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Research paper



A Study on Cybersickness Reduction Method using Oculomotor Exercise

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Abstract

VR content has problem in causing cybersickness to user. Nevertheless, the main reasons causing cybersickness have not been identified. In this paper, we proposed a cybersickness reduction method using oculomotor exercise. The proposed method was examined through an experiment measuring human factors such as simulator sickness questionnaire (SSQ) and blood sampling. Experimental results with oculomotor exercise showed that cortisol in blood were not increased. Therefore, it was confirmed that the proposed method was effective for reducing cybersickness reduction.

Keywords: *Virtual reality, Cybersickness, Cybersickness reduction, Human factor, Oculomotor exercise*

1. Introduction

Virtual reality (VR) is a high-end user computer interface that involves real-time simulation and interactions through multiple sensorial channels [1]. Recently, a market of VR content has been growing rapidly performance improvement of a head-mounted display (HMD). However, VR content has problem in causing motion sickness to user. Such a motion sickness symptom is called cybersickness, which provides an uncomfortable feeling to the user, and may continue for several days if the one is heavy [2, 3]. Cybersickness symptoms include headaches, nausea, vomiting, pallor, sweating, fatigue, drowsiness, and disorientation [4, 5]. In severe cases, cybersickness symptoms are maintained for several days [6].

Nevertheless, the main reasons causing cybersickness have not been identified. The hypotheses that are well known for causing cybersickness are sensory conflict theory [6] and posture instability theory [6]. The sensory conflict theory [6] is that the conflict between the senses of the vestibular organ and the visual organ causes the cybersickness. Vestibular and visual organs provide direction and motion information of a human body. While watching VR content, the visual organ delivers information about moving body, but the vestibular organ does not deliver. Therefore, the virtual environment conflicting both senses induces cybersickness to user. The postural instability theory [6] is that posture instability of a human body induces the cybersickness.

Human being has the characteristics to keep a stable posture in any situations. However, the virtual environment is a new environment that has not been experienced before, it is difficult for the person who can not adapt to the virtual environment to keep the posture stability. Therefore, the virtual environment that is difficult to keep the stable posture induces cybersickness to user, too. Conventional studies [1, 7] have proposed through cybersickness reduction methods focused on content and device. However, few cybersickness reduction ones focused on users has been studied. In this paper, we propose a cybersickness reduction method focused on users. The proposed method introduces an oculomotor exercise and is examined based on a human factor experiment.

2. Cybersickness Reduction Method using Oculomotor Exercise

Human being keeps posture stability through vestibulo-ocular reflex and vestibule-spinal reflex movements [8]. The vestibulo-ocular reflex is a movement to keep place eye at a constant position in according to the body movement. The vestibule-spinal reflex is a movement responding muscles to keep the body balance in according to the body movement. Consequently, the body keeps the posture stable through two reflex movements. By conventional studies, oculomotor exercise [9] was effective for two reflex movements. Therefore, the proposed method using oculomotor exercise can reduce cybersickness by improving posture stability. Oculomotor exercise method [9] for cybersickness reduction as shown in Table 1.

3. Experiments and Discussions

In this section, to see if the proposed cybersickness reduction method (that is, cybersickness reduction method using the oculomotor exercise) is effective, a human factor [1] experiment is conducted and their results are discussed. The human factor is human cognitive and physical characteristics to optimize user's response, usability, stability, and social influence [1]. In this experiment, both cognitive and physical human factors were used.

The cognitive human factor is simulator sickness questionnaire (SSQ) and the physical human factor is cortisol. SSQ is the most widely used sickness symptom questionnaire to evaluate cybersickness [10]. The cortisol in blood is a method of measuring mo-

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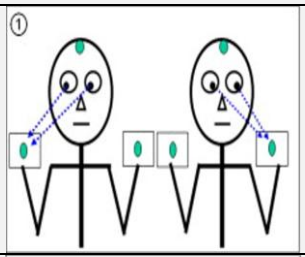
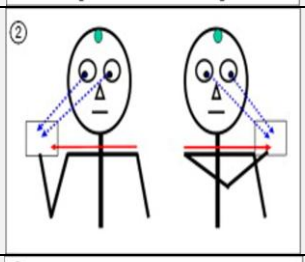
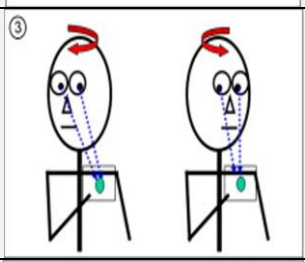
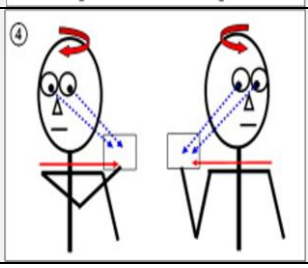
Table 1: Oculomotor exercise method

Exercise order		Schematic figures	Exercise method	Exercise time (second)	Total exercise time (minute)
1	Saccadic eye movement exercises		The saccadic eye movement exercise included moving the eyes horizontally between two stationary targets while keeping the head still.	75	5
2	Smooth pursuit exercises		The smooth pursuit exercise included moving the target horizontally and tracking it with the eyes while keeping the head still.	75	
3	Adaptation X1 exercises		The adaptation X1 exercise included moving the head horizontally while keeping the stationary target in focus.	75	
4	Adaptation X2 exercises		The adaptation X2 exercise included moving the head and target in opposite directions horizontally while tracking the target with the eyes.	75	

tion sickness, it increases with the occurrence of motion sickness symptom [11, 12].

Figure 1 shows the experimental setup for physical human factor measurement. The subject wore the HMD and performed blood sampling in the left arm. Figure 2 shows the content scene used in the experiment. The content watching time is set to 9 minutes because longer watching one results in stronger cybersickness.

The experiments according to oculomotor exercise were separately performed for two days because longtime watching VR content induces fatigue. Thus the experiment was separately performed for two days in order to reduce the bias by the eyestrain of the subject. The subjects were controlled by a supervisor to keep forward-looking while oculomotor exercise to prevent bias of head rotation. 14 subjects (7 male and 7 female, age: 20-28) participated in the experiment and they were all healthy. The first experiment watched VR content without oculomotor exercise, the second experiment watched VR content after oculomotor exercise. SSQ, one of cognitive human factors, was measured two times: before- and after-experiment. The blood sampling, one of physical human factors, was conducted every three minutes to check changes in hormone ingredient.

Figure 3 compares SSQ nausea scores before- and after-experiments. The nausea scores measured after-experiment were higher than the ones measured before-experiment in both experiments. Figure 4 compares the SSQ oculomotor scores before- and after-experiments. The oculomotor scores measured after-experiment were higher than the ones measured before-experiment in both experiments. Figure 5 compares the SSQ disorientation scores before- and after-experiments. The disorientation scores measured after-experiment were higher than the ones measured before-experiment in both experiments.

Table 2 and Table 3 show the results of the cognitive human factors. Table 2 showed the results of SSQ scores for the subject group without oculomotor exercise analyzed by t-test to examine

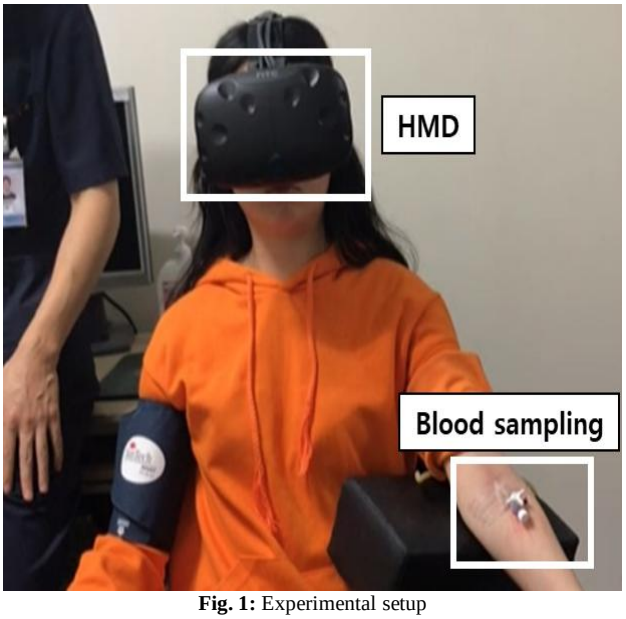


Fig. 1: Experimental setup



Fig. 2: VR content used for the experiment

whether or not VR content used in the experiment caused cybersickness. The t-test was compared before- and after-experiment. The significance level was confirmed at $p<0.05$. From t-test result, a significant difference was only found at disorientation. Although t-test results did not show significant differences, Figure 3, 4 and 5 showed that the scores of nausea, oculomotor, and disorientation were increased. From them, it was found that watching VR contents induced cybersickness. Table 3 showed the t-test results of SSQ scores according to with and without oculomotor exercise. The t-test used the SSQ differences (scores) between before- and after-experiment to analyze the effectiveness for cybersickness reduction. The significance level was at $p <0.05$. From the t-test result, it was found that there was no significant difference between subject groups with and without oculomotor exercise. From this result, cybersickesss reduction was not found in cognitive human factor.

Figure 6 shows the change of physical human factor through regression analysis. Experimental result indicated that cortisol in blood did not increase with oculomotor exercise. However, cortisol increased without oculomotor exercise.

Table 4 shows the results of the physical human factors analyzed by t-test. The significance level was confirmed at $p<0.05$. The cortisol in the group without oculomotor exercise was observed a significant difference. Whereas, the cortisol in the group with oculomotor exercise was not observed a significant difference. This means that the proposed method is effective for reducing cybersickness.

4. Conclusion

In this paper, we proposed a cybersickness reduction method using oculomotor exercise. The proposed method introduces an oculomotor exercise and was examined based on a human factor experiment. As an experimental result, the effect of cybersickness reduction was not confirmed in the cognitive human factor (SSQ) according to oculomotor exercise. However, the effect of oculomotor exercise for cybersickness reduction was confirmed in the physical human factor (blood sampling). The cortisol in the group without oculomotor exercise was observed a significant difference. Whereas, the cortisol in the group with oculomotor exercise was not observed a significant difference. Generally, the cortisol in blood increases when motion sickness occurs [11, 12]. Experimental results indicated that cortisol in blood did not increase with oculomotor exercise. Therefore, we confirmed that the proposed method is effective for reducing cybersickness.

The conventional studies for cybersickness reduction have focused on the cognitive human factor. As most of studies were dependent on SSQ measurement, so the results were hard to be considered objective. Our results (as shown in Fig. 3, 4 and 5) have confirmed that. Whereas, from the cortisol (one of physical human factors) measurement results (Fig. 6 and Table 4) it was found that there was a significant difference between subject groups with and without oculomotor exercise. From the results, it was found that the proposed method (focused on the physical human factor) could affect cybersickness reduction.

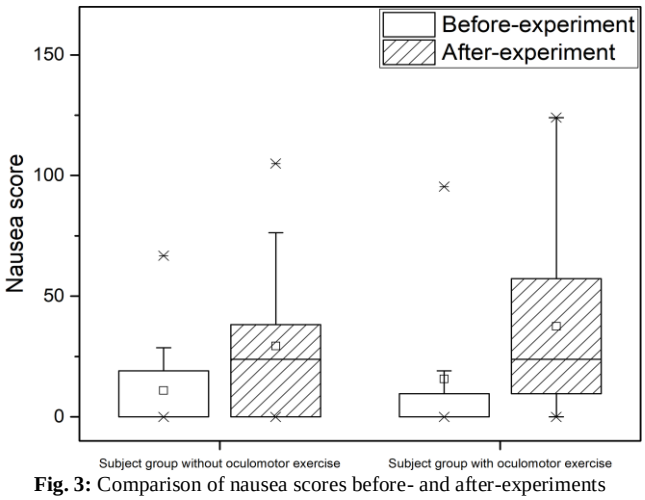


Fig. 3: Comparison of nausea scores before- and after-experiments

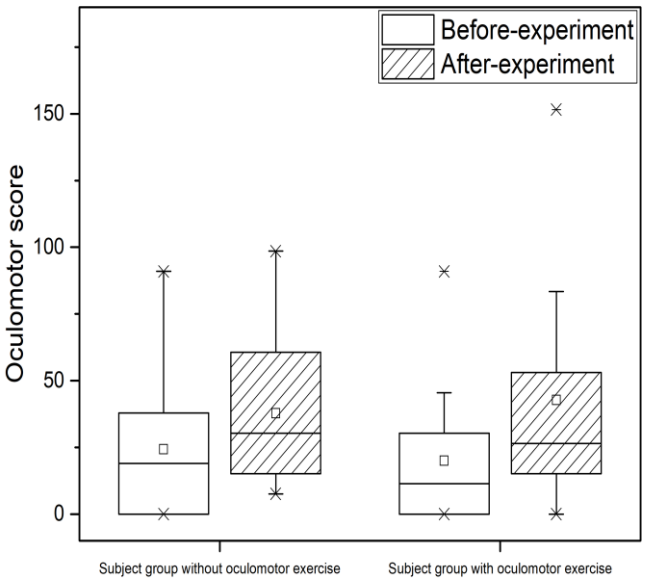


Fig. 4: Comparison of oculomotor scores before- and after-experiments

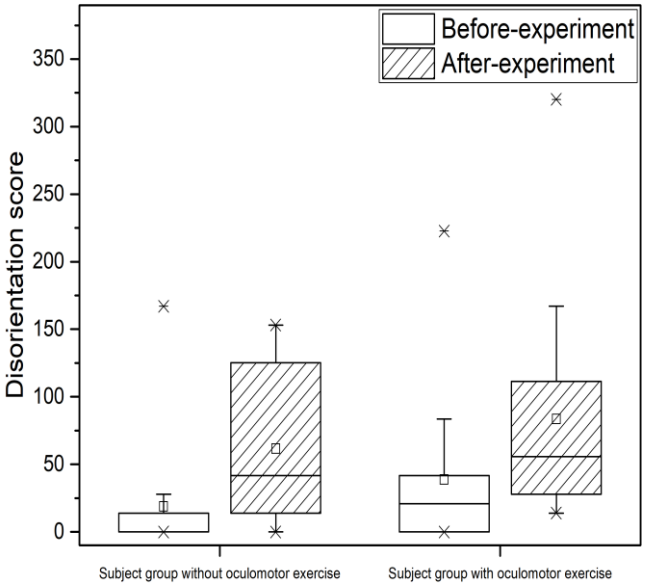


Fig. 5: Comparison of disorientation scores before- and after-experiments

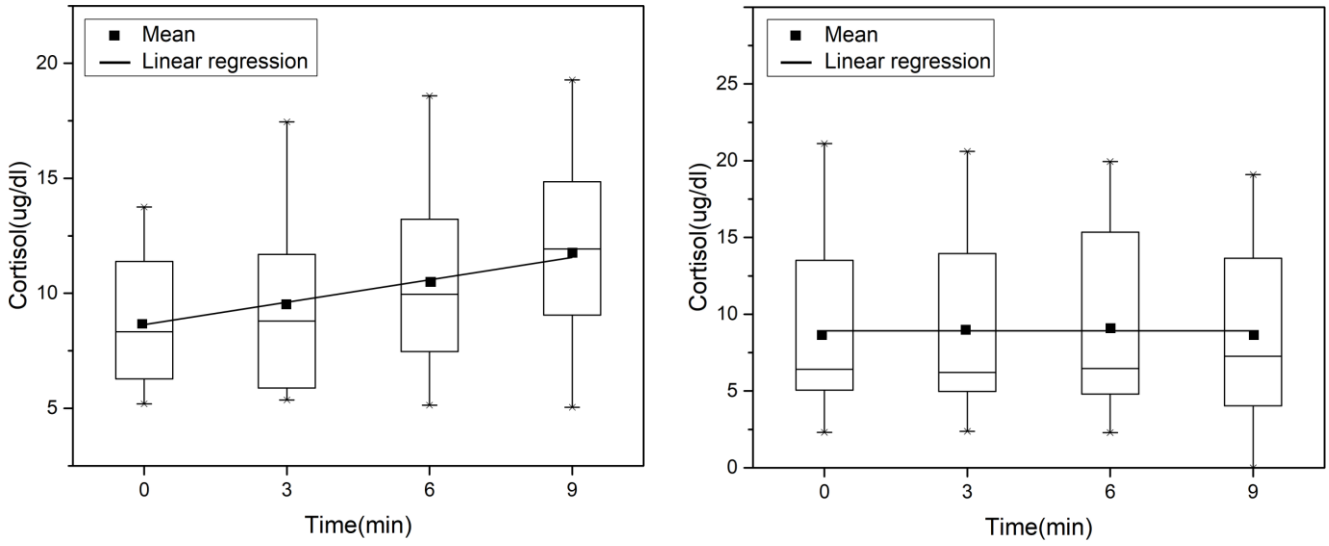
Table 2: SSQ score according to before- and after-experiments t-test result

	Nausea		Oculomotor		Disorientation	
	t	p	t	p	t	p
Subject group without oculomotor exercise	-1.877	.830	-1.578	.139	-2.648	.020*

* : p<.05

Table 3: SSQ score according to experiments with and without oculomotor exercise t-test result

	t	p
Nausea	-.254	.803
Oculomotor	-.704	.494
Disorientation	-.087	.932



(a) Subject group without oculomotor exercise (b) Subject group with oculomotor exercise

Fig. 6: Changes in measured data on time

Table 4: The cortisol t-test result

	Cortisol	
	t	p
Subject group without oculomotor exercise	-5.072	.000***
Subject group with oculomotor exercise	.104	.919

***: p<.001

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