Feasibility Study on Estimating Visual Attention using Electrodermal Activity

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Abstract—Electrodermal Activity (EDA) refers to change in the electrical properties of skin during mental exertion caused by tension and agitation. In recent studies, it has been revealed that there is an overlap between the brain activation area where emotion occurs and the brain activation area responsible for attentiveness. Consequently, in this paper we test our hypothesis that, given these findings, visual attention can be estimated via EDA. The results of experiments conducted verify that EDA can be used as an attention index.

Keywords—Skin conductance response; Precuing Methods; Visual Search;

I. INTRODUCTION

One major cause of accidents is attention decline over time while driving a car or working with machine tools. At least one study has been conducted to estimate attentiveness using eye information such as gaze duration and blink in order to prevent these accidents [1]. If an attention degree estimate is enabled mechanically, safety can be improved. However, the relationship between such eye information and attention is not clear. On the other hand, it has been revealed that there is an overlap between the brain activation area where emotion occurs and the brain activation area responsible for attentiveness [2]. From this relationship, we focused on Electrodermal Activity (EDA), which is used as an index to measure affective degree such as stress, strain, and excitement in psychology [3, 4].

If estimation of attention degree can be determined using EDA, not only the relationship between attention and eye information, such as a blink and gaze duration can become clear, but also estimation of degree of attention. This paper describes the results of verification as to whether visual attention can be estimated by EDA.

II. SUMMARY AND HYPOTHESIS OF ELECTRODERMAL ACTIVITY

A. Summary of Electrodermal Activity

EDA is an electrical phenomenon involving the sweat glands in mental sweating that occur because of excitement or strain. It is also the change in the electrical characteristics of the skin surface.

EDA is divided into sustained activity and transient activity. Sustained activity fluctuates over a long time, whereas transient activity finishes the change in several seconds. Further, sustained activity is used as an index indicating the awakening state, whereas transient activity is used as an index indicating emotion.

![Figure 1. Examples of SCL and SCR measurements](image-url)
The electrization measurement method of EDA is used to measure apparent resistance through electricity to skin from the outside of the human body. The sustained activity measured by the electrization is skin conductance level (SCL). Similarly, the transient activity measured by the electrization is skin conductance response (SCR). Figure 1 shows examples of SCL and SCR measurements. As can be seen in Figure 1, SCL reaction is measured by changes over a relatively long time, whereas SCR reaction is measured by a change in a relatively short time.

B. Hypothesis between Attention Degree and Electrodermal Activity

The Cerebral Limbic System comprise the Cingulate Gyrus, Hippocampus, and Amygdala in the brain. In recent studies, it has been revealed that the Cerebral Limbic System is activated when a person is attentive. In addition, the Cerebral Limbic System is known to have a close relation with emotion. For this reason, we postulate that EDA occurs when a person is attentive. In our study, because the SCR reaction varies depending on the degree of emotion, we hypothesized that SCR varies in accordance with degree of attention. Consequently, we focused on visual attention for the basics of estimating degree of attention.

III. VERIFICATION BY PRECUING METHESIS

We verified whether EDA occurs when a person is attentive by means of Precuing Methesis. This section describes the experiment conducted and the results obtained.

A. The Precuing Methesis Experimental Method

Precuing Methesis is used as an experiment to check visual attention in psychology [5]. Here, we applied Precuing Methesis to EDA as follows. We displayed a target stimulus, such as a circle, in the field of vision of the subject and asked the subject to push the reaction key as soon as the target stimulus appeared. However, we displayed a clue on a subject before displaying the target stimulus. Figure 2 shows the kinds of clues given. The condition in which a clue shows the true position of the target stimulus is called “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 the “neutral condition.” We measured the reaction time from the moment the target stimulus was posted to when the subject pushed the key. The procedure outlined above is the basic Precuing Methesis method.

In our experiment, we used a biological amplifier (Biolog, S&ME) to measure EDA, and measured at 500 Hz in a sampling period. The subjects comprised nine men, and one woman (22–24 years old). We explained the contents of the experiment before the start and obtained their informed consent.

Figure 3 shows the experimental environment utilized. We carried out the experiment in a private room to eliminate distractions and allow the subjects to pay attention only to the screen. Each subject sat on a chair and an electrode was attached to the finger-tip of the left hand. The subject was then directed to push the switch when given a certain signal by the experimenter. This switch started the experiment. Figure 4 shows the time distribution of the clue and the target stimulus. “Valid condition,” “neutral condition,” and “invalid condition” was carried out twice each in the experiment. We inspected the EDA at 15 sec from the switch being operated to start the experiment by the subject, and also inspected the SCR reaction at that time.

B. Precuing Methesis Experimental Results

Figure 5 shows an example of the experimental results obtained. The red bar in the graph shows the time of the switch in each condition. Table 1 shows the average result of the reaction time and the number of SCR reactions. There were few differences in reaction time in each condition. However, the result shows that there are a number of SCR reactions that are approximately twice the norm in each condition. These results show that SCR reaction occurs during the problem of Precuing Methesis. In addition, the number of SCR reactions during the problem is greater than any other time. This relates to the suggestion above that SCR reaction occurs while visual attention is engaged.
IV. VERIFICATION BY VISUAL SEARCH

The preceding section confirms that SCR reaction in EDA occurs when a person is attentive. This section discusses the results of verification as to whether SCR reaction varies as the degree of attention varies.

A. Visual Search Experimental Method

In order to verify our hypothesis in this paper, we conducted an experiment to measure the SCR reaction in a visual search task.

Visual search is used to measure the reaction time when a subject searches and finds the target stimulus from much jamming stimuli with various features such as colors and shapes. Visual search that uses one feature as a clue is called “feature search,” whereas visual search that uses multiple features is called “conjunction search,” and the reaction time is slower because detection of the target stimulus becomes more difficult in association with an increase in jamming stimuli [6].

Like the Preceding Methsis experiment, we used biological amplifier (Biolog, S&ME) to measure EDA, and measured at a sampling period of 500 Hz. The subjects also comprised nine men and one woman (22–24 years old). As before, we explained the contents of the experiment to them before the experiment and obtained their informed consent. Figure 6 shows the actual experimental environment.

In the experiment, we had each subject press the switch at the starting signal, and had him/her press the switch again for the target stimulus. The signal from the switch was sent to the biological amplifier and synchronized with SCR reaction. Four images were used in Visual Search: Two Images were used for “feature search” and the other two for “conjunction search.” Figure 7 gives examples of both types of search.

Figure 8 shows the measurement of SCR. In general, SCR reaction elevates 1–2 sec behind the stimulus. Thus, in this experiment, we defined the value when the subject pressed the switch at the starting signal as the “standard value,” the maximum value after 10 sec from the start as the “peak value,” and the difference between the “standard value” and “peak value” as the “SCR reaction (μΩ⁻¹).”
B. Visual Search Experimental Results

Figure 9 shows examples of the experimental results obtained. Figure 9(a) shows one subject’s experimental result, while Figure 9(b) shows the result for one conjunction search. Further, Table 2 shows the reaction time results for each condition.

The average reaction time for “feature search” is 0.912 sec, and that for “conjunction search” is 1683 sec. Consequently, we deduced that “conjunction search” needed more attention, because “conjunction search” was more difficult than “feature search.” Figure 10 shows that SCR reaction value also tends to elevate in “conjunction search.” In addition, when average values are compared, the SCR reaction value in “conjunction search” is approximately 1.5 times greater than it is in “feature search.”

To evaluate the significant difference in the average value between “feature search” and “conjunction search,” which both have the same number of jamming stimuli, we conducted t-tests. As shown in Figure 10, the result for each test was P < 0.05, confirming the significant difference.

The above results suggest that SCR reaction occurs when a person is attentive, and that the reaction value varies according to the degree of attention.

V. CONCLUSION

In this paper, we tested the hypothesis that “EDA can be used as an attention index,” because the part of brain that manages attention overlaps with the part that manages emotion.

First, using the Precuing Methsis technique, we confirmed that SCR reaction occurs in EDA when a human is paying attention. Then, we verified that SCR reaction varies according to degree of attention by confirming that the SCR reaction value in “conjunction search” requires more attention and tends to be higher than that in “feature search.” In addition, analysis of the average of SCR reaction value by means of t-test confirmed that there is a significant difference with a result of P < 0.05.

Thus, we conclude that degree of attention can be estimated via EDA.

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REFERENCES