EEG analysis for surprise in VR traffic environment

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Abstract

On the assessment of user experience in VR traffic environments, a method to evaluate the mental state of subjects is required to measure the effects of dynamic events in the traffic environments. EEG is one of the promising devices for measuring the subject mental status. We propose to analyze EEG responses against traffic scenes, including traffic accidents, for the evaluation of the surprise feelings of subjects in VR traffic environments by a set of HMD and an EEG device. Throughout the experiments, we examined whether EEG can evaluate subjects' emotional states in response to the events in VR space. Three traffic scenes and 10 subjects were prepared for the experiment. The EEG analysis was made on beta frequency band power related to surprise response.

Keywords

VR, HMD, EEG, Emotion, Surprise feeling, Traffic assessment, Vehicle accident

1. Introduction

State-of-the-art VR technology could provide an immersive experience of the real world [1-5]. It could be useful for the assessment of the scenes which are challenging to prepare in the real world. Some studies focus on user experience evaluation in VR environments [5-7]. The evaluation in the assessment of user experience is essential in these research topics.

In conventional studies, a subjective evaluation questionnaire is used for the assessment [6]. Using a subjective evaluation questionnaire, it is difficult to measure the mental state of the subjects against the events in the experiment.

The use of physiological signals could solve this problem. Among physiological signals, we focused on EEG. It has been reported that EEG can estimate the emotional state of subjects [8]. Using EEG, we could identify the subject's consciousness in the experiment.

Studies on VR and EEG have also been conducted [5] [9-11]. Further study is needed to reveal emotional states against the events in the VR environment.

In this paper, we propose to analyze EEG responses against traffic scenes, including traffic accidents, for the evaluation of the surprise feelings of subjects in VR traffic environments. We chose traffic accidents as a dynamic event.

Subjects in the experiment will have a surprising experience through an accident caused by a momentary collision of vehicles reproduced in a VR space. The beta frequency band in the frontal lobe EEG is used for EEG analysis. It has been reported as an indicator of vigilance and concentration [12][13]. We hypothesize that there is a relationship between the beta frequency band with surprise and then investigate the power of the beta frequency band.

The VR space is constructed using Unity. We prepared ten subjects for the experiment. The subjects will watch vehicle collision scenes a total of two times.

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2. Related work

2.1. Studies using VR and EEG

Studies have been conducted using VR and EEG [5][9][10][11][14][15]

The study by Dorota Kaminska et al. classified stress levels in a VR environment [9]. They stated that emotion classification was possible for EEG data while wearing VR, similar to previous studies.

The study by Valasileios Aspiotis et al. investigated whether the experience of heights in a VR space affects stress using EEG [15]. The results showed that subjects could experience high stress even at heights reproduced in VR.

Based on these previous studies, it is possible to estimate consciousness in the state of wearing VR and present an experimental environment similar to the natural environment.

2.2. Emotion estimation by EEG

Studies using EEG have been applied various fields, including physiological research such as cognition, medicine and education [16-19]. It has been reported that emotion estimation is possible in EEG studies [8][20].

Wei-Lang et al. reported that frontal lobe EEG is effective in emotion estimation [21]. They reported that frontal lobe EEG could categorize emotional states during movie viewing into three types: positive, neutral, and negative.

Saira-Bano et al. reported that subjects' fatigue affects the beta frequency band [22]. For this reason, we will use a short VR wearing time of 7 minutes in the experiment.

3. EEG analysis method

Subjects wear the VR device while wearing the electroencephalograph. A previous study reported that wearing the VR device and electroencephalograph simultaneously did not affect the data [9]. Figure 1 shows the actual VR and EEG being worn.

We adopt only FP1 and FP2 at the frontal lobe for the EEG sensing as these two are thought to play a dominant role in finding surprising feelings.

Figure 1: Attachment of equipment

When dealing with EEG, the effects of noise must be considered [23]. In this study, subjects were instructed not to move their heads during the experiment to minimize the effects of noise.

For the EEG data obtained from the experiment, the EEG was converted from the time domain to the frequency domain by FFT. The time average of the beta frequency band was then calculated, and the beta frequency band power was calculated. In the following, the beta frequency band power is called BP.

4. VR traffic environment

In this study, a road space was constructed in a VR space. The VR space consists of 155m x 160m. Figure 2 shows the actual road space constructed.

Figure 2: VR Space

The VR situation in the experiment consists of three turns: Turn1 to familiarize the subject with VR, Turn-2 with no accidents, and Turn-3 with accidents. Turn-1 is a video to familiarize the subject with the VR space and includes Turn1-1 with no vehicles present (Figure 3) and Turn-1-2 with vehicles present (Figure 4). Turn-2 is where no vehicle collisions occur (Figure 5). Turn2 is provided for comparison with Turn-3 (Figure 6).

Subjects are positioned in the VR space at the roadside. Figure 7 shows the subject's placement position and viewing range. Subjects watch the scene in VR within the range shown in Figure 7.

The surprise experience of this study is presented in Turn-3. In this turn, a vehicle crash scene is recreated, and the subject watches the vehicle crash scene in front of the subjects. All VR turns consist of 30 seconds. The vehicle collision, in Turn-3, occurs 20 seconds after the start of the turn.

Figure 3: Turn-1-1

Figure 4: Turn-1-2

Figure 5: Turn-2

Figure 6: Turn-3

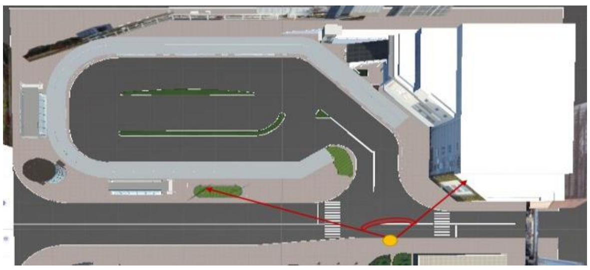

Figure 7: The subject's position and range of vision

5. System

This study used HTC's VIVE Pro Eye (VIVE) as the VR device and Emotive's EMOTIV EPOC Flex as the EEG measurement device.

The VR space was constructed using Unity. The VIVE Pro Eye has a display resolution of 1440 x 1600 pixels per eye, a frame rate of 90 Hz, and a viewing angle of 110 degrees.

The time window to calculate the frequency of EEG is set to 2.0 seconds at the sampling frequency of 128Hz. The window is shifted at 0.125 seconds intervals.

6. Experiment

Before starting the experiment, subjects were instructed not to move their heads. This instruction was to minimize noise generation due to head rotation. Because the subject's visual range is limited, the vehicle collision video was set to occur in front of the subject's eyes.

The experiment consists of turns for EEG acquisition during closed-eye rest and open-eye rest, Turn-1, Turn-2, and Turn-3. Turn-2 and Turn-3 are played twice. In the following, the first occurrence of Turn-2 is referred to as Turn-2-I, and the second occurrence of Turn-2 is referred to as Turn-2-II. The same convention applies to Turn-3, with Turn-3-I and Turn-3-II.

Figure 8 shows an overview of the experiment flow. After the experiment, a subjective evaluation questionnaire was conducted using a 5-point rating scale. The question is "How much are you surprised by the scene you watched?" It was conducted using rating items where 5 indicated "surprised" and 1 indicated "not surprised." Figure 9 shows the questionnaire sheet.

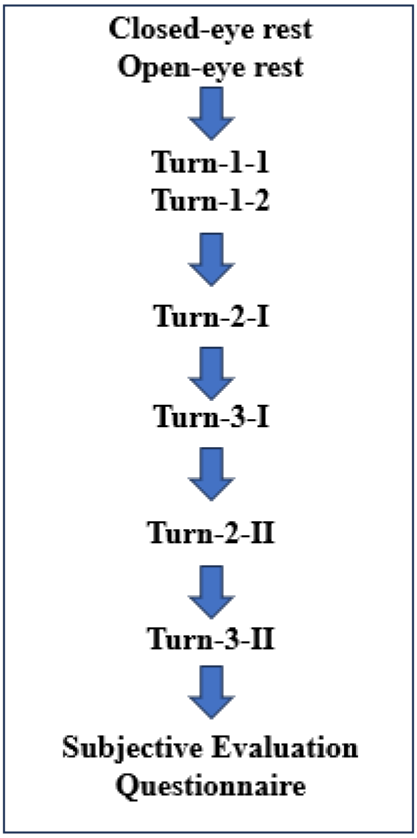

Figure 8: Experiment flow

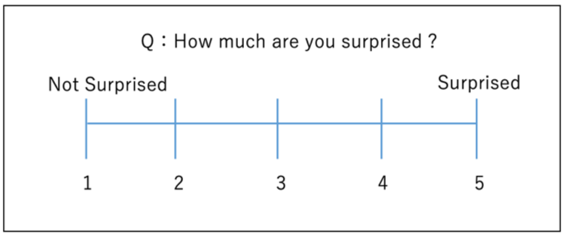

Figure 9: Questionnaire sheet

The EEG was analyzed during the resting state with closed eyes, resting state with open eyes, Turn-2, and Turn-3. The analysis time for the resting state with closed eyes, resting state with open eyes and Turn-2 was 30 seconds, while the time used to analyze Turn-3 was 3 seconds after the vehicle collision.

7. Results of Experiments

We report the results of an experiment. 10 people took part in the experiment. All subjects were interviewed prior to the experiment, and it was known that all of them had VR experience. All subjects were in their 20s (9 males and 1 female).

7.1. Results of subjective evaluation questionnaire

Figure 10 shows the results of the subjective evaluation questionnaire. 8 out of 10 people in Turn-3-I gave a rating of 5. Turn-3-II had a lower value than Turn-3-I.

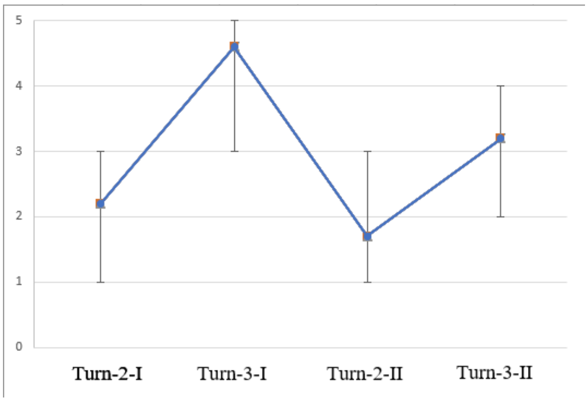

Figure 10: Results of the subjective evaluation questionnaire

7.2. EEG analysis results

Figure 11 shows the changes in BP during open-eye rest, Turn−2-I, and Turn-3-I relative to the baseline values of BP during closed-eye rest. The horizontal axis is the subject label, and the vertical axis is the BP value. Turning to the bar graphs for each subject, the analysis results for open eye rest, Turn-2, and Turn-3 are displayed.

As a result, BP was highest during the traffic accident in 6 out of 10 people.

Figure 12 shows the increase and decrease in BP for Turn-3-II when Turn-3-I was used as the baseline. Both the horizontal and vertical axes are the same as in Figure 5. As a result, in 8 out of 10 people, Turn-3-I had higher BP values than Turn-3-II.

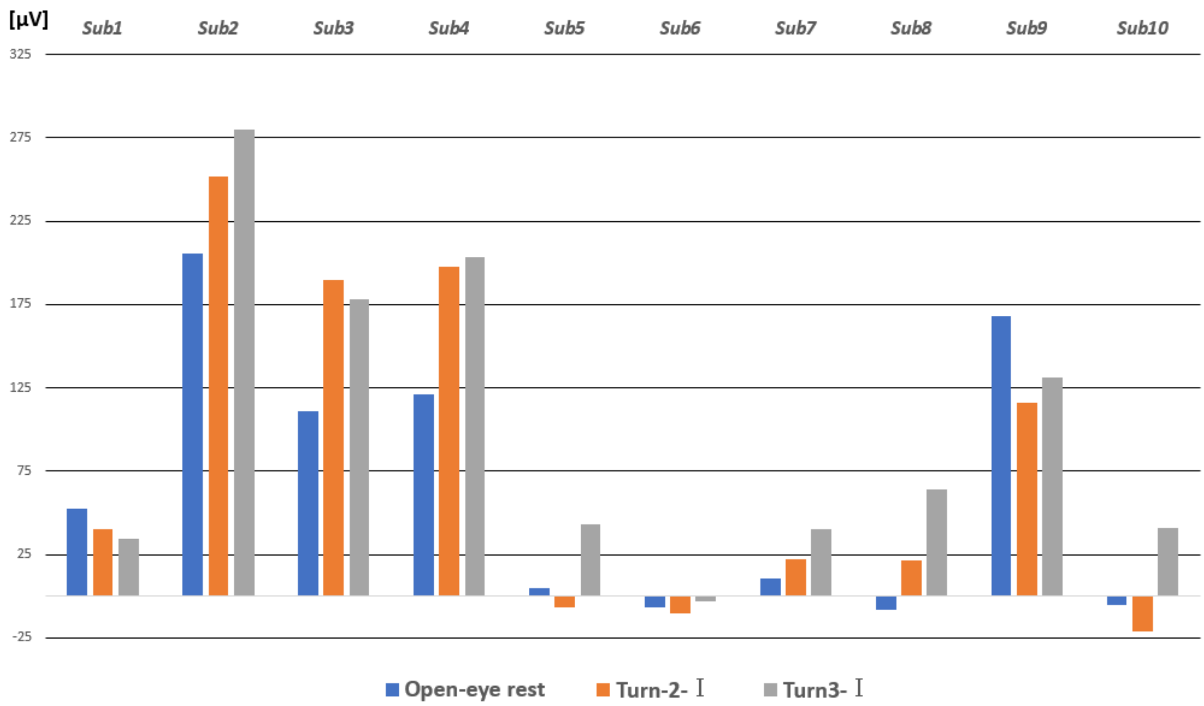

Figure 11: Results of beta frequency band power: Baseline close-eye rest

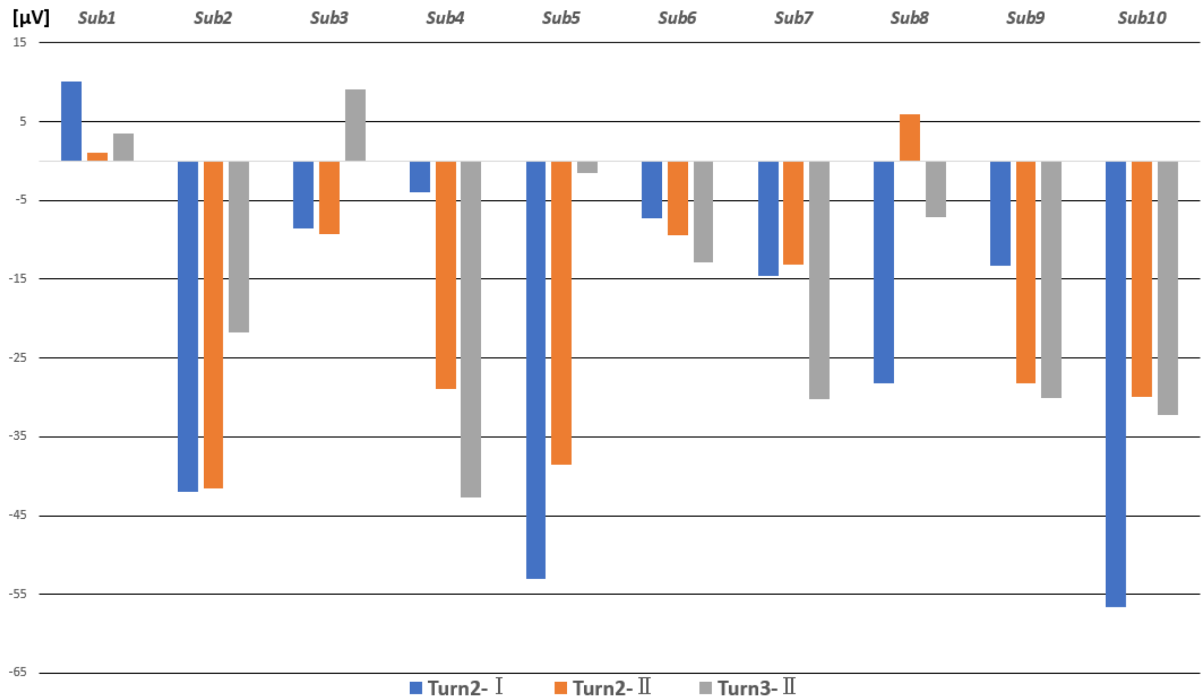

Figure 12: Results of beta frequency band power: Baseline Turn-3- Ⅰ

7.3. Discussion

Based on the subjective evaluation questionnaire results, this study provided the participants with a sufficient surprise experience.

The lower values in the subjective evaluation questionnaire for Turn-3-II than for Turn-3-I were due to familiarity with the repeated occurrence of the event.

The results of the EEG analysis showed that BP values were maximal for more than half of the subjects. This result suggests that it is highly likely that the BP was obtained in the EEG when the subjects were surprised. Comparison with the EEG data obtained during the repetitions showed higher BP values for Turn-3-I than for Turn-3-II in most subjects. This EEG result could be consistent with the results of the subjective evaluation questionnaire and could be due to the same cause.

There are individual differences in EEG. The fact that no increase in BP was observed for all subjects in this study is mainly due to individual differences. In order to consider that BP is associated with surprise, a statistical study needs to be conducted with a more significant number of people. In this study, the age range of the subjects was limited to those in their 20s. It is necessary to expand the scope of the survey in order to consider the more general application.

8. Conclusion

We proposed to analyze EEG responses against traffic scenes, including traffic accidents, for the evaluation of the surprise feelings of subjects in VR traffic environments. We chose traffic accidents as a dynamic event. We focused on surprise feeling as an emotional state and the analysis was conducted on the beta frequency band.

Three traffic scenes and 10 subjects were prepared for the experiment. We conducted a traffic experiment and EEG analysis focusing on the emotional state of surprise to examine whether EEG is effective in estimating emotion for momentary events in VR experiments.

The relationship between surprise and EEG was investigated using EEG data obtained when subjects were surprised and a subjective evaluation questionnaire administered after the experiment.

The experiment results showed that BP values increased the most during the surprise experience in 6 out of 10 people. As a result of the repetition of the surprise experience, in 8 out of 10 people, the BP value decreased during the second surprise experience compared to the first surprise experience. This could be consistent with the results of the subjective evaluation questionnaire.

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9. References

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