HR Changes in Driving Scenes with Danger and Difficulties Using Driving Simulator

Yukiyo Kuriyagawa[1], Mieko Ohsuga[2], and Ichiro Kageyama[1]

[1] Nihon University, 1-2-1 Izumi-cho, Narashino-shi, Chiba, 275-8575, Japan
[2] Osaka Institute of Technology, 5-16-1 Omiya, Asahi-ku, Osaka 535-8585, Japan
Kuriyagawa.yukiyo@nihon-u.ac.jp, ohsuga@bme.oit.ac.jp, kageyama.ichiro@nihon-u.ac.jp

Abstract. To provide a safe and comfortable driving environment, extracting a variety of stress scenes experienced by drivers and utilizing them for investigating actual causes and ways to assist drivers is effective. To find scenes that could be investigated efficiently in this way, we proposed a method based on changes in a driver's physiological indices that emotional changes may have caused. In this paper, we examined the possibility of applying this method to experimental situations using a driving simulator (DS). An experiment using a DS has an advantage over one done in a real life situation in that the experimental parameters can be controlled. This paper examines the relationship between a driver's emotional changes and physiological changes during driving. As a result, we suggest that whether an event is recognized and how much emotion it caused can be estimated by combining measurements of changes in heart rate (HR), skin conductance (SC), and respiration.

1 Introduction

Recently, scientists in Japan have actively pursued research using drive recorders to analyze the causal processes and factors in traffic accidents and latent accidents [1]. Before and after a traffic accident a drive recorder records operation conditions as a trigger of a vehicle's behaviour. It tries to obtain information that will help to decrease traffic accidents. In addition, we have measured a driver's emotional changes to detect problem situations in daily driving. We think that measuring these emotional changes can effectively decrease not only traffic accidents but also driving workload. A driver may be startled when he encounters potentially dangerous situations or hazards (e.g. an abrupt crossing by a pedestrian, a sudden braking of the car in front of him), while he is emotionally strained when he has to predict dangerous or difficult situations (e.g. pulling into traffic or passing another car). We can measure appropriate physiological responses that will enable us to extract a driver's startled response and emotional strain without disturbing the driver's driving. We observed two kinds of heart rate (HR) changes, GL (gentle and lasting) and SA (sharp and abrupt), in data taken from drivers during real car driving (see Figure 1). Considering the temporal relationship between the HR changes and the relevant events, it was suggested that the target of study in the subjective reports would be different for GL

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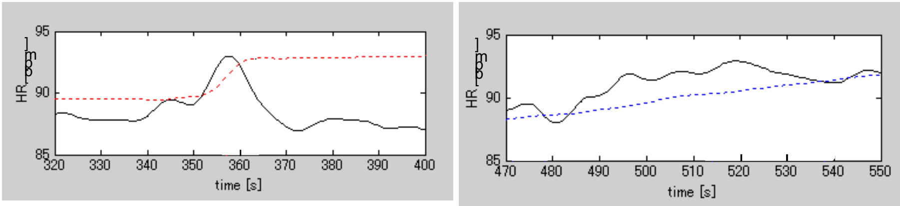

(a) GL (gentle and lasting) (b) SA (sharp and abrupt)

Fig. 1. Two major categories of HR fluctuation

and SA [2]. For the GL the target of study would the time when GL came to an end. For the SA rate the target of study would be the time when SA began.

In our research we used a driving simulator to analyze in detail the changes in HR and their correspondence to the driving situation. From the results, we observed two kinds of HR that occur in the same way as when a driver is driving a real car. In addition, we suggest there are two kinds of HR changes in GL. We think that HR change depends on the driver's feeling; for example, how does the driver perceive the event?;, and how does the driver handle the event?

In this study, we examined the relationship between the driver's feelings and HR changes.

2 Measurement of Data During Use of a Driving Simulator

2.1 Experimental Scenario

We carried out an experiment using a Driving Simulator (DS) with a spherical screen and a 6-DOF motion base in our laboratory (see Figure 2). In on-road experiments using a real vehicle, it is not possible to set up actual dangerous situations and collect reproducible data. However, experiments using a driving simulator (hereafter "DS") can set up various, specific driving conditions.

Therefore, DS experiments have an advantage in driving research. DS studies can compare the results among different subjects under the same experimental conditions or investigate the variations in response by the same subject by repeatedly executing the same experiments. As objects of examination for a traffic incident we set up two points in the simulation in which the driver came to a narrow one way passage on the main road he was driving on. (see Figure 3). The approaches to these places where the road narrowed were different. The road curved differently for each place. Therefore, the anticipation tension time until the driver discovered the narrowing of the road was different for each place, and his approach was also different. The main road in the driving scenario was a double-lane country road. In addition, in the scenario there was a lot of traffic, so the subjects would not know what aspect of their driving would be tested in the simulation. The accelerator and the brake were controlled by a computer program; and the driver only had to control the steering wheel. The purpose was to control the time from a subject's discovery of an incident event to the time of his reaction to it. To maintain the appropriate tension, the driving speed was kept at

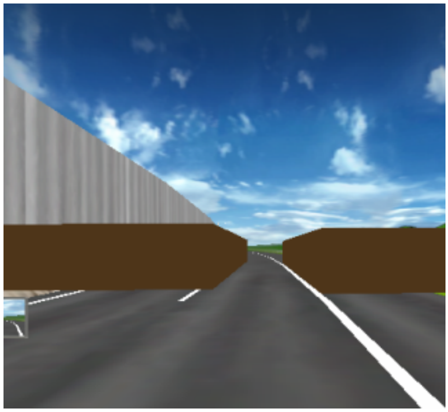

Fig. 2. The road narrowed on the Driving Simulator

Fig. 3. Driving Simulator

approximately seventy km/h. The subjects participated in an experimental session of eight minutes.

2.2 Procedure

We first conducted a practice session that aimed to familiarize subjects with the DS system and the sensors for measuring physiological responses. In the practice session, the subjects were made to experience an accident intentionally at one of the places in the simulation where the road narrowed. The purpose was to cause an anticipation tension in all subjects there.

After each experiment, the subject was required to report about the object of the examination when he expected the incident: when he recognized the incident how he felt about the incident; and how he handled the incident, during the experimental driving.

2.3 Measurement

To examine the extracted situations multi-dimensionally, the subject's physiological measurements, - ECG, SC and respiration - were recorded by Polymate (AP1124). These measurements differed at the time of the discovery of the street nearby according to the direction of the subject's eyes during driving. The physiological indices used for examining a subject's response change when the subject discovers an incident, so we measured when exactly the subject discovered an incident by having him use a push-button. In addition, the driver's view and his or her facial expression was video-recorded (see Figure 4).

Fig. 4. Front view of a driver and his facial expression on the Driving Simulator

2.4 Subjects

Eight young drivers participated in the experiment. Their driving frequency was from twice a month to seven times a week. After the experiment was explained, each subject signed an informed consent form.

3 Results

3.1 Data Processing of Physiological Indices

HR changes were quantified by the following data processing. First, radiofrequency noise and baseline fluctuations were removed from the measured chest electrocardiogram (ECG). Second, an R-wave enhancement filter was applied and R waves were detected [3]. Instantaneous HR was obtained from the sequence of R-R intervals beat by beat and then converted into equi-interval data by 3-order spline interpolation. The interpolated HR was passed through a low-pass filter (cut-off frequency, 0.08 Hz), which removed the respiratory and Mayer wave components of heart rate variability. The other physiological responses yielded raw data that allowed us to observe details of the changes.

3.2 Correspondence of Physiological Indices, Subjective Reports, and Driving Behavior

In the practice session all subjects caused an accident at one of the places where the road narrowed, as intended by the experimenters. So, the interviews with the subjects about the first place where the road narrowed showed that the subjects had various feelings about it. Such comments as “I will cause a car accident when I come to a place like this” and “It was possible to pass through the narrow area because I have become accustomed to driving” illustrate this point. So when the subjects came to a second place where the road narrowed during the simulation, most of them made positive comments such as "It is possible to pass through this narrow area if I drive as well as I did before’ after they had experienced going through the first narrow passage. Here, by visual observation, HR elevation could be seen in the data of subjects who felt strong danger.

Figure 5 shows one example of the results. Zero is shown in Figure 5; it occurred when the subject pushed a button to show he detected a narrowing of the main road. The narrow passage was set to come up in the scenario while the subject was driving on a curve on the main road. There was about 15 seconds from where the road started to curve to the subject’s discovery of the narrowing of the road to a one-way passage.

(1)Physiological indices

HR decreased in all subjects before they came to the places where the road narrowed. Respiratory amplitude decreased for subjects B, D, and E, and increased for subjects A and C. In addition, SC rose in subjects C and D when they discovered the road narrowing, and SC rose in subjects A and B when they went into the narrow passage.

(2)Subjective reports

Most subjects commented, "(Because I was able to safely pass the first place) I thought it would be safe if I drove as fast as I did for the first place" However, subjects A, B, and C also answered, "I drove carefully from the point when I detected that the road became narrow", "I drove carefully because I couldn't get a good enough grip on my senses", and "I was afraid although I was able to drive well through the narrow passage ", etc. It seemed that the subjects had uneasiness even when they came to the second place where the road narrowed.

(3)Driving behaviour

All subjects confirmed the position of the vehicle and the places where the road narrowed. They operated the steering wheel as well when they came across the second place where the road narrowed as they did when they came across the first place.

From these results, it was shown that HR rose in the scenes in which a subject felt strong danger or difficulty. HR decreased in the scenes that did not require concentration when there was no feeling of strong danger. The respiratory amplitude also decreased intensively in response to the event, and then increased when the event was over. This result was the same as one we had in a past finding. In addition, for SC we could not find a clear relationship between a subject's emotional change and his handling of the event.

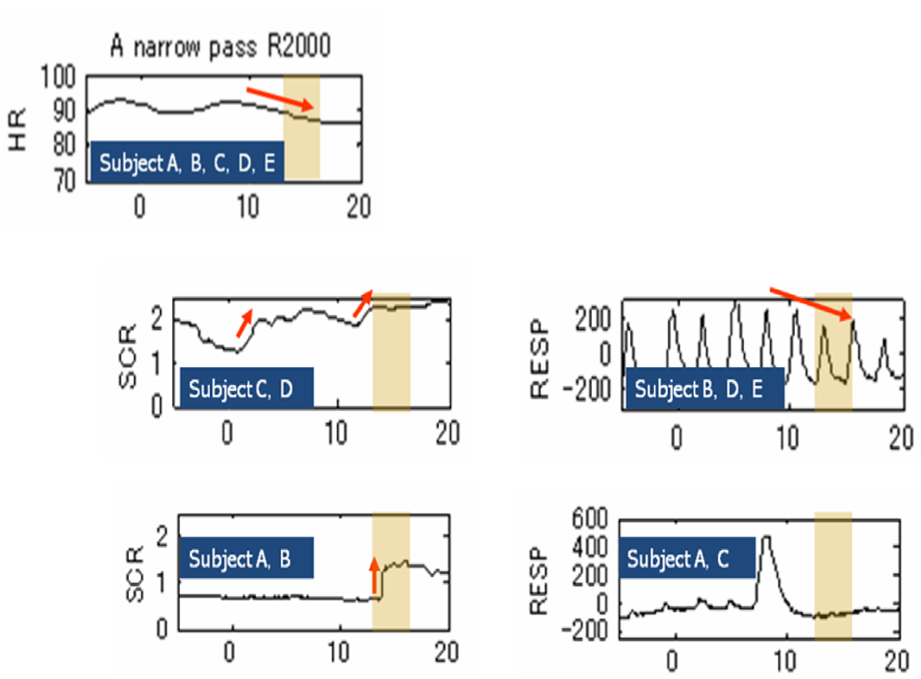

Fig. 5. Example of HR changes, SC, and Respiration at R2000 curve

4 Discussion

In this study, it was confirmed that HR decreased when subjects concentrated on going through a narrow, one way passage while driving on the main road. On the other hand, it was also confirmed that HR increased when the subjects had a dangerous feeling in experiencing an incident. Therefore, we found that the style of HR change differed according to the style of coping with an incident. We think that the HR increase before coming to a place where the main road narrowed to a one-way passage depended on a subject's concentration more than on the activation of his sympathetic nervous system. Moreover, we confirmed that SC changed when the subject discovered an incident.

In a former report [5], we suggested the possibility that SC might show acknowledgment of an incident when HR did not do so. But the opposite was the case in this study. The data showed large individual variations in SC, and there were also many subjects who did not appear to show any reaction to the incident in terms of SC change. So we need to examine the relationship between SC change and emotional change in the future. Also, we confirmed the trend that respiratory amplitude increases and decreases synchronously with HR increase and decrease, respectively.

5 Conclusions

In this study, we examined the relationship between a driver's feelings and HR change. As a result, it was clarified that HR rose when the subject had a strong dangerous feeling in regard to an incident. On the other hand, HR decreased because the subject paid attention to handling the incident. We also observed that in many cases respiratory amplitude increased when HR rose, and breath amplitude decreased when HR decreased. Therefore, we suggest that a driver's emotional change can be detected by breath amplitude.

Furthermore, SC change was also observed in discovering and dealing with an incident. However, the change was not the same for all subjects and driving situations. Given this result, we can say that in this report we clarified the relationship between HR change and a driver's emotional change; however, we have also left a lot of issues unresolved in regard to the relationship between SC, respiratory amplitude and a driver's emotional change.

Therefore, we will increase the number of subjects and continue examination of these research topics.

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