Measurement of fNIRS to Estimate Emotion in a VR System

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ABSTRACT

Virtual Reality (VR) had a banner year in 2016. VR has attracted a lot of media attention because many companies have launched Head Mounted Displays (HMDs) and other related products. As a result, the term “immersive feeling” has become more widely known. In this study, we have planned to evaluate immersive feeling of VR content using HMD. For that purpose, we performed an impression survey to find adjectives related to immersive feeling. The results showed that “Thrilling / Not thrilling”, “Complex / Simple”, and “Stereoscopic / Planar” are greatly related to immersive feeling. Then, we created two types of VR content: roller-coaster content expected to generate high immersive feeling (thrilling, complex and stereoscopic), and grassland content to generate low immersive feeling (not thrilling, simple and planar). We used a questionnaire and fNIRS for these evaluations. Performing the experiment to experience two contents stereoscopically using a HMD, we found significant differences between two contents for the immersive and exciting feelings from questionnaire results. In addition, we found the differences of the standard deviations of oxygenated hemoglobin during experiencing two contents. They were larger in the rolling coaster content than those in the grassland content for some participants. We expect that the differences are symptoms of immersion and/or excitement feelings.

Keywords: Virtual Reality, Head Mounted Display, fNIRS, Emotion, Immersive feeling, Excitement

1. Introduction

Virtual Reality (VR) had a banner year in 2016 and has attracted a lot of media attention because many companies have launched Head Mounted Displays (HMDs) and other related products. (Virtual Reality Society, 2016). As a result, the term “immersive feeling” has become more widely known. In previous studies, immersive feeling was evaluated using 2D or 3D displays (Jennetta et al., 2008) (Sakamoto et al., 2013). However, those displays can show only a frontal scene. On the other hand, HMD can provide a stereoscopic scene in all directions. Therefore, using HMD would give a more immersive feeling than 2D or 3D displays. Thus, we planned to evaluate immersive feeling using HMD by creating VR contents.

We performed an impression survey of the term “immersive feeling,” and performed factor analysis to create VR contents and to determine question items for their evaluations. Then, we experimentally evaluated immersive feeling in VR systems using HMD with the two created pieces of content. We used a questionnaire and fNIRS for the evaluations. The experimental result suggests a strong correlation between immersive feeling and a sense of excitement.

2. Impression survey

The objective of the impression survey is to create VR content giving a high immersive feeling and VR content giving a low immersive feeling. We created a questionnaire by referencing previous research (Iimura et al., 2012) as follows:

1. Do you know the term “Virtual Reality (VR)”?
   (yes / no)
2. Do you know the term “Immersive feeling”?
VR contents and to determine question items for their “immersive feeling,” and performed factor analysis to create using HMD by creating VR contents. Thus, we planned to evaluate immersive feeling would give a more immersive feeling than 2D or 3D stereoscopic scene in all directions. Therefore, using HMD frontal scene. On the other hand, HMD can provide a et al., 2013). However, those displays can show only a the term “immersive feeling” has become more widely related products. (Virtual Reality Society, 2016). As a result, we have launched Head Mounted Displays (HMDs) and other attracted a lot of media attention because many companies become more widely known. In this study, we have planned to evaluate immersive feeling of VR content using HMD. For term immersive feeling was much lower than that of VR.

Table 1 shows descriptive statistics of answers to question 3. We analyzed the results of question 3, and Table 2 presents the results of the factor analysis. Three factors were extracted from the analysis. The main components of these factors are as follows:

1. Ease, Relaxing, Ordinary, Natural
2. Artificial, Clear, Dynamic, Bright
3. Stereoscopic, Thrilling, Complex

Then, we named these factors “Relaxing,” “Active,” and “Exciting,” respectively. Figure 2 shows ratios of answers for question 3 for each factor. As shown in Figure 2, many volunteers answered that the Exciting factor was necessary. Therefore, we focused on the Exciting factor and created content.

3. Experimental Method

To evaluate the degree of immersive feeling in the VR system with HMD, we created two VR contents based on the results of the impression survey mentioned above. By the results of the preliminary experiment, the revised contents, 155 sec. each, are as follows:

- Roller coaster content: we expect this content to have high scores for Exciting factor. It contains falling and turning fast three times each.
- Grassland content: we expect this content to have low scores for Exciting factor. It contains only straight, flat forward motion.

We also created a questionnaire as shown below by referencing previous research (Jennetta et al., 2008) (Witmer et al., 1998). Evaluation was carried out using a VAS (Visual Analog Scale) method.

Q1. Was the content thrilling?

(Yes / No)
If the answer to question 2 is “yes”, go to question 3.
3. Which factors are necessary to give an immersive feeling?

We used 12 pairs of adjectives with five-point Likert scale (-2 to +2) for this question.

The impression survey on immersive feeling was conducted with 84 volunteers in their 20s. Figure 1 shows results for questions 1 and 2. For question 1, 75 out of 84 (89%) answered yes. Therefore, it can be said that the term VR is generally recognized. For question 2, 35 out of 84 (42%) answered yes, which means that recognition of the term immersive feeling was much lower than that of VR.

Table 1 shows descriptive statistics of answers to question 3. We performed an impression survey of the term “Virtual Reality (VR)" and fNIRS for these evaluations. Performing the experiment to experience two contents stereoscopically we created two types of VR content: roller-coaster content expected to generate high immersive feeling and VR content giving a low immersive feeling. We created a questionnaire as shown below by referencing previous research (Jennetta et al., 2008).

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Q2. Did you feel the content to be planar or stereoscopic?
Q3. Did you feel the content to be simple or complex?
Q4. Did you feel motion sickness from experiencing the content?
Q5. Did you care about the surroundings while experiencing the content?
Q6. Did you feel that you were moving?
Q7. Did you get distracted during the content experience?
Q8. Did you feel as if you were in a virtual space?
Q9. How long was the content time? (Short or long)
Q10. How was the content? (Boring or interesting)

Figure 3 shows our experimental system. Changes in cerebral blood flow rate are measured by fNIRS. Participants repeats both VR contents twice. The experimental procedure is shown in Figure 4.

4. Experimental Results and Discussion

We performed an experiment with eight male participants in their 20s. The order of experiencing two contents was counter-balanced.

Figure 5 shows the results of questionnaire. The results of paired t-test show significant differences between two contents at a 1% level for 8 out of 10 question items. These results indicate that the roller coaster content is more exciting and more immersive the grassland content.

As for the data obtained from fNIRS, we obtained data for 7 participants because of a measuring problem for the other one participant. In addition, we excluded data in case that the participants felt discomfort caused by VR sickness because it is known that the discomfort affects the cerebral blood flow rate (Kadoi et al., 2015). Then we analyzed 20 data in total. From the running averages of fNIRS data, we found that the changes of oxygenated hemoglobin for the roller coaster content are larger than those for the grassland content for some participants. Figure 6 shows the running averages of oxygenated hemoglobin for the second time of a participant. This result might suggest the relation between change of cerebral blood flow rate and immersive and/or exciting feeling.

4. Conclusion

In this study, we have planned to evaluate immersive feeling of VR content using HMD. For that purpose, we performed an impression survey to find adjectives related to immersive feeling. The results showed that “Thrilling / Not thrilling”, “Complex / Simple”, and “Stereoscopic / Planar” are greatly related to immersive feeling. Based on the results, we created two types of VR content: roller-coaster content expected to generate high immersive feeling, and grassland content to generate low immersive feeling. Performing the
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