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ELECTRODERMAL ACTIVITY-BASED FEASIBILITY STUDY ON THE RELATIONSHIP BETWEEN ATTENTION AND BLINKING

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Abstract—Various factors are believed to cause blinking. One of these factors is attention. However, the relationship between blinking and attention has not yet been elucidated. In this study, we focus on electrodermal activity (EDA) to demonstrate this relationship. EDA is an electrical phenomenon involving the glandular releasing of sweat that is caused by mental excitement or strain. We employ EDA to quantify attention as a means to elucidate the blinking–attention relationship. We conduct an experiment based on EDA and present the results to verify this relationship.

Index terms*:* Skin conductance level, skin conductance response, precueing method, blink rate.

I. INTRODUCTION

A major cause of accidents is decline of attention over time while driving or working with machine tools. One study estimated attentiveness using an index from physiopsychology to prevent such accidents [1]. The study indicated that blinking activity changes according to psychological factors; moreover, the relationship between blinking and attention has been suggested [2, 3]. One advantage of measuring blinking is that it can be easily performed without physical contact by using tools such as video cameras [4, 5, 6].

In previous research, an experimenter presented the subject with a problem; blinking was measured when the subject focused on the problem and the relationship between attention and blinking was supposedly verified [7]. The verification was based on the premise that a subject focuses his/her attention by working on a problem. However, this method cannot remove influencing factors, such as subject motivation and will. In other words, a subject may not actually exert much attention; instead, the subject might work on a problem merely by inertia. In this case, the premise mentioned above is not substantiated. Therefore, to verify the relationship between attention and blinking, a method of objectively measuring attention is needed.

We therefore focus on electrodermal activity (EDA), which is an electrical phenomenon of the glandular releasing of sweat that is caused by mental excitement or strain. In psychology, EDA is used as an index to measure affective degrees, such as stress, strain, and excitement [8, 9]. EDA has been shown to have a meaningful relationship with attention [10]. In this study, we use EDA as a means of objectively measuring attention to elucidate the relationship between attention and blinking. We herein describe the experiment we conducted based on EDA and the results that verify this relationship.

II. SUMMARY AND HYPOTHESIS OF ELECTRODERMAL ACTIVITY

A. Summary of Electrodermal Activity

An electrical phenomenon, EDA involves both the glandular releasing of sweat that is caused by mental excitement or strain, and changes in the electrical characteristics of the skin.

EDA is divided into sustained activity and transient activity. Sustained activity fluctuates over a long time period, whereas transient activity completes the change in several seconds. Sustained activity is used as an index to indicate the awakened state; transient activity is used as an index to indicate emotion.

The electrification measurement method of EDA is used to measure apparent resistance through electricity to skin from outside the human body. The sustained activity measured by the electrification is the skin conductance level (SCL). Similarly, the transient activity measured by the electrification is the skin conductance response (SCR). Figure 1 shows examples of SCL and SCR measurements. As shown in Figure 1, the SCL reaction is measured by changes over a relatively long time, whereas the SCR is measured by changes over a relatively short time.

Figure 2 shows an SCR state occurring. The SCR has a latent time of 1.4 to 3.5 s after stimulation. The reaction reaches its peak in 1.6 to 4.0 s. In this study, we considered such a delay.

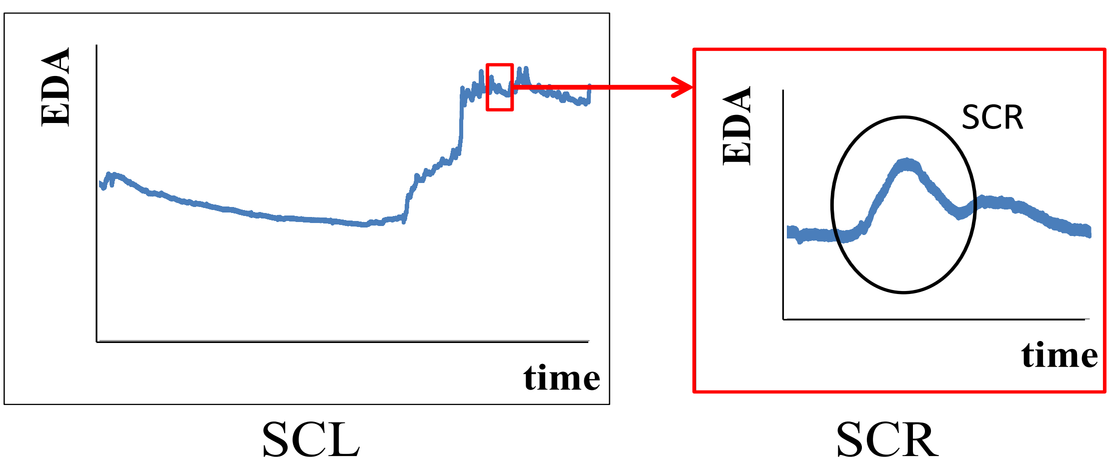


Figure 1. Examples of SCL and SCR measurements

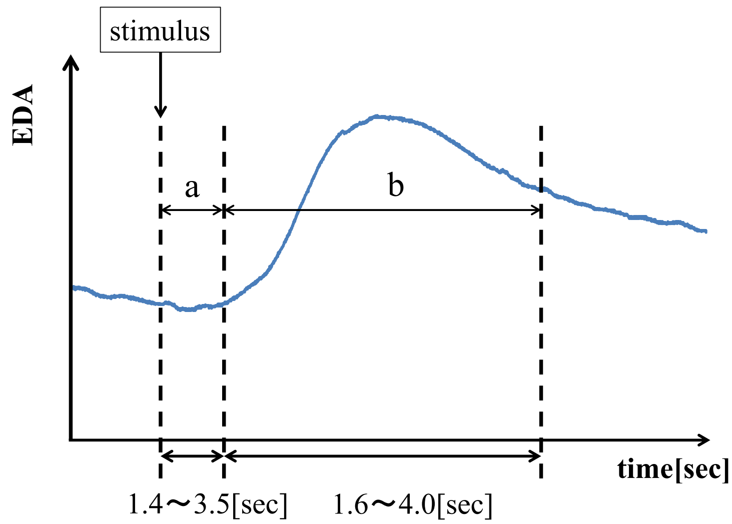


Figure 2. Delay of SCR occurrence

B. Relationship Between Attention and Blinking

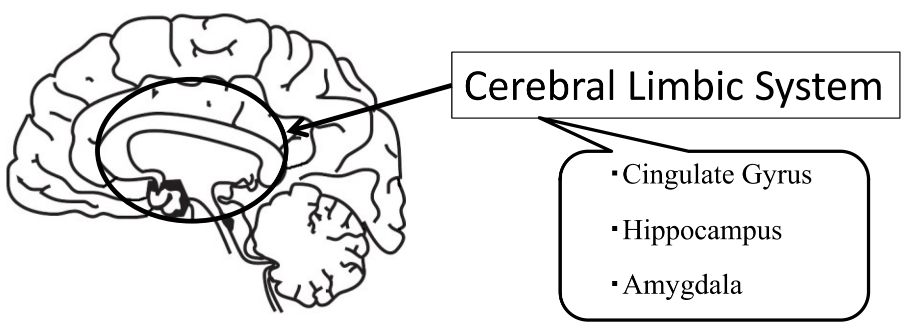


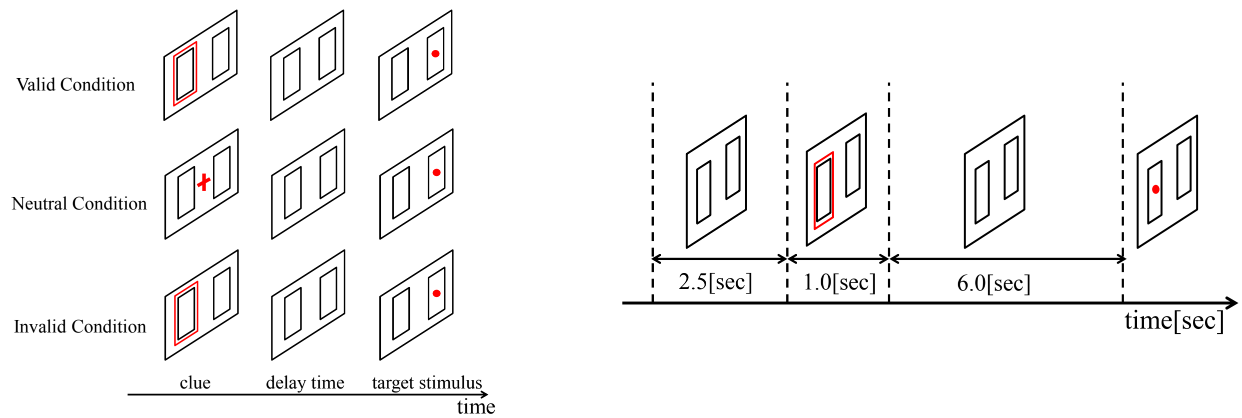
Figure 3. Cerebral limbic system

Figure 3 depicts the brain's cerebral limbic system, which is comprised of the cingulate gyrus, hippocampus, and amygdala. Recent studies have revealed that the cerebral limbic system is activated when a person is attentive. In addition, this system is known to have a close relationship with emotion. For this reason, we postulate that EDA occurs when a person is attentive [9]. Because SCR varies depending on the degree of emotion, we hypothesize that it likewise varies in accordance with the degree of attention. We verified this hypothesis with an experiment of visual attention typically used in psychology. The results suggest that a significant relationship exists between attention and EDA [8].

III. EXPERIMENT

To verify the relationship between attention and blinking, we induced in subjects the state in which their attention was acted on by the precueing method used in psychology. We simultaneously measured blinking and EDA and investigated their correlation. In this chapter, we describe our experimental methods and results.

A. Experimental Set-up



a. Types of clues   b. Time distribution of the clue and target stimulus

Figure 4. Precueing method

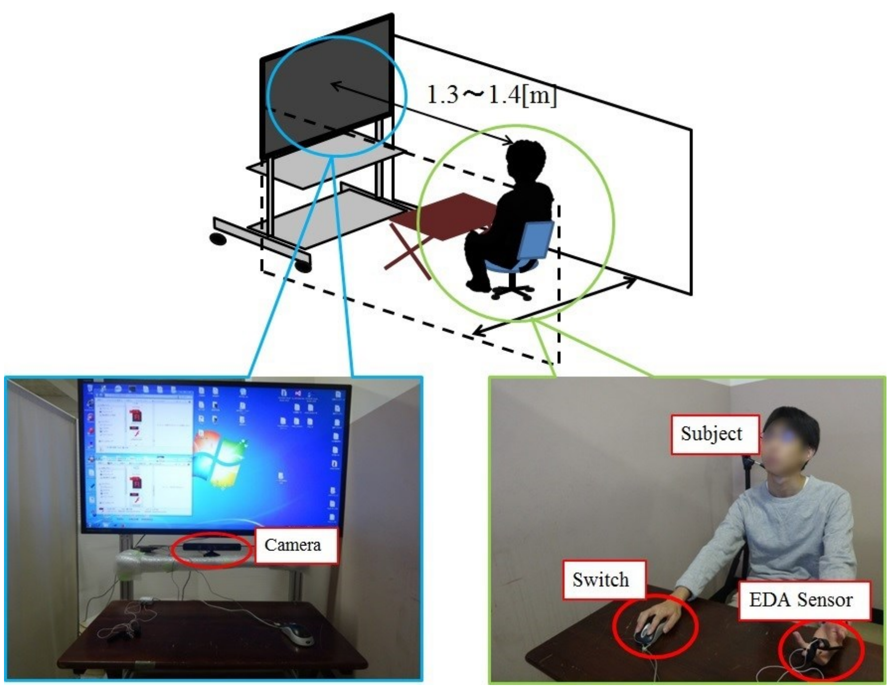


Figure 5. Experimental environment

The precueing method is an experimental technique typically used in psychology to verify visual attention [8]. In this study, we applied the basic precueing method to EDA as follows. We displayed a target stimulus, such as a circle, in the subject's field of vision and asked the subject to push the reaction key as soon as the target stimulus appeared. However, we first presented a clue to the subject before displaying the target stimulus. Figure 4a shows the types of clues provided. The condition in which a clue shows the true position of the target stimulus is called a "valid condition." Conversely, the condition in which a clue does not show the true position of the target stimulus is called an "invalid condition." Further, the condition involving neither of these conditions is called a "neutral condition." We measured the reaction time from the moment the target stimulus was posted to when the subject pushed the key.

In the experiment, we used a biological amplifier (Biolog, S&ME) to measure EDA; it was measured at 500 Hz in a sampling period. The unit of EDA is expressed in [$\mu\Omega^{-1}$]. The experimental subjects included four men and one woman between the ages of 22 and 24. We explained the contents of the experiment before initiating it and obtained their informed consent.

Figure 5 shows the experimental environment. We implemented a camera sensor and video to measure blinking. We performed the experiment in a private room to eliminate distractions and enable the subjects to focus their attention only on the screen. Each subject sat in a chair; an electrode was attached to a fingertip of the left hand. The subject was then directed to push a switch when given a specific signal by the experimenter. This switch initiated the experiment. Figure 4b shows the time distribution of the providing of the clue and target stimulus. The valid, neutral, and invalid conditions previously defined were each engaged twice during the experiment.

We inspected the EDA at 15 s from the point at which the subject initiated the experiment with the switch. At that time, we additionally inspected the SCR. Figure 6 graphically depicts this 15-s interval with the EDA and SCR. At first, to set a baseline of the subject's normal state, we measured both EDA and blinking for 3 min when the subject was relaxed. Then, we experimented using the precueing method. The blink rate was calculated as the number of times a blink occurred within 1 min. The blink rate of the subject's normal state was calculated during the first 3 min of the experiment. Figure 7 shows the blink rate calculation method during the precueing method. As shown in the figure, the blink rate in each condition during the precueing method was calculated for approximately 30 s; i.e., for 10 s before the target stimulus was posted, for 10 s during the stimulus presentation, and for 10 s after the stimulus presentation.

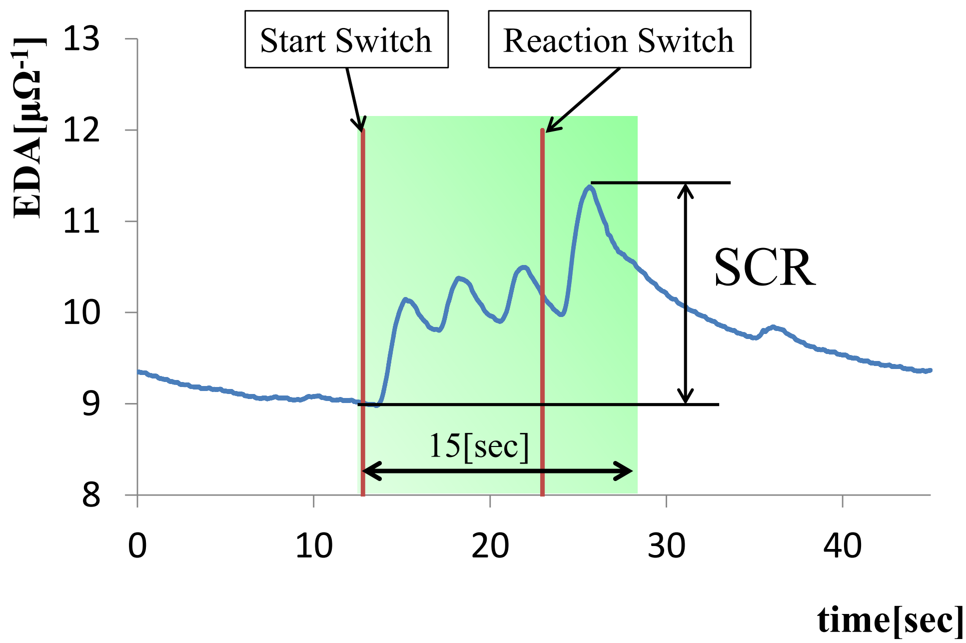


Figure 6. Measurement of SCR

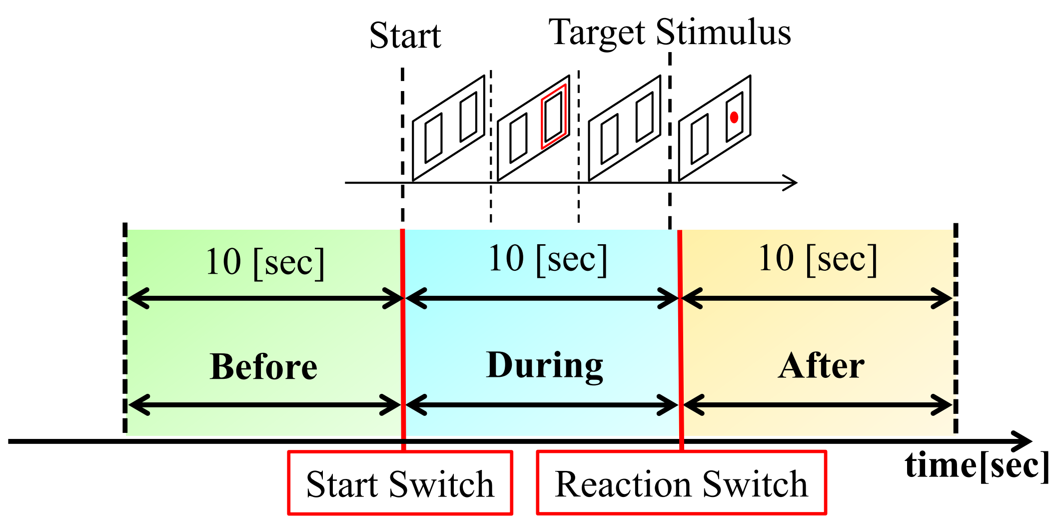


Figure 7. Blink rate calculation for the precueing method

B. Experimental Result

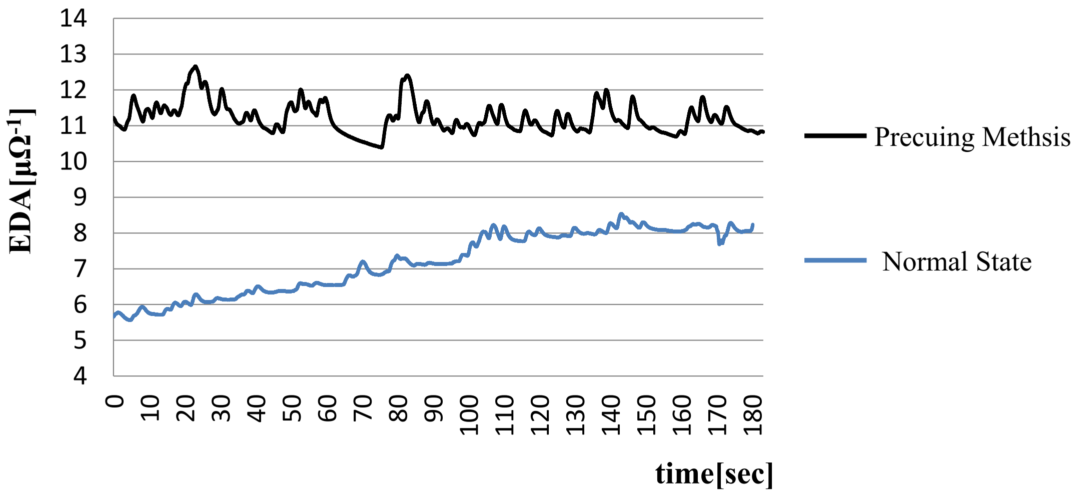


Figure 8. Example of experimental result for one subject

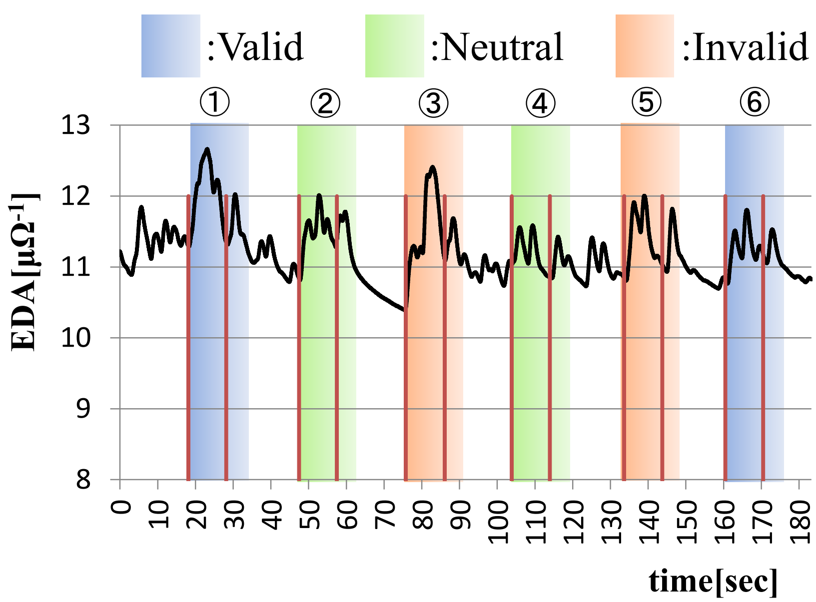


Figure 9. EDA result for one subject

Table 1: Experimental result for another subject

	Normal state	**①: Valid**	**②: Neutral**	**③: Invalid**	**④: Neutral**	**⑤: Invalid**	**⑥: Valid**
Blink Rate [blinks/min]	27.5	50.0	51.8	50.3	51.6	63.3	59.4
SCR[$\mu\Omega^{-1}$]		1.370	1.178	2.006	0.551	1.154	0.987

Figure 8 depicts a graph of the EDA experimental result for one subject. One line denotes when the subject was in a normal state; the other line denotes when the precueing method was used on the subject. In terms of SCL, it was confirmed that the peak conductance during the precueing method was higher than that of the normal state. Accordingly, it was confirmed that the activity of the brain during the precueing method was more active. Figure 9 presents EDA data of the subject during the precueing method from the time the switch was activated; the 15-s segment of the EDA measurement range is denoted with color. Based on data shown in the figure, it was confirmed that SCR occurred during the precueing method.

Table 1 shows the respective blink rates in the normal state and in each condition of the precueing method, as well as SCR. Based on data in the table, it is evident that the blink rate during the precueing method was 1.5 to 2 times higher than in the normal state.

Table 2 shows experimental results for four other subjects. EDA during the precueing method was generally higher than in the normal state, which was the case shown by Figure 8. In addition, as shown in Table 2, it was observed that SCR occurred during each condition. Therefore, it was confirmed that attention was engaged by the precueing method. Similarly, as shown in Table 2, it was observed that the blink rate was higher during the precueing method than in the normal state. These results suggest that the blink rate increased when attention was engaged.

Table 2: Experimental results for four other subjects

		Normal state	**①: Valid**	**②: Neutral**	**③: Invalid**	**④: Neutral**	**⑤: Invalid**	**⑥: Valid**
Subject 1	Blink Rate [blinks/min]	27.9	79.3	66.5	69.9	80.8	86.1	71.4
	SCR[$\mu\Omega^{-1}$]		1.067	1.046	0.308	0.560	0.336	0.690
Subject 2	Blink Rate [blinks/min]	19.3	33.2	29.6	25.1	36.5	37.3	33.0
	SCR[$\mu\Omega^{-1}$]		2.255	0.002	1.598	0.656	2.992	0.199
Subject 3	Blink Rate [blinks/min]	31.2	45.4	41.3	40.0	37.4	35.4	43.1
	SCR[$\mu\Omega^{-1}$]		4.520	2.342	3.621	1.062	1.335	0.928
Subject 4	Blink Rate [blinks/min]	15.9	19.6	21.7	21.5	21.5	19.5	33.6
	SCR[$\mu\Omega^{-1}$]		0.145	0.021	8.848	2.499	2.665	0.003

Ⅳ. CONCLUSIONS

In this paper, we described an experiment based on EDA to verify the relationship between attention and blinking. We performed the experiment using the precueing method of psychology. Based on the experimental results, we confirmed that each subject's attention was objectively engaged by EDA. In addition, the results suggested that the blink rate was higher when attention was engaged than in a normal state. We therefore determined that blinking was affected by attention based on EDA.

In future work, we intend to further clarify the relationship between attention and blinking based on EDA. In addition, we plan to evaluate EDA using statistics to account for individual subject differences.

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