Evaluation of Physiological and Psychological Stress in Head Driver Leading Self-Driving Truck

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Abstract: The purpose of this study is to evaluate physiological and psychological stress in truck driver towing self-driving trucks. The truck A with which two self-driving truck B and C are coupled in series is run along a guide line expressway for running for about 30 minutes, 3 times in a day. This experiment last 3 days, with 3 subjects derived the lead truck while towing 2 self-driving truck. For safety, driver was on the self-driving trucks B and C. In addition, each subject towing self-driving operation 3 times, solo operation (not towing self-driving) was 1 time. The bio-signal data (ECG, body temperature, skin temperature) of the subject were continuously measured at each driving phase. Subject’s data phase "solo" compares with the towing data compared to detect the difference. As a result of those data, we have significant increase in skin temperature and heart rate between solo and towing operations.

Keywords: Automatic Driving, Self-Driving Truck, Biological Monitoring, Autonomic Nerve, Heart Rate Variability (HRV)

1. INTRODUCTION

For next-generation automotive technology needs safe autonomous driving system. These technologies are indispensable for supporting our logistics. As a preliminary step to a fully autonomous driving system, drivers are required to tow and control autonomous trucks. However, the physical and physiological stress of truck drivers towing self-driving trucks has not been clarified. At least, driving with towing self-driving trucks will cause some result or change psychological effect. Such psychological effects may be clarified by measuring and analyzing the cardiac autonomic nerves [1,2]. In particular, heart rate variability analysis is excellent for evaluating stress and tension when there is little body movement noise. In this study, we analyzed biometric data of truck drivers for the purpose of quantitatively and objectively evaluating the stress of drivers who drive autonomous trucks.

2. METHOD

2.1 Protocol

We studied 3 healthy subjects (3 males; age, 50 ± 2 y). All of them drove a truck towing self-driving trucks (liner formation) 3 times and all of then drove a truck without towing self-driving trucks (solo) a time. During which bio-signals were monitored with wearable sensors.

Formation 1(F1: approximately 10:05 - 10:50, towing self-driving trucks), formation 2 (F2: approximately 12:05-12:35, towing self-driving trucks), and formation 3 (F3: approximately 15:00 - 15:45, towing self-driving trucks) and drove solo was approximately 16:30 and 17:45 (without towing self-driving trucks). This data was measurement in end of October, 2020. Subject I on the first day, subject 2 on second day, and subject 3 on third day. There was no difference in weather and road surface condition.

2.2 Measurements

ECG, and acceleration signals during driving were recoded with a Holter ECG recorder using disposable electrodes (MyBeat, Union Tool Co., Ltd., Tokyo, Japan). From about 8:45 to 17:45, ECG, body surface temperature, and acceleration signals were measured by the same time and sampling frequency of the ECG was 1000 Hz. The ECG sensor was removed from 12:35 to 13:00 due to check the waveform. Collected bio-signals were stored on the device, and analyzed by laptop computer. ECG, and triaxial acceleration signals were sampled at 125, and 31.25 Hz, respectively.

2.3 Data analysis

From bio-signals obtained by the ECG sensor, and automatically converted R-R interval to CSV file. R-R interval time series were also analyzed for the conventional HRV indices. The amplitudes of very-low-frequency (VLF, 0.0033 – 0.04 Hz),
low-frequency (LF, 0.04 – 0.15 Hz), and high-frequency (HF, 0.15 – 0.4 Hz) component were averaged over every minute.

2.4 Statistical analysis
The SAS program package (SAS Institute, Cary, NC, USA) was used for statistical analysis. HRV metrics were compared among 4 states, F1-3(with towing self-driving trucks), and solo (without self-driving trucks), by the analysis of variance (ANOVA) using the Mixed model procedure with subject as the random effect. The impact of each phases was evaluated by repeated measures ANOVA with the Mixed procedure with minute. Statistical significance was considered with a type 1 error level of 0.05.

3. RESULT
A total of 195 min of each signal were obtained (driving with towing self-driving trucks: F1-3, driving without towing self-driving trucks: solo) During the driving with towing self-driving trucks, skin temperature was higher than without self-driving trucks (Figure 1), but it declined over time (<.0001).

4. DISCUSSION
Figure 1 shows the skin temperature in F1-F3 and solo. Normally, body temperature is affected by the circadian rhythm, so human body temperature is constantly fluctuating with a rhythm of high during the day of activity and low during the night of sleep. Body temperature begins to rise shortly before waking up in the morning and peaks from evening to night. Therefore, it seems that the body temperature is the highest during the time of solo driving, but in this try out, body temperature is the highest in F1 phase and gradually decreases.

Elevated body temperature is a type of physiological reaction caused by psychological stress and strained. Although the number of subjects was small, the result that the body temperature decreased from F1 to F3 was seems to acclimation to stress of driving with self-driving trucks because reflected in the bioregulatory system such as the autonomic nervous system.

In this study, measurement while driving truck with a non-contact sensor would be desirable [3]. And also, if possible to detect dangerous operation and conditions such as drowsiness [4], it is useful for safe driving.

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