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EDA-BASED ESTIMATION OF VISUAL ATTENTION BY OBSERVATION OF EYE BLINK FREQUENCY

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Abstract- This paper describes the relationship between visual attention and eye blink frequency. In an experiment, we prompted the activation of a subject's visual attention and examined the influence of visual attention (as measured using electrodermal activity (EDA), which is meaningfully correlated with visual attention) on the subject's eye blink frequency. Experimental results show that engagement of visual attention decreased eye blink frequency and that when visual attention was not activated, eye blink frequency increased. Knowledge of this relationship provides a technique using EDA to objectively determining a subject's visual attention status.

Index terms: Electrodermal activity (EDA), visual attention, eye blink, skin conductance response (SCR), index of physiological psychology, pre-cueing technique.

I. INTRODUCTION

A decline in attention is a causative factor in many accidents including traffic accidents and misoperation of machine tools. To prevent such accidents, an index from physiopsychology is thought to be useful for estimating a mental state of a human [1, 2, 3, 4]. The eye blink rate is one such index and is effective for estimating attentiveness. The eye blink rate can be easily measured without physical contact by the use of tools such as video cameras [5, 6, 7]. In addition, it has been found that eye blink activity changes in response to psychological factors, and various relationships between the eye blink rate and attention have been proposed [8, 9].

In related research, experimenters gave subjects tasks and investigated the relationship between the eye blink rate and attention by observing the eye blink [10]. In this method, there is an assumption that the subject's attention is engaged while he or she works on the task. However, this method does not take into account such influencing factors as the subject's motivation and will. That is, a subject may not actually have exercised his or her attention even though he or she has worked on the task. Therefore, in order to assess the relationship between attention and blinking, a method for objectively measuring attention is needed.

We therefore focus on electrodermal activity (EDA), which is an electrical phenomenon from the glandular release of sweat that is caused by mental excitement or strain. In psychology, EDA is used as an index to measure degrees of affect such as stress, strain, and excitement [11, 12]. EDA has been shown to have a meaningful relationship to visual attention [13]. In this study, we use EDA as a means of objectively measuring visual attention to elucidate the relationship between visual attention and blinking. We herein describe the experiment we conducted based on EDA and the results that verify this relationship.

II. EDA-BASED ESTIMATION OF VISUAL ATTENTION

a. Summary of EDA

Electrodermal activity is a change in the electrical characteristics of the skin, especially the palm and the sole of the foot, due to sweating caused by mental exertion. There are two methods of measuring EDA: electrification and potentiodynamics. With electrification, the change in apparent skin resistance or impedance is measured by electrifying the skin from outside the body; potentiodynamics is a method that measures the variation in skin potential directly. The change measured via electrification is called the "skin conductance change (SCC)," and the change measured by potentiodynamics is called the "skin potential activity (SPA)."

Both SCC and SPA are phenomena that overlay steep transient changes against the general background level. The general background level for SCC is called the "skin conductance level (SCL)," and that for SPA is called the "skin potential level (SPL)." The transient SCCs are called the "skin conductance response (SCR)," and changes in SPA are called the "skin potential response (SPR)." SCR and SPR are collectively called the "galvanic skin response (GSR)." Figure 1 shows a diagram of these relationships.

In this study, we used electrification to measure EDA; therefore, the SCL and SCR data were able to be obtained. Figure 2 shows an example of the measurement of SCL and SCR. As shown in the figure, the SCL reaction is measured by changes over a relatively long time period, whereas SCR is measured by changes over a relatively short period.

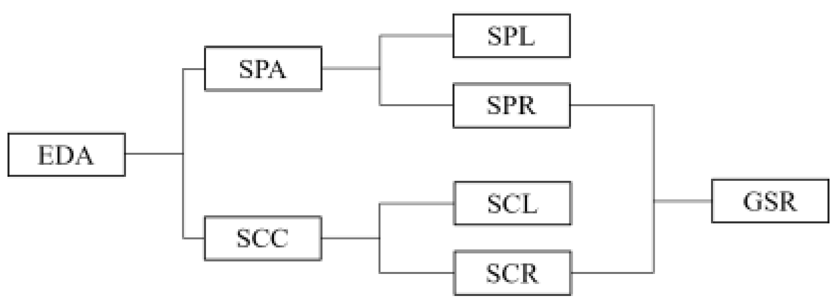

Figure 1. Classification of electrodermal activity (EDA) measurement terminology

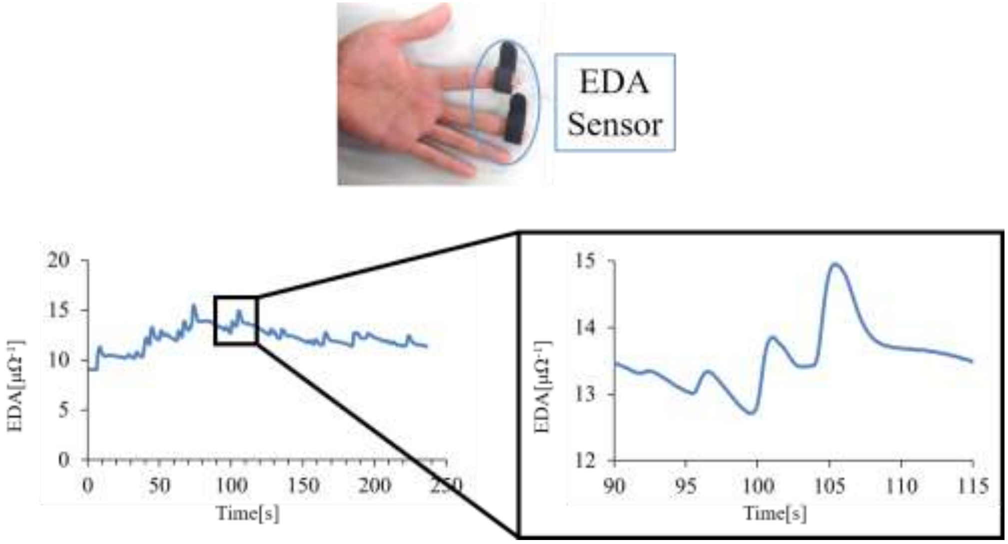

Figure 2. Example of skin conductance level (SCL) and skin conductance response (SCR) measurement

b. Relationship between visual attention and EDA

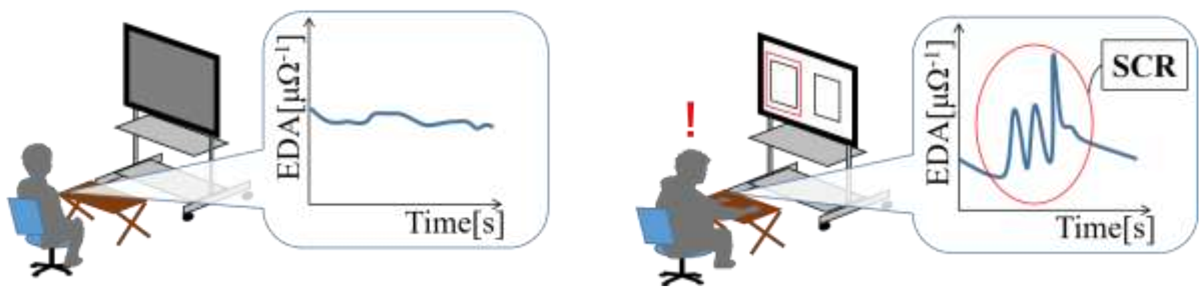

Figure 3. Relationship between visual attention and EDA

There is a significant relationship between EDA and visual attention. We performed a psychological experiment in which the subject's visual attention was exercised, and we verified the relationship between visual attention and the eye blink rate. As shown in Figure 3, it was confirmed that an SCR, reflecting transient changes in EDA, occurs when visual attention is engaged. In addition, our results indicated that the quantity of SCRs fluctuates according to the degree of visual attention engaged [8].

Based on these findings, we can determine whether a subject's visual attention is engaged in the following manner:

1. We have subjects devote themselves to a task that exercises their visual attention.

2. We measure the EDA of subjects while they are immersed in the task.
3. If an SCR occurs while a subject is attending to the task, we conclude that the subject's visual attention is engaged.

The relationship between visual attention and eye blink rate was verified after the engagement of visual attention was confirmed on the basis of EDA as described above. Thereby, it becomes possible to evaluate the relationship more objectively.

III. EXPERIMENT

a. Method

In this experiment, the situation in which the subject's visual attention was engaged was established by a pre-cueing technique. Each subject was presented with a task during which he/she pushed a reaction switch as soon as a target stimulus was displayed in his/her field of vision. To engage the subject's visual attention, a cue was presented before the target stimulus was displayed, as the pre-cueing technique. Figure 4 shows the target stimulus, the cues used in the experiment, and the task flow. The red circle was used as the target stimulus. Three cues were employed. A condition in which the cue indicates the true position of the target stimulus is called a "valid condition." Conversely, a condition in which the cue indicates a position that is not the true position of the target stimulus is called an "invalid condition." A condition involving neither of these situations is called a "neutral condition."

Figure 5 shows the time period that the subject works on the task. The time period of the task was defined as the time from the moment the subject pushed the switch to begin the task to the moment the switch was pushed again when the subject identified the target stimulus. Figure 6 shows the respective time periods before, during, and after the task; the periods were of equal length. If the subject's visual attention was engaged during the task, EDA fluctuated more than in the other periods because an SCR occurred. For this study, the mean value of the fluctuation in EDA per unit time is given by

$$\Delta G = \frac{\sum |\Delta g|}{T} \quad (1)$$

where ΔG is the mean value of the fluctuation in EDA per unit time ($\mu\Omega^{-1}$/s), Δg is the increase or decrease in EDA ($\mu\Omega^{-1}$) over a short time interval, and T is the time elapsed during which the

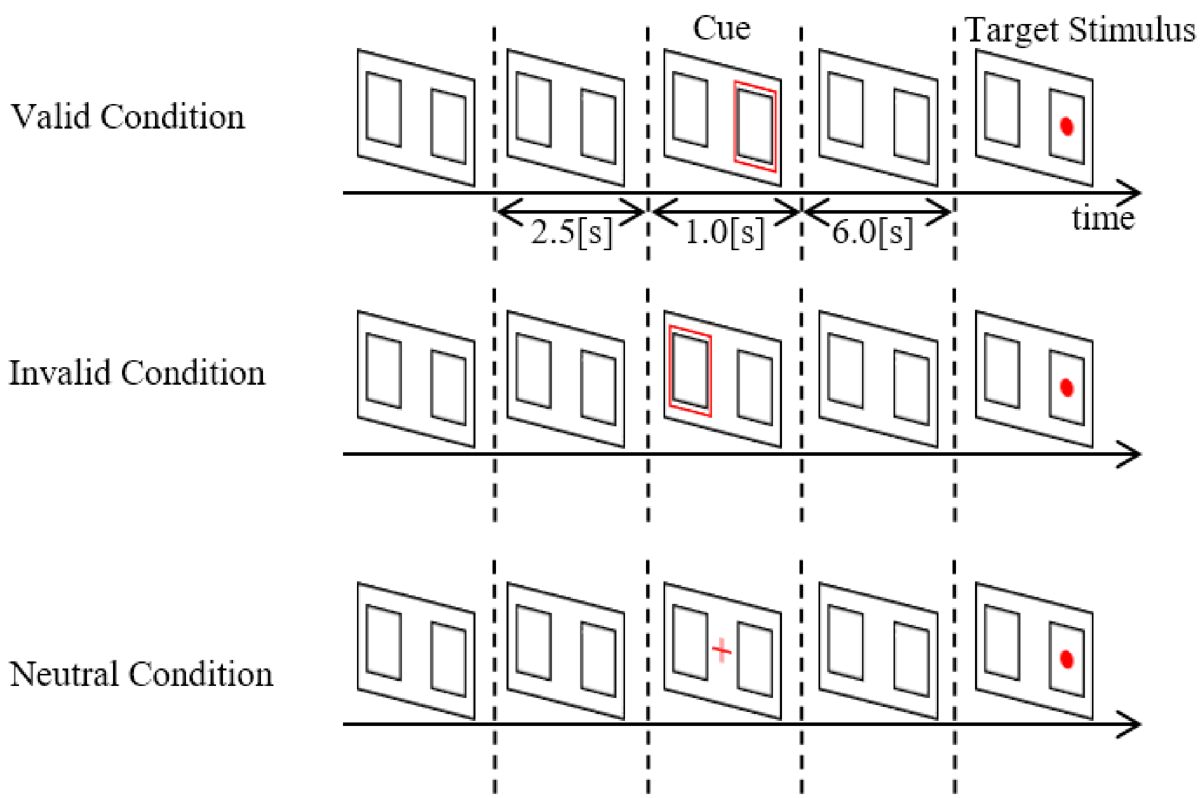

Figure 4. Pre-cueing technique

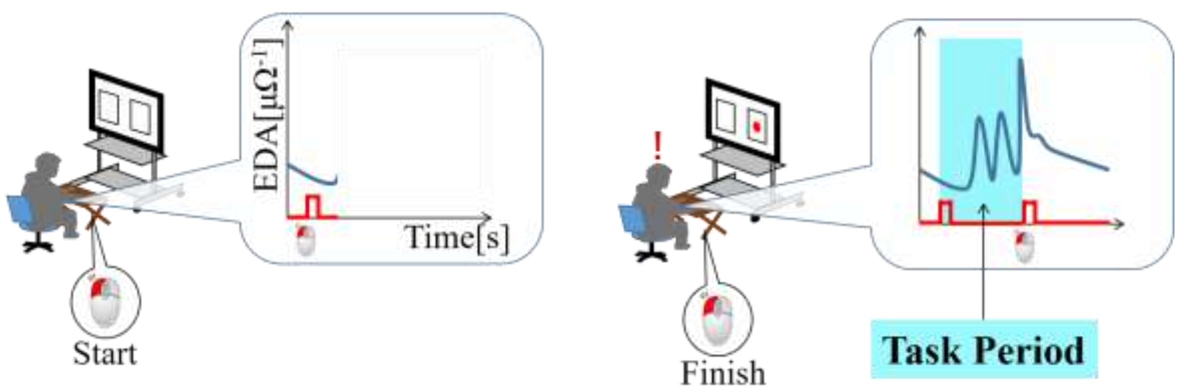

Figure 5. The time period during the task

subject worked on the task. Mean values for the fluctuation in EDA per unit time were respectively calculated for the periods before and during the task to determine whether the subject's visual attention was engaged. If they differed significantly according to the *t*-test, it was determined that the subject's visual attention was engaged during the task, and for these cases,

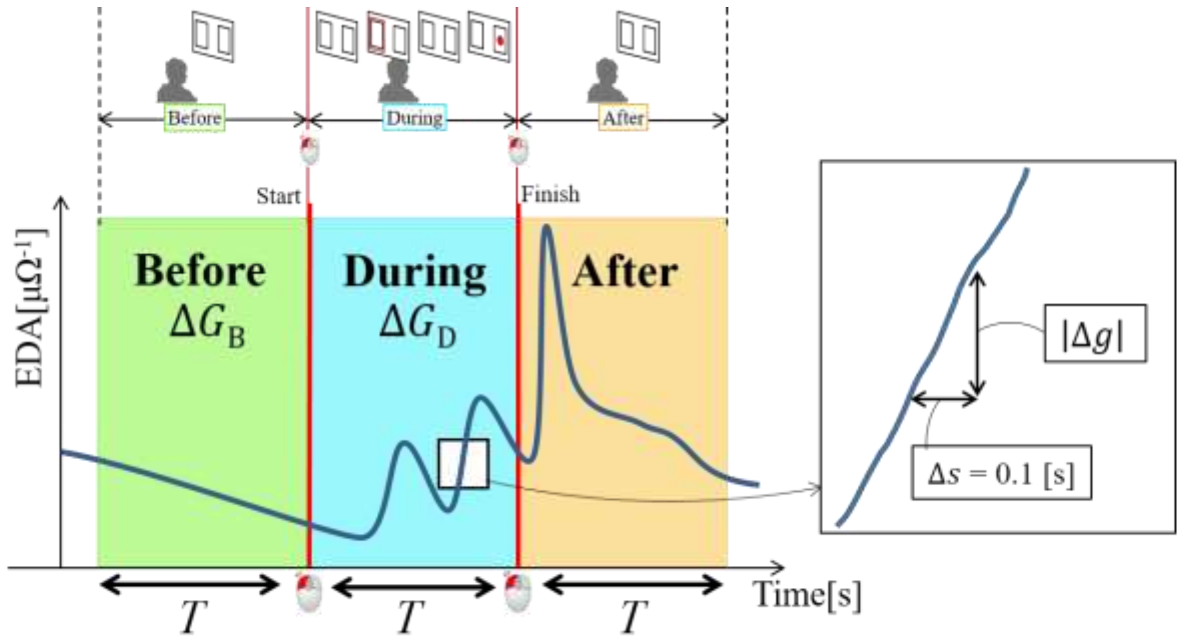

Figure 6. The respective time periods before, during, and after the task

the number of blinks per minute (blink rate) was calculated for each period. The average of all the subjects' blink rates was assessed with Tukey's multiple comparison procedure.

b. Experimental setup

The subjects were 19 men and 2 women between the ages of 21 and 25. As shown in Figure 7, each subject was seated in a chair and pushed the switch with the right hand. An electrode was attached to a fingertip on the left hand. The task was shown on a display. The state of the subject was recorded with a video camera installed under the display to observe blinking. The subject was directed to push the switch when he/she identified the target stimulus. The task was initiated after the subject was given a signal to begin, when the subject pushed the switch. The subject engaged in the task five times; each time, a different cue was used. For each subject, EDA and blinking were simultaneously measured from the moment the task was initiated.

Figure 8 shows the hardware configuration used in the experiment. We used a biological amplifier (Biolog, S&ME) to measure EDA; it was measured at 500 Hz in a sampling period and was expressed in units of $\mu\Omega^{-1}$. Blinking was observed from images obtained by camera at 30 Hz in a sampling period. The switch signal was sent to the biological amplifier to be synchronized with the EDA.

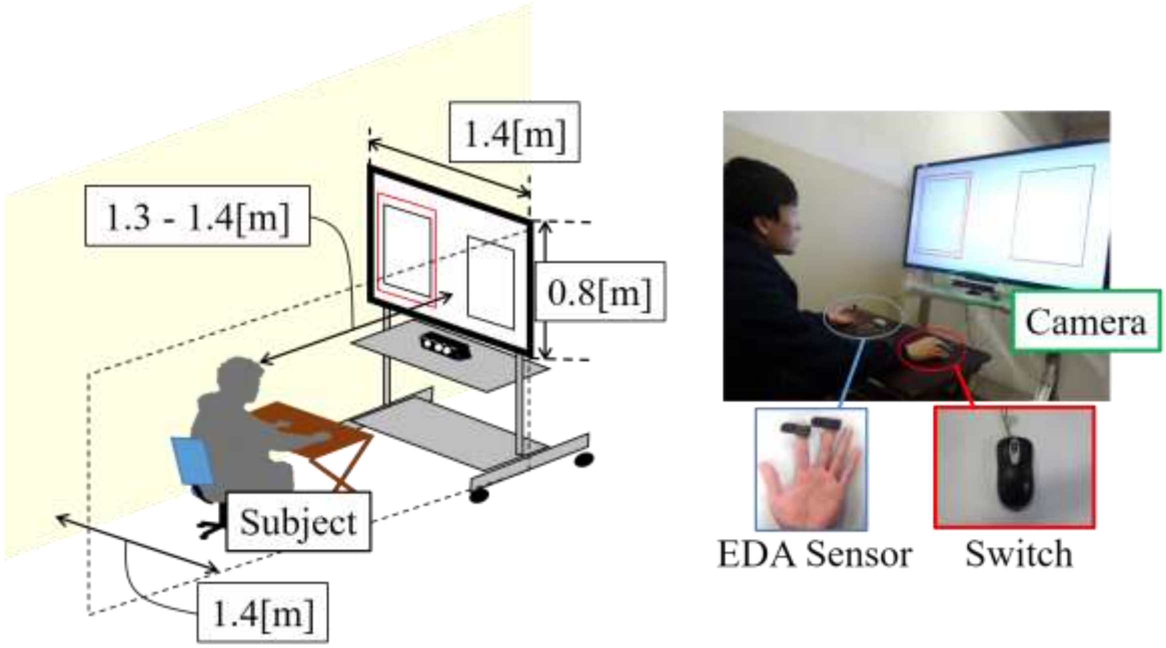

Figure 7. Experimental environment

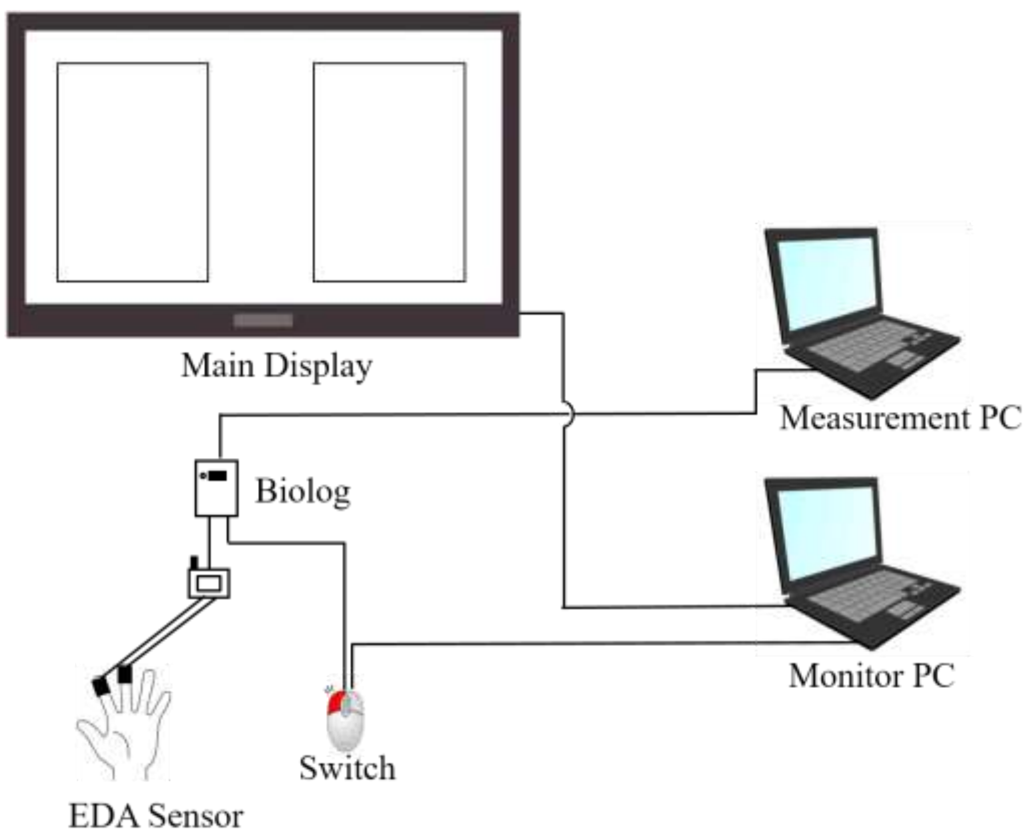

Figure 8. Hardware configuration

c. Result

Figure 9 presents, as an example, the experimental results for one subject. Red lines denote the switch signals; (1)–(5) are the trial numbers of the task. Sections (1)–(5) between the red lines are the time periods in which the subject performed the task. SCRs occurred in trials (1)–(4).

Table 1 shows the same subject's mean values for the fluctuation in EDA per unit time in the periods before and during the task; it also presents the *t*-test results. Significant differences in mean values were found in trials (1)–(4). From these results, it was determined that this subject's visual attention was definitely engaged in trials (1)–(4). Therefore, in trials (1)–(4), the blink rates were calculated for the three respective periods. All subjects' blink rates were calculated similarly.

Figure 10 shows the averages of all subjects' blink rates. The average blink rate in the period before the task was 35.2 blinks/min, that during the task was 23.5 blinks/min, and that after the task was 43.3 blinks/min. The average blink rate in the period during the task was less than that in the period before and the period after the task. The average blink rate in the period after the task was greater than that in the period before and the period during the task. Using Tukey's multiple comparison procedure, it was shown that the difference in average blink rate between the periods during and after the task was significant. These results suggest that the blink rate decreased when visual attention was engaged and increased when the visual attention status shifted from attentive to inattentive.

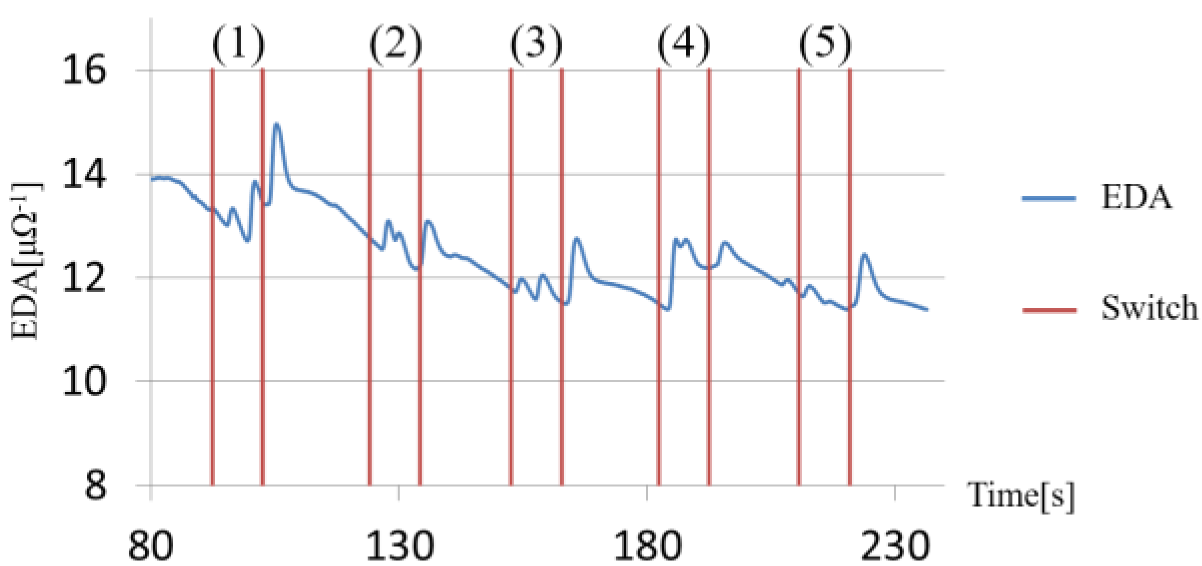

Figure 9. Experimental result for EDA (subject A)

Table 1: Comparison of the mean values of the fluctuation in EDA before (ΔG_B) and during (ΔG_T) the task (subject A)

Trial	(1)	(2)	(3)	(4)	(5)
$\Delta G_B[\mu\Omega^{-1}/s]$	0.072	0.081	0.061	0.039	0.074
$\Delta G_T[\mu\Omega^{-1}/s]$	0.279	0.198	0.165	0.226	0.079
t[-]	1.07×10^{-9}	2.07×10^{-10}	9.59×10^{-14}	5.11×10^{-7}	0.22
Significant? (t < 0.01)	*	*	*	*	-

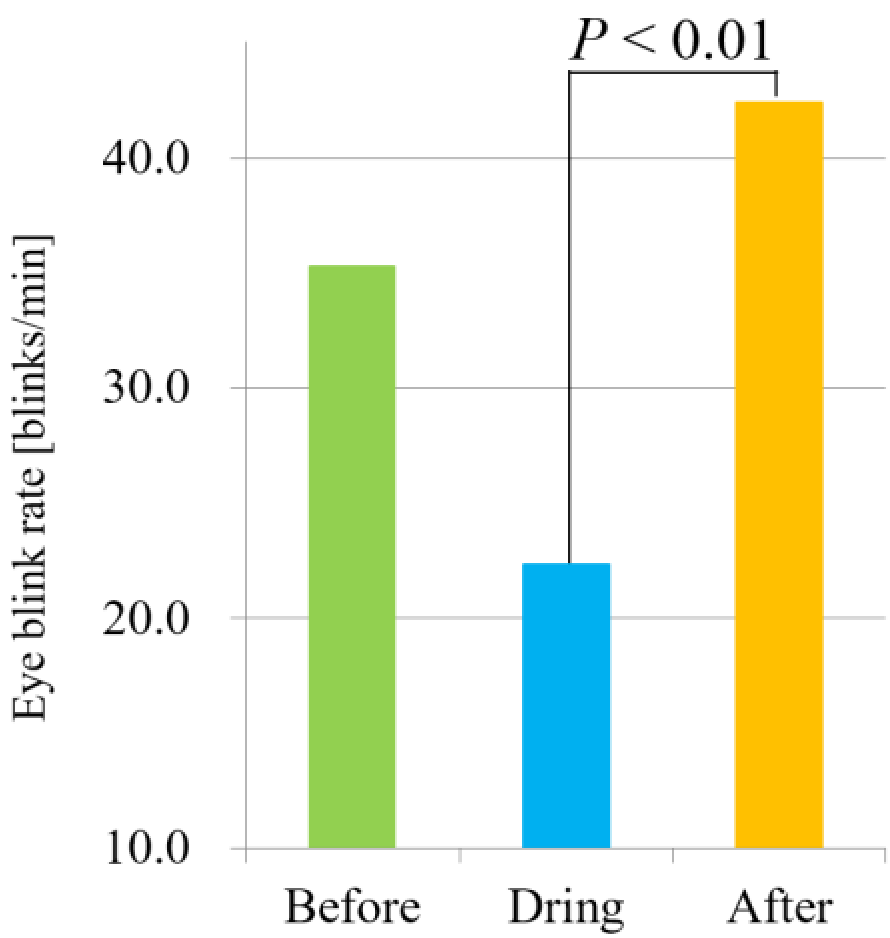

Figure 10. Average eye blink rates for all 21 subjects

IV. CONCLUSION

In this paper, we described an experiment using EDA to verify the relationship between visual attention and blinking. In the experiment, the state of the subject's visual attention and blinking were observed. The visual attention status (engaged or not engaged) was determined by EDA. The blink rate during the period when visual attention was definitely engaged was calculated and compared with those in periods when visual attention was not engaged. The experimental results showed that blink rate decreased when visual attention was activated and increased when the visual attention status shifted from attentive to inattentive. These findings enable a more objective evaluation of the relationship between visual attention and blinking when using EDA to determine whether visual attention is engaged.

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