Physiological and Psychological Evaluation by Skin Potential Activity Measurement Using Steering Wheel While Driving

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Abstract. This paper proposes a new method for practical skin potential activity (SPA) measurement while driving a car by installing electrodes on the outer periphery of the steering wheel. Evaluating the psychophysiological state of the driver while driving is important for accident prevention. We investigated whether the physiological and psychological state of the driver can be evaluated by measuring SPA while driving. Therefore, we have devised a way to measure SPA measurement by installing electrodes in a handle. Electrodes are made of tin foil and are placed along the outer periphery of the wheel considering that their position while driving is not fixed. The potential difference is increased by changing the impedance through changing the width of electrodes. Moreover we try to experiment using this environment. An experiment to investigate the possibility of measuring SPA using the conventional and the proposed methods were conducted with five healthy adult males. A physical stimulus was applied to the forearm of the subjects. It was found that the proposed method could measure SPA, even though the result was slightly smaller than that of the conventional method of affixing electrodes directly on hands.

Keywords: Skin potential activity · Mental workload · Mental state · Safety driving

1 Introduction

The likelihood of car accidents is largely dependent on the physiological and psychological states of drivers. According to a survey, half of all car accidents occur because of the violation of safe driving. The likelihood of this violation is affected by the mental workload of drivers [1, 2]. Therefore, it is important to evaluate the physiological mental state of drivers in order to prevent accidents. In particular, an accumulation of mental workload while driving adversely affects the physiological and psychological states of the driver. Therefore, in this study, we aim to evaluate the physiological and psychological states of the driver by measuring skin potential activity (SPA) during vehicle operation.

Sweating of the palms and soles of the feet is one of the indicators used to evaluate mental workload. Skin potential activity (SPA) can be measured as a method of detecting

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mental sweating. SPA is a physiological index to electrically measure the sweat gland activity under sympathetic innervation. Conventional SPA measurements are taken by applying electrodes to three positions on the arm. These three positions represent an exploration, a reference, and a ground electrode. The exploration electrode is placed on the palm, the reference electrode is place on the forearm, and the ground electrode is placed on the forearm flexor. The potential difference between these electrodes is used as physiological index. However, this method is difficult to practically use during vehicle operation, because it is requires installation of the mounting type of electrode to the forearm for every ride. Furthermore, a sense of discomfort from the attachment and detachment of electrodes may be experienced.

Thus, we have devised a method of acquiring SPA measurements without causing discomfort to the driver by placing the electrodes on the car steering wheel. In this study, we propose a method of measure SPA through installation of the electrodes to the vehicle steering wheel, and we examine whether or not it is possible to use this method of SPA evaluation by experiment.

2 Measuring SPA Through the Steering Wheel

Evaluating the psychophysiological state of the driver while driving is important for accident prevention [3, 4]. We investigated whether the physiological and psychological states of the driver can be evaluated by measuring SPA while driving. Figure 1(a) shows the typical placement of electrodes for SPA measurement. The electrodes are placed on the flexor region of the forearm, and their potential difference is used as the evaluation index. However, this method inconveniences the driver; hence, a new method of measuring SPA was devised, in which the electrodes are placed on the car's steering wheel as illustrated in Fig. 1(b). The electrodes are made of tin foil and they were placed along the outer periphery of the wheel. It should be noted that their positions while driving were not fixed. The potential difference was increased by changing the impedance through changing the width of the electrodes.

Fig. 1. Sample data waveform of AC-EOG

3 Experiment

We conducted an experiment to verify whether or not SPA can be measured using the proposed method as well as the conventional method. In this experiment, subjects were five healthy adult males.

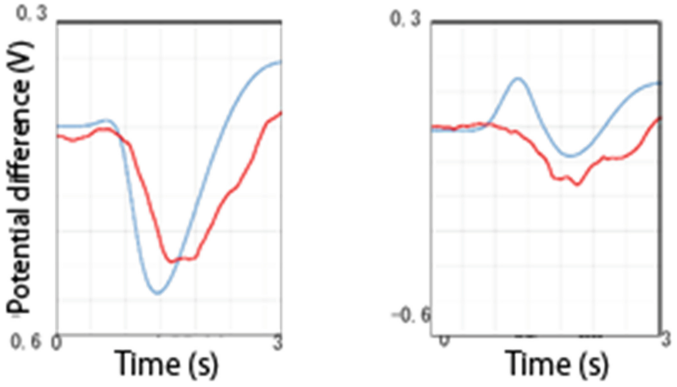
3.1 Experimental Procedure

First, the subjects gripped a steering wheel and rested for approximately three minutes. Then, the subjects were stimulated three times through use of a rubber ring to stress the forearm. The subjects then waited with their eyes closed so as not to know the timing of the stimulus. Electrodes were placed on the right forearm of subjects based on a feature method, and attached to the steering wheel based on the proposed method. Experiments were conducted when the wheel was grasped with both hands and when the wheel was gripped with the left hand. Figure 2 shows the experimental environment.

Fig. 2. Experimental environment

3.2 Evaluation of the Experimental Results

Experiments to investigate the potential of measuring SPA using the conventional and the proposed methods were conducted with five healthy adult males. A physical stimulus was applied to the forearm of the subjects, and their reactions were compared (Fig. 3 shows an example of the resulting waveform). Table 1 shows the experimental results. Variation in the signal amplitude was observed in the resulting waveforms for all subjects. This paper demonstrates the feasibility of acquiring SPA measurements via the proposed method by comparing the results with those of the conventional method. In this experiment, the amplitude ratio tended to increase in one and both hands together. Additionally, the measurement accuracy was expected to improve by changing the electrode conditions. However, the overall standard deviation ratio increased using the proposed method. This means that the amplitude of artifacts is increased as compared with the conventional method. The cause is thought to be that the artifact amplitude and reaction amplitude both increased because of the large potential fluctuation on the side of a lot of perspiration quantity.



Red: proposed method. Blue: previous method.

Fig. 3. Example of SPA waveform with stimulations (Color figure online)

Table 1. Evaluation results

Subjects	One hand		Both hands	
	Amplitude ratio	SD ratio	Amplitude ratio	SD ratio
A	1.07	4.60	0.64	2.01
B	2.42	1.79	2.33	8.76
C	0.51	1.07	0.50	1.08
D	0.93	2.22	0.48	0.22
E	0.60	13.36	0.52	7.34

4 Conclusion

In this paper, we proposed a new method for practical skin potential activity (SPA) measurements while driving a car by installing electrodes on the outer periphery of the steering wheel. An experiment using the method was conducted with five subjects. It was found that the proposed method could measure SPA, even though the signal amplitude were slightly smaller than that of the conventional method of affixing electrodes directly on hands.

In the future, we will verify the combination of impedances of the electrodes, and aim to achieve more accurate measurements. In addition, we will improve the accuracy by correlating the individual difference with noise. Subsequently, we intend to evaluate the mental workload while holding the car's steering wheel.

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