ORIGINAL ARTICLE

STUDY OF CYBERSICKNESS ON NON-IMMERSIVE VIRTUAL REALITY USING SMARTPHONE

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ABSTRACT

Cybersickness is one of the psycho-physiological responses affecting human performances when it is interacting with Virtual Environment. Virtual Environment (VE) is an advanced technological model generated by computer which allows users feel the real-life presence like that in the real environment. However the repetitive exposure to VE causes sickness, especially the eyestrain when the eyes are forced to make an accommodation and focus on the virtual object. This symptom can be identified on the eye's movement and the eyes muscle contraction. Thus, it is considered significant to evaluate the contraction of eye's muscle. The objective of this study is to analyse the eyestrain in the constant use of smartphone for playing the war game. Empirical study was conducted to gather the relevant data. Ten subjects, who were familiar with the war game, were involved in this study. Electromyography (EMG) was used to record the signal of muscle contraction on lateral eyes muscle. Statistical analysis was conducted to test the hypothesis. The result of this study showed that there was a significant difference in visual acuity between normal brightness and 0% brightness and 100% brightness of smartphone while sitting in operating. There was also significant difference in visual acuity between the normal brightness 0%, 50%, and 100% of brightness depending on the lying down position. As for the higher contraction on lateral rectus muscle of the eyes occurred in lying down position than in sitting position at any level of brightness.

Keywords: *Cybersickness, Non-Immersive VE, Electromyography, Eyestrain, Muscle contraction*

INTRODUCTION

The smartphone is a device to communicate, get information, and find a source of entertainment like playing a computer game for many people in the world. In Indonesia, this device is very popular since more than 50.8% of the population owns a smartphone[1]. 65.98% out of this number uses it for browsing, chatting, calling, reading news, etc., while the remaining 54.13% of people utilizes it for playing a game[1].

Playing game using smartphones is a very popular and fun activity. Therefore, many software applications for playing games are offered online. Among most popular games are First-Person-Shooter (FPS Game), Online Battle Multiplayer Arena (MOBA), Real Strategy (RS Game), Simulation, and others. These games are developed by virtual environment concept involving three dimensions (3D) objects. This environment produces feelings of real-life presence when players interact with it. Such interaction can be non-immersive, semi-immersive, and full-immersive[2].

However, non-immersive interaction by using smartphone causes negative effects to user. This is because of the constant exposure in virtual environment for a long term that may lead to sickness, like cybersickness[3]. Cybersickness is the unwanted human psycho-physiological symptom during the involvement of the virtual environment during and after[4]. The symptoms experienced by player encompass gastrointestinal distress, postural instability or disorientation, and visual symptoms or eyestrain[5]. Nonetheless, there is a rare evidence to show the severity of such symptom and the factors to affect it, especially the eyestrain. Thus, it is significant to evaluate the use of smartphone for playing games.

This study aims to analyse the eyestrain due to the use of smartphone for playing VE: the war game, in two different positions: sitting and lying down.

METHODS

A. Subject
Ten university students, five males and five females of 20 – 25 years participated in this study. All participants were familiar with the activity of playing games using a smartphone. They play games for 1-3 hours per day. The participants had no medical history on eyes sores, such as strabismus, nystagmus, myopy, hypermetropy, and cylinder.

B. Apparatus
The main devices in this study were Smartphone, Game software applications, Snellen-Chart, and Electromyography. The smartphones had the feature of 5.0 inch size and 540 x 960 pixels Lollypop (5.0.2) Android version were exerted to display the non-immersive virtual environment strategy game. The game application was "defence zone 3HD" and supported with audio

plugin device 3.5mm hands-free stereo headset, which functioned as stimulus.

Optotype Snellen-Chart was used to test visual acuity of the eyes. The optotype consisted of a series of letters of different sizes and levels in inches. Visual acuity was expressed in fractions. The numerator showed the distance of the patient to the chart, while the denominator indicated the distance of the patient whose vision is still normal.

An electromyography (Vernier Software and Technology, USA) was used to investigate the muscle contraction of eyestrain. The electrodes used in this study were AG / AGCL electrode sensors. Raw signal from the EMG recorded electrodes was attached on hand cleaned with an alcohol swab. The raw EMG signal recorded data would be calculated using Logger-Pro 3.8.7 version form Lab quest tools.

C. Empirical Study

i. Experimental Design

Experiment that was conducted in Ergonomics Laboratory. Fig. 1 described two positions used in this study for playing games using smartphone, like sitting position. The smartphone was positioned at 25 cm of distance from the respondent's eyes for both.

The experiment was done for 40 minutes for three level of brightness: low, medium, and high. 5 minute period was required to test the visual acuity after each respondent finished the game. Overall, the experiment took about two and a half hours to complete for each respondent for two positions.

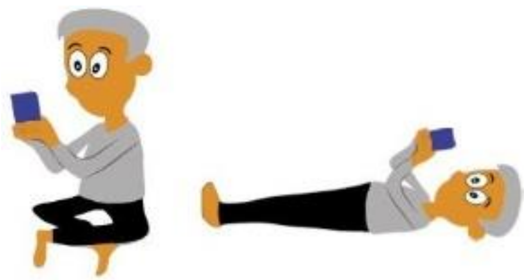

Figure 1: Experiment Position

The visual acuity was measured for the right and left eyes respectively using Snellen chart, in which one of the eyes was closed and another eyes was open to read the optotype. The eye was closed by a sterile palm of hand.

Before starting to play the game, the respondents were required to install the EMG to be placed on their eyes and neck. Two electrodes (green & red) were placed on the surface skin outside of the respondent's eyes and one ground electrode (black) was placed on the respondent's neck as an area that had small body resistance.

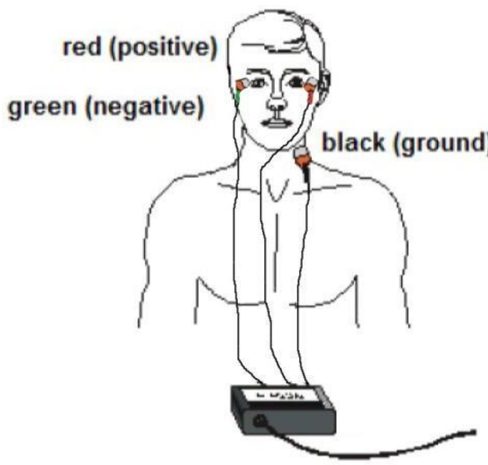

Figure 2: EMG Replacement

As in Fig.3, Musculus Rectus Lateral (MRL) from both eyes as a reference was placed on the electrode to look for eyestrain data from the visual fatigue conditions. A total of 500 samples of MRL activity were recorded using EMG. The use of vaginal or anal probes might be improved by setting high pass filters to stabilize the baseline shifts due to instable contact between probe and muscle-/-skin surface. The high pass setting was 10Hz, 500Hz low pass, and 100ms decay.

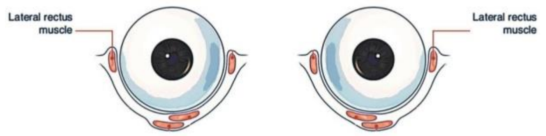

Figure 3: Lateral Rectus Muscle

ii. Task

The games were a non-immersive virtual game of 3HD Defence Zone. The game was about strategical war (see Fig.2). Respondents were instructed to play such game using a smartphone supported with an earphone audio plugin for each position and for every condition for 40 minutes.

Figure 4: Snap Shot Display of "Defence Zone3HD"

The task rules on Defence Zone 3HD in this experiment was started from playing mission part 1 to the next mission, as far as the mission went on by each respondent. Under certain conditions, there was a game over status on display, and each respondent was required to repeat playing in the current playing mission.

iii. Procedure of Experiment
The experiment started with the explanation about the objective of this study to respondents as well as how to do the experiment in playing games with a smartphone. A 10-minute exercise session was provided to make the respondent familiar to the game.

Afterwards, the locations of lateral rectus muscle were identified sine it functioned as one of the extraocular muscle takeovers of the eyeball. According to[6], the location of the lateral rectus muscle was around anterior-lateral sclera beside the eyelids. At this muscle, the two electrodes (green & red) were attached on the surface of the skin and one ground electrode (black) was attached on the neck.

Before starting the experiment, subjects were asked to sit comfortably, hold the smartphone on their hand, and plug in the earphone correctly. The electrodes were removed from the skin when respondents completed the task.

iv. Statistical Data Analysis
Data analysis was based on distribution data of optotype error utterance that was obtained after each respondent finished the task. Afterwards, analysis was conducted to the result of RMS mean signal on muscle activity of lateral rectus muscle.

Non-parametric statistical analysis using the Kruskal-Wallis test and Mann-Whitney test with 5% of significance level was performed to determine the significant differences between each muscle activity and positions, conditions of lighting, and gender when playing game.

RESULTS

A. Result of Visual Acuity Test
Table. 1 presents the guideline for visual acuity test which consists of Snellen Chart Decimal (SND) value and order of visual acuity. The value of SND explains the eye vision numbers from a long distance to a short distance. The order level explains the order of class heights from the SND value.

***Table 1**: Guideline of visual acuity*

Value (SND)	1	0,8	0,67	0,5	0,4	0,33	0,25	0,167	0,1
Level	1	2	3	4	5	6	7	8	9

The result of the visual acuity test for normal room condition; (220lux of lighting), shows that the optotype right and left eyes error utterance has a value of 0.67 which was in level 3. Thus, all respondents had 20/30 of the visual acuity. This explains that the respondents only have vision at 20 feet distance than what normal people can see in 30feet distance. The value of 0.67 SND refers to[7] as an illustration of the sample data that most respondents have a nearly normal right and left eye vision group without having any serious problems and can still be dealt with during this experiment.

Furthermore, each eye of the respondents has a visual acuity value during the normal conditions and conditions after playing game in a sitting position and lying position with three level of brightness (low, medium, and high). Each experimental task has some descent level that occurs between normal condition and the condition after playing the game.

The SND level of the respondent's right eye during normal condition (not playing game) as compared to the condition after playing the game in a sitting position and 0% brightness states has an average descent at 2 levels, which means that the right eye vision of the respondent's normal condition, on average has decreased by 2 levels against the task of playing the game in a sitting position and 0% brightness in this study. Under normal conditions, the sitting position and 50% brightness have a decrease in the average level of 1 level, and the sitting position at 100% brightness has 2 levels. Under normal conditions, the position and 0% brightness have a decrease in the average level of 2 levels, sleeping position and 50% brightness have 2 levels of decrease, and the position at 100% brightness has 2 levels.

B. Result of Eyestrain Test
Each of the average value of the lateral rectus muscles contraction based on sitting position and lying down positions has a value of 0.036484 millivolts for a sitting position with smartphone brightness of 0%, a sitting position with 50% smartphone brightness is 0.039343 millivolts, and a sitting position with 100% brightness smartphone is 0.042463 millivolts. Then the contraction of the lateral rectus muscle is 0.1668830 millivolts in the lying down position with smartphone brightness of 0%, the lying down position with 50% smartphone brightness is 0.138692 millivolts, and that with 100% smartphone brightness is 0.147859 millivolts.

Likewise, the average value of the lateral rectus eye muscle contraction based on type of position of the experiment is that, it has a value of muscle contraction of 0.03943 millivolts at the sitting position and the contraction value of 0.1511 millivolts for lying down posistion. The following figure explane the entire data above.

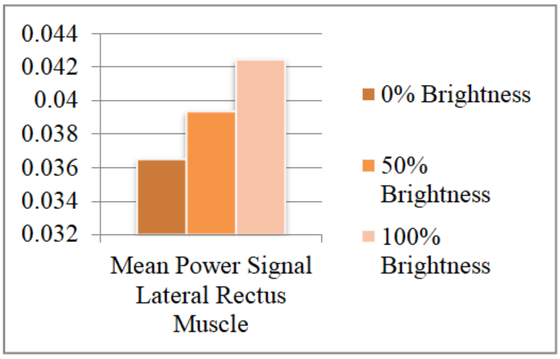

Figure 5: Mean Power Signal Lateral Rectus Muscle on Sitting Position

Fig. 5 shows information on the increasing values from the brightness level of 0%, 50%, and 100%. The histogram describes the comparison of the overall average value of all respondents of each type of brightness tested, and in the graph, the overall average value of ten respondents showed, an increase in contraction of the lateral rectus muscle from the lowest brightness trial to the highest brightness in the experimental treatment of sitting position. In the experiment, six out of ten respondents experienced a decrease in muscle contraction from 0% brightness to 50% brightness. The lateral rectus muscle experienced more contractions when exposed to 0% brightness as compared to 50% brightness.

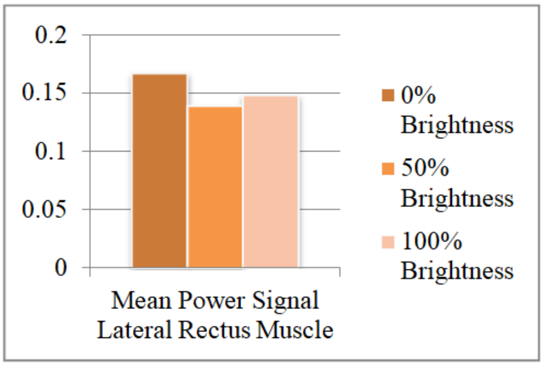

Figure 6: Mean Power Signal of Lateral Rectus Muscle on Lying Down Position

Fig. 6 gives information on the value of muscle contraction experiencing a decrease when the brightness level is 0% to the brightness value of 50%. However, when the brightness is 100% the muscle contraction increases again. The histogram describes the comparison of the overall average value of all respondents from each type of brightness tested.

In the experiment, five out of ten respondents experienced an increase in contractions from the lowest brightness to the highest brightness, while two out of ten respondents experience a decrease in muscle contraction from the lowest brightness to the highest brightness, and the remaining two respondents showed a decrease and increase.

C. Result of Statistical Test

The Kruskal-Wallis test and the Mann-Whitney test were used in this study as a non-parametric statistical tests if at the time the data were proven to be not normally distributed and the sample size was less than 30. According to [9], the non-parametric test has many assumptions while nonparametric methods make fewer assumptions, and they are more flexible, more robust, and more applicable to non-quantitative data.

In this study, some samples used the Independent Sample T-Test since test differences made on data follows a normal distribution.

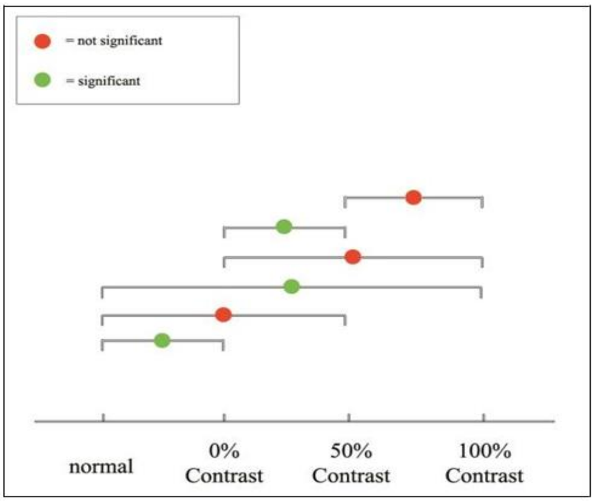

Figure 7: The Difference of Smartphone Conditions at Sitting Positions on Right Eyes Acuity

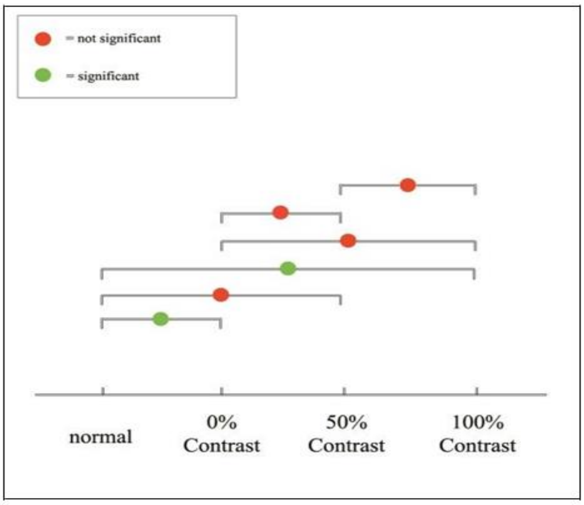

Figure 8: The Difference of Smartphone Conditions at Sitting Positions on Left Eyes Acuity

As shown on Fig. 7 and Fig.8 on eye vision there are significant differences including experiments with normal eye vision and vision conditions at 0% brightness and 100% brightness in the eyes of the respondents in a sitting position. It is evident that the brightness level is at the highest which influences the visual acuity or eye vision of the respondents during the sitting experiment.

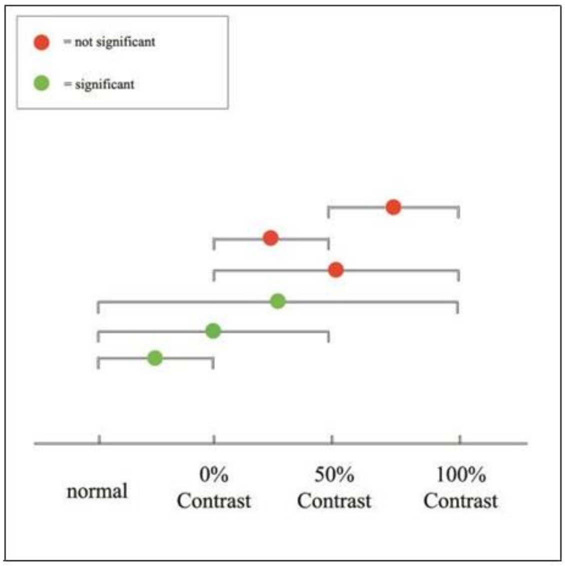

Figure 9: The Different Smartphone Conditions at Different Positions on Right and Left Eyes Acuity

Based on Fig. 9 the lying down position has the same experimental results as that in the sitting position, in that the brightness level of 0% and the brightness level of 100% had a significant effect on eye acuity. Similarly, 50% brightness level also affect the visual acuity of the respondent's visual acuity.

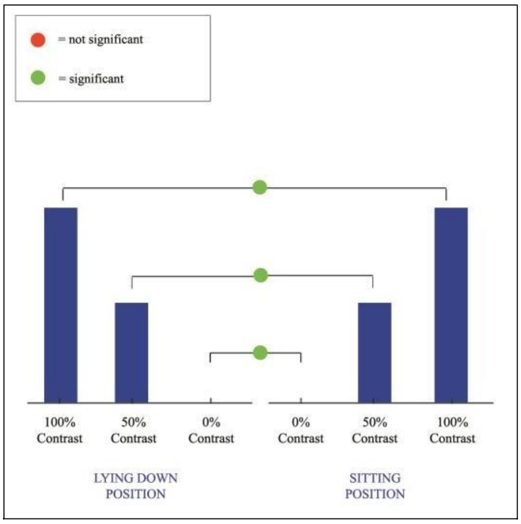

Figure 10: The Different Smartphone Conditions at Sitting and lying down Positions on Eyestrain

There is no significant difference in the contraction of the lateral rectus muscle as a reference for eyestrain in the sitting position in three types of brightness that had been tested and there is no significant difference in the lateral rectus muscle contraction in the lying down position in the three types of brightness that had been tested.

DISCUSSION

A. Visual Acuity Analysis
Each levels of eye vision scores both during the experimental sitting position and lying position has an average value of almost reaching the level of 4 and is worth the same as a visual 0.5 or 20/40 in comparison to the visibility of normal people. However, eye vision in that lying position has a higher value than the eye vision in a sitting position, with differences between 0.2 decreases in vision ranking. According to[8] people who are accustomed to reading in a lying position, make the contraction of the eye muscles work harder, because usually the light is blocked by the book or head, so that the eye gets insufficient lighting and causes visual acuity to decrease.

B. Eyestrain Analysis
In general, Fig. 5 and Fig. 6 explaned that the contraction of the lateral rectus eye of the respondent has an average value based on the type of experimental position. For example, the sitting position had an increase from 0.03943 millivolts and the lying down position led to contraction value of 0.1511 millivolts during sleeping position, with the average increase in value of 0.11167 millivolts. It is meant that the Eyestrain would be experienced for both position when playing a game with increasing the level of brightness, because the eyes would be forced to adapt. Thus, the optimum brightness leve should be applied, not too dark and not too bright, whether it is in the sitting or the lying down position.

C. Statistical Analysis
As a result (see Fig. 7 and Fig. 8), the level of accommodation to see an object is strongly influenced by the level of exposure of the object's brightness to the lowest brightness and the highest brightness. However, the reason is further strengthened by significant difference between the brightness level of 0% and the brightness level of 50% which has a significant decrease in eye vision value. These results indicate that the difference in normal eye vision conditions with the highest brightness level and the lowest brightness level for sitting position will cause a decrease in the visual acuity of the eye, especially for brightness levels of 0% that leads to a very significant decrease in visual acuity.

As for Fig. 9 founded the same effect on visual acuity between the siiting and lying down position. This result proves that the brightness level of the smartphone in this experiment (0%, 50%, 100%) only affect the respondent's visual acuity, which continue to decline from the normal eye conditions. These results are corroborated by the statement[8] which states that people who are accustomed to reading in a lying down position make the contractions of the eye muscles work harder, because light is usually blocked by books or heads, so that the eyes are not adequately illuminated and thus it can cause the decreasing visual acuity.

While Fig. 10 explaned that that the brightness from the lowest to the highest brightness in the lying down position causes high muscle contraction as compared to those of the sitting position. In spite of no signficant difference for both position on eyestrain among three type of brightness.

CONCLUSION

Evaluation of the relationship between smartphone used in non-immersive VE (war-game strategy) towards cybersickness, such as on eye vision shows thet there are significant differences based on the experiments between normal visual vision and visual acuity at 0% brightness and 100% brightness on both of the respondent's eyes for a sitting position. The posistion of the respondent's eye vision has the same experimental results as that in the sitting position, that is the brightness level of 0% and the level of 100% brightness had a significant effect. Furthermore, a 50% brightness level also affect the visual acuity of the respondent's eyes. The analysis of the reading contractions of the lateral rectus muscle as a reference of eyestrain indicates that the brightness level from the lowest to the highest brightness in the lying down position causes a high muscle contraction as compared to those in the sitting position.

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