Basic Study on Assessment of the Driver’s Condition Based on Physiological Indices

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The purpose of this research is to identify situations where a driver is unable to perform tasks properly because of psychological stress, etc., and devise means to help them. Basic research began with the aim of developing a technology to gauge the mental state of without relying on subjective evaluation of drivers, such as physiological indices and behavioral data. A system that can measure various physiological and behavioral data including electroencephalograms (EEG) was constructed. As a result of experimenting with the system, it was found that the occurrence and recovery of psychological sway appeared in physiological changes such as EEG and pupil diameter.

Keywords: physiological indices, train driver, EEG, psychological upset

1. Introduction

Even a well-trained driver can be taken by surprise or upset by when confronted with a sudden accident. In such situations, humans may experience delays in making accurate decisions and taking action, or make unusual mistakes. Moreover, drivers work alone. When upset by a sudden disaster or accident, they need prompt external support to recover their mental state necessary for them to be able to make appropriate decisions and respond immediately.

The final purpose of this study is to assess drivers’ mental and physiological state based on physiological data to provide constant back up during working hours and in the event of an accident. Basic research was commenced on these premises.

A system (biological information complex measurement system) was established to develop the experimental environment. The system measures various types of data relating to the driver whilst driving, using a driving simulator, including physiological measurements such as brain waves from the entire head, gaze, electrocardiograms, measuring respiration and sweating, as well as behavior measurement using multiple cameras. Some experiments measured the participants’ physiological indices and behavior during simulated railway driving using this system.

This article introduces this system and reports on the key findings obtained, namely changes in EEG, heart rate, respiration, pupil diameter, etc. in psychological reaction to sudden events, and the process of recovery from the emotion.

2. Psychological process hypothesis during psychological upset

When a person is psychologically upset, they are unable to analyze their situation calmly, in other words, their “mind goes blank.” Therefore, it is necessary to detect and provide support in such situations, without having to rely on subjective evaluation. The psychological process after such an event can be divided into two broad phases: “Psychological Process 1 (P1)” without psychological upset, and “Psychological process 2 (P2)” with psychological upset (Fig.1). The autonomic nervous system consists of the sympathetic nervous system and the parasympathetic nervous system. Generally, the sympathetic nervous system becomes active when excited, and the parasympathetic nervous system is said to be enhanced in a relaxed / resting state, although some reports say that it is activated even in a state of collecting information calmly [1], [2]. If there is no psychological upset, it is considered that the situation is comprehended calmly allowing the subject to take appropriate action, and that the parasympathetic nervous system is said to be enhanced in a relaxed / resting state, although some reports say that it is activated even in a state of collecting information calmly [1], [2]. If there is no psychological upset, it is considered that the situation is comprehended calmly allowing the subject to take appropriate action, and that the parasympathetic nervous system responds by focusing on information collection as a reaction of the autonomic nervous system. When a psychological upset occurs however, the nerve becomes excited and the sympathetic nervous system becomes dominant. In fact, as shown in Fig. 1, what happens is a Type A reaction (Psychological Process 1) where appropriate action is taken, i.e. analysis of the situation is made without causing any psychological upset; a Type B reaction (Psychology Process 2 → 1) where appropriate action is taken eventually although a temporary psychological upset has occurred, or a Type C reaction (Psychological Process 2) where the psychological upset is more lasting [2].
3. Establishment of a biological information complex measurement system

3.1 Requirements as a measurement system

Recent years have seen the development of a variety of simple devices to measure physiological states, in the shape of watches or other wearable items, but they are not necessarily very accurate. One major reason for the lack of accuracy is that the fluctuation in physiological state varies significantly from one individual to the next making it difficult to find a measurement device that suited to everyone. However, experiments found that it was possible to identify the variation in physiological indicators from person to person [1]. As such, a biological information complex measurement system (Fig. 2) was developed, to allow the acquisition of a range of data during driving operations using the latest technology.

3.2 Configuration of the measurement system

(1) High density sensor EEG measurement system

Available methods to measure brain activity include functional magnetic resonance imaging (fMRI) and near infrared optical brain measurement (NIRS). In this study, the high-density sensor EEG measurement system (NetStation GES400, EGI) was selected because of relatively low physical restraint and high temporal and spatial resolution. This high-density electroencephalograph (EEG) can measure brain waves across almost all of the head surface through 128 electrodes connected in the shape of a net covering the entire head. In addition, it is easier to wear than conventional EEG.

(2) Other physiological measurements (heart rate, breathing, sweating, etc.)

Physiological measurements other than brain activity, the heart rate, respiration, sweating, etc. can be wirelessly captured
using a biosignal recording device (Polymate V, Miyuki Giken).

An eye tracker (Glasses 2, Tobii) that can measure eye movements such as eye gaze measurement and pupil diameter, and a motion sensor (Motive: Tracker, OptiTrack) that can accurately measure the position and movement of people and objects with an infrared camera are operated together so that the eye gaze can be measured automatically even if the head moves.

(3) Integrated driving and biometric analysis program

In order to understand and analyze the measured data in an integrated manner, an "Integrated Driving / Biometric Analysis Program" that can display the measured driving log, EEG, autonomic nervous system index (described later), and activity amount in a unified manner was developed. This makes it possible to "visualize" all the data and analyze the relationship between the data.

3.3 Features of the Measurement System

The high-density EEG measurement is mainly for medical purposes such as treatment of epilepsy and for brain research, and as in this study, research which incorporates such measurements as part of a measurement system, such as recording of human physiology, behavior and driving information, is rare. In addition, the whole measurement system is also pioneering in that it realizes multi-sensing in a situation close to the real environment. Furthermore, development of software that integrate the analysis of these various types of data allows simpler and more intuitive data analysis.

4. Detection of characteristic physiological changes during simulated driving operation

An experiment was carried out to identify the physiological indicators that can highlight a psychological upset caused by a sudden event whilst driving a train.

4-1 Methods

The experimental system was established with a simple railway operation simulator and a biological information complex measurement system with a large monitor and steering wheel controller (Fig. 3).

In the experiment, simulated driving tasks lasting approximately 30 minutes (running between seven stations) were conducted seven times with break in between each session. 13 healthy male subjects took part in the exercise (participant IDs: S01 to S13), and were instructed during the experiment to operate within the speed limit according to a timetable, and in case of an emergency instructed to apply the emergency brakes and to sound a horn.

After performing the learning task four times to become familiar with the driving environment, subjects were confronted with accident scenarios involving obstacles (fallen trees) on the track. Physiological data was measured through EEG, heart rate, respiration, pupil diameter and eye movement, sweating, etc.

5. Results of experiments

(1) Pupil diameter

Changes in pupil diameter were examined in seven subjects not wearing glasses when they were confronted with the accident scenarios (participant IDs: S04, S06, S10 to S13), because pupil diameter measurement with an eye tracker was possible on these candidates. The period of 30 seconds immediately before the detection of a fallen tree was defined as "the normal period," while the period between detection of the fallen tree to the emergency stop (16 seconds on average) was defined as the "abnormal period."

A comparison of pupil diameters during the normal

Fig. 3 Image of experiment settings
and abnormal periods revealed that the pupil diameter in all seven subjects had enlarged immediately after the detection of the fallen tree (Fig. 4) [4]. This was considered to be attributable to activation of the sympathetic nervous system aroused by the abnormal situation, causing pupil dilation. The six participants, except S12 who had the longest response time to the emergency brakes, returned to the range of ± 5% of the average pupil diameter measured during the normal period, within 10 seconds after seeing the fallen tree. This indicates the process in the Type B reaction shown in Fig. 2, where a temporary psychological upset occurs making the sympathetic nervous system dominant, followed by a rapid return to a calm state (parasympathetic nervous system dominant).

(2) Brain activity and autonomic nervous system

As a rough indication of the duration of psychological upset, the time from the detection of the fallen tree to the brake operation (hereinafter referred to as the reaction time) was examined. The reaction times of nine participants (participant IDs: S02 to 04, S07 to 09, S11, S12) excluding cases where the subject drove through unaware of the obstacle and measurement outliers, are shown in Fig. 5. Data is arranged in order of shorter reaction time. S08’s reaction time was the shortest, and S12’s was the longest. Therefore, brain activity, autonomic nervous system index, and brake operation before and after obstacle detection of S08 and S12 were examined (Fig. 6).

For EEG analysis, the changes in the distribution of the α wave component, which increases in the resting state and decreases with mental load, e.g. during mental computation, are shown in the upper panel of Fig. 6. Each figure shows the distribution of the α wave component for 3 seconds before and after the detection of the fallen tree. The lower graphs show the heart rate and respiration waveform, which are typical autonomic nervous system indicators, in the upper two panels, and the braking operation in the third panel. The arrows indicate the point of time when the fallen tree was spotted. Based on this result, S08, who had the shortest response time, showed almost no change in the distribution of the α wave component before and after the discovery, but S12, who had the longest response time, showed a change in the prefrontal cortex (part before the crown) turning blue immediately after the discovery. This shows that the α wave was attenuated. The prefrontal cortex is the location where cognition occurs and situational judgments are made, and it is inferred that the α wave was attenuated due to the mental load rising without being able to apprehend the situation. Similar results were also obtained in another experiment, corresponding to Psychological Process 2 (continuation of the psychological upset state) in the psychological model in Fig. 2.

With regard to changes in the heart rate and respiration, although the heart rate rose immediately after the detection and the sympathetic nervous system became temporarily active in S08, parasympathetic dominant responses, which were reduction of the heart rate and elongation of the respiratory interval, were immediately indicated. On the other hand, in a participant of S12, the increased heart rate rose immediately after the detection and remained high, while the respiration amplitude decreased and became shallow. This is a stressed response, which is also consistent with changes in pupil diameter. The psychological process corresponding to the reaction of S08 was considered to be Type B in Fig. 2, while for S12 the reaction matched Type C in Fig. 2.

6. Conclusions

A biomedical information complex measurement system was developed, including an EEG measurement device capable of measuring the entire head surface area. Using this system, physiological measurement experiments including brain activity during simulated driving were conducted. Results revealed characteristic EEG changes in the subjects taking part in the experiment who had a delayed response before taking appropriate behavior when the accidents occurred.

Future work aims to establish a physio-psychological state estimation method based on physiological measurements, which is hoped could lead to practical application of a driver assistance system through assessments based on these findings.

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References

[1] Nakagawa, C., Akiu N., Yoshie S., Kojima T., Watanabe T. and Suzuki A., “Basic study on assessment of state of the drivers based on physiological indices,” RTRI Reports, Vol. 33, No.1, pp. 5–10, 2019 (in Japanese).
**Distribution of α waves**  ※α waves attenuate as brain activity increases

![Diagram of brain activity changes](image)

**Fig. 6** Examples of changes in various physiological indices in accident task [1]

(a) S08 (Shortest brake response time)
(b) S12 (Longest response time)

![Diagram of physiological indices](image)

Before Accident: 
- Front
- Top
- Back

After Accident:
- Front
- Top
- Back

**Referencess**
1. Nakagawa, C., Akiu N., Yoshie S., Kojima T., Ikehata, M., Suzuki A. and Ushiba J., "Basic study on changes of the autonomic indices when a train driver becomes unsettled in driving," presented by the 56th Conference of Japan Ergonomics Society, June 5-6, Kobe, Japan, pp. 322-323, 2016 (in Japanese).

2. Task force of the European society of cardiology and the North American society of pacing and electrophysiology, "Heart rate variability - Standards of measurement, physiological interpretation, and clinical use," _European Heart J_, Vol.17, pp.354-381, 1996.

3. Nakagawa, C., Akiu N., Yoshie S., Kojima T., Ikehata, M., Suzuki A. and Ushiba J., "Basic study on changes of the autonomic indices when a train driver becomes unsettled in driving," presented by Human Interface Symposium, Koganei, Japan, September 6-9, pp. 359-362, 2016 (in Japanese).

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