation of eye oscillation in response to "Unpleasant" images was confirmed when photographs of emotional expressions were introduced in addition to the facial images which were presented. The frequency ranges and duration were also confirmed during this experiment.

The brightness level of the pictures was not considered during the design of this experiment, though several features and especially brightness affect the saliency of the visual attention of the viewers. In a previous study, the influence of the level of brightness was ignored, as all visual stimuli were similar photos of facial expressions. To confirm the factor of brightness in the experiment, the relationships between picture brightness and viewer's subjective evaluations are summarized in Figure 5. The horizontal axis indicates the rating values, and the vertical axis indicates the values for DC components of photographic data, using DCT analysis. The error bars show the standard errors of DC components as a level of brightness.

In regards to the relationships between picture brightness and viewer's subjective evaluations, a small correlation was observed. The effectiveness of viewer's ratings of the deviation of DC components is not significant however, according to the results of one-way ANOVA $(F(8, 460) = 1.69, p = 0.10)$. Therefore, the degree of contribution of picture brightness should be considered carefully in the feature studies.

Another question is the mechanism which causes eye oscillation when "Unpleasant" images are displayed. The phenomenon was observed when both facial images and normal pictures were viewed. The latencies in appearance of the differences in CPSD powers and chronological analysis suggest that the oscillations may be caused by image recognition and the activation of some area of the brain. The details of the information processing process are unclear. In regards to our daily experience, as we may be reluctant to view unpleasant images, the detailed of this phenomenon should be examined in greater detail.

As the phenomenon may be a stable one, responses can be used to evaluate the viewer's emotional impressions of images such as those used in HCI design or psychological analysis. To examine the validity of using this technique, the influence of various factors such as brightness or the color of stimuli should be confirmed. The study of these factors will be the subject of our further study.

VI. Conclusion

The possibility to evaluating viewer's emotional condition when evoked by their viewing photographs was examined using frequency analysis of eye movements. As the previous studies suggested, at lower frequencies some cross power spectrum densities of eye movements were generated by the invoked emotional conditions created using the facial images which were shown to subjects. To create the stimulus using images, a set of normative emotional stimuli photographs was introduced, and a typical video based eye tracker was employed to measure eye movement.

In regard to the chronological analysis of the cross power spectrum densities (CPSDs) of eye movement, a significant difference was confirmed at 400–1033.3ms after stimulus onset in the frequency range of 3.75-7.5Hz. From the differences that were extracted from the durations and frequency ranges, the powers of CPSDs for "Unpleasant" images were significantly higher than were the ones for "Pleasant" images. Also, as the differences began between 333.3 and 866.6ms, it suggests that an early response has occurred.

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