Virtual Reality Self Induced Cybersickness: An Exploratory Study

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Abstract. Virtual reality (VR) has been used successfully in several studies, namely in the area of safety warnings design. However, regarding cybersickness, this technology it is not innocuous. We report results concerning cybersickness related with awareness of the secondary effects of VR before doing an experiment. Two groups of participant were found. A group that read the consent form (CF) with attention and a group that did not pay attention to the CF and just signed it. The consent contained information about the experiment and also an alert on the secondary effects of VR. In the VR experiment, participants were asked to accomplish a task in a virtual environment (VE) related with other study. Findings suggest that for those who read the consent form carefully, thus, were more aware about VR side effects, there were more symptoms of cybersickness and more withdraws. These reported results rise some practical and also ethical issues related with VR experiments that are discussed in this paper.

Keywords: Cybersickness · Virtual environment · Virtual reality

1 Introduction

Virtual Reality (VR) is a technology which has the ability to immerse the user in a 3D virtual environment through the use of, among other devices, the head mounted display (HMD) [1]. Extant literature has showed that research regarding safety warnings and emergency situations has already been done using VR [2, 8]. VR offers the possibility of overcoming important research methodological limitations, particularly ethical and safety issues. It also allows systematic manipulation of the environment's features and experimental variables to profit internal validity. However, a threat to the use of this technology are unwanted side effects that can occur. Users may experience some discomfort during or after a VR session [9]. Discomfort can be related with some symptoms such as dizziness, eyestrain, nausea, sweating, among others, which are commonly defined as cybersickness. Symptoms of cybersickness are similar to those of motion sickness and, according Stanney and colleagues [10], they are more serious than the simulator sickness. Although similar, the three types of sickness are caused by exposure to different situations. Simulator sickness happens in aviation simulators, cybersickness

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is related to immersion in VR and motion sickness is relative to daily situations, such as being a passenger in a car, bus, or vehicle in general.

The causes of cybersickness are not fully explained but are supported by three main theories, (i) the poison theory, (ii) the postural instability theory, and (iii) the sensory conflict theory [1]. The first suggests that the discomfort felt in the VE is similar to a poison ingestion, which causes physiological effects involving coordination of the visual, vestibular and other sensory input systems. Thus, a defense of the body acts as a warning and try to remove the toxic substances from the stomach through vomiting [11]. The second states that the individual tends to create tools to maintain a stable posture in the VE. However, due to the constraints of certain environments stable posture can not be maintained and individual remains in a prolonged constant postural instability, it can provoke cybersickness. An example is the motion sickness, which results from prolonged instability in the control of posture [12]. According Riccio and Stoffregen [12], it is related to the behavior and not to the sensorial stimulus. The third, and the most accepted theory, considers that cybersickness can be caused by a conflict between the visual system and the vestibular system. These conflicts arise when the individual expects a kind of stimulus based on their experience but receives different sensory information [1]. For example, the visual system receives information that suggests movement, but the vestibular system informs the individual that he/she is stopped, or that his/her movement is not synchronized with the visual movement [13, 14].

Beyond these theories, several authors relate some factors that increase the likelihood of users developing symptoms, that are individual factors and those associated with device and task. For more details on other factors that cause cybersickness see [9].

Device. One of the main factors associated to device is flicker. Several aspects affect the perception of flicker. Display flicker induces eye fatigue and has been shown to be a factor that causes cybersickness [1, 9, 15]. Flicker is related to contrast, which in turn is related to luminance level. Contrast is the ratio of the highest and lowest luminance provided by the display [16]. Refresh rate is another aspect that influences the perception of flicker, when refresh rate is slow, promotes flicker [16]. Refresh rate is the number of frames per second that a display hardware updates its buffer. Likewise, a wider field-of-view increases the likelihood of flicker perception, since peripheral vision is more sensitive to flicker than the central vision [9, 17].

Task. Individuals who have control in a simulator are less susceptible to motion sickness, likely because it can anticipate future motion and eliminate or reduce a possible cue conflict [9]. Longer exposure to virtual environments also results in incidences of sickness [18]. McCauley and Sharkey [18] also suggest that the same can occur if the tasks in the virtual environment have high linear and rotational acceleration rates.

Individual. Included in the individual factors are gender, age, and experience with the simulator. Women have a larger field of view than men and wide field of view increases the incidence of cybersickness [1, 9, 19, 20]. Children from 2 to 12 years old are more likely to develop symptoms but this decreases rapidly to age 21 and then decreases more slowly. Around 50 is almost non-existent [9, 21]. Increased experience with the simulator leads to a decrease in the incidence of the sickness [9]. Kolasinski [9] says that

individual creates a tolerance to the stimuli that trigger the sickness while learning how to behave in order to avoid the sickness.

This work aim to report some differences in individual factors related with their awareness of the secondary effects of VR at the time of simulation, namely available time to read and be aware of all possible secondary effects of a VR simulation/experiment written in a consent form. The main hypothesis is that subjects who have more time to make the experiment and pay more attention to consent form have a higher probability of get cybersickness symptoms than the ones who had less time to make the experiment and just signed the consent form without a very deep reading of it.

2 Method

2.1 Participants

Participants was volunteers that was participating in a study about compliance with safety warnings using dual task procedures with different levels of cognitive workload. Fifty four volunteers participated in this study. They were 27 male and 27 female within the ages of 17–58 (M = 29.7; SD = 10.6). Six participants dropped out the experience, two male and four female. Therefore, the valid sample was 48 participants within the ages of 17–53 (M = 28.7; SD = 9.7).

2.2 Apparatus

Tasks were performed on a Desktop Station with an Intel® Core™i7 – 4790K CPU processor, 8 GB, NVIDIA GeForce GTX 980 video card. Virtual environment interaction was performed using a gamepad, Head Mounted Display (HMD), model DKII, OCULUS Rift (OLED display, resolution 960 × 1080 per eye, 100° field of view) and wireless PHILIPS earphones, model SHC5102/10.

2.3 Measurements

To assess participant's cybersickness symptoms, the Simulator Sickness Questionnaire (SSQ) [22] was used. This instrument was adapted from the translation into Brazilian Portuguese language made by Carvalho et al. [23] to measure whether there was some kind of discomfort or sickness during the simulation. Participants indicate the level of severity of 16 symptoms on a 4-point scale, where 0 meant "None" and 3 "Severe".

2.4 Procedure

Before start the experimental session and after explaining the purpose of the experiment, participants were asked to sign the consent form and fill the demographic questionnaire. The consent form provided the explanation of the procedure as well as the possibility of risks and discomfort, such as nausea, during the simulation, and stated the feasibility of quit the experience at any time. Participants who may experience vertigo or conditions such as heart disease, depression or pregnancy were excluded. The experimental session was divided into 3 parts: (1) training session; (2) VR simulation session and (3) response to some questionnaires, among them the SSQ. The average total time was 30 min.

3 Results

Six participants dropped out of the test before it ended. Of these, 5 were in the read consent form condition (readers) and 1 in the non-reading consent form (no readers).

Results from SSQ are presented in Table 1 and Fig. 1, for total score, nausea, oculomotor and disorientation scores. These scores were obtained according procedure described by Kennedy et al. [22].

Table 1. Results from SSQ.

	Total score		Nausea		Oculomotor		Disorientation	
CF reading	Yes	No	Yes	No	Yes	No	Yes	No
Mean	25.7	13.8	15.8	8.4	24.1	11.5	28.5	17.9
Median	15	7.5	0	0	15.2	7.6	13.9	13.9
StDev	29.2	16.3	26.6	13	23.5	13.2	36	23.9
p value	0.179		0.598		0.069		0.402	

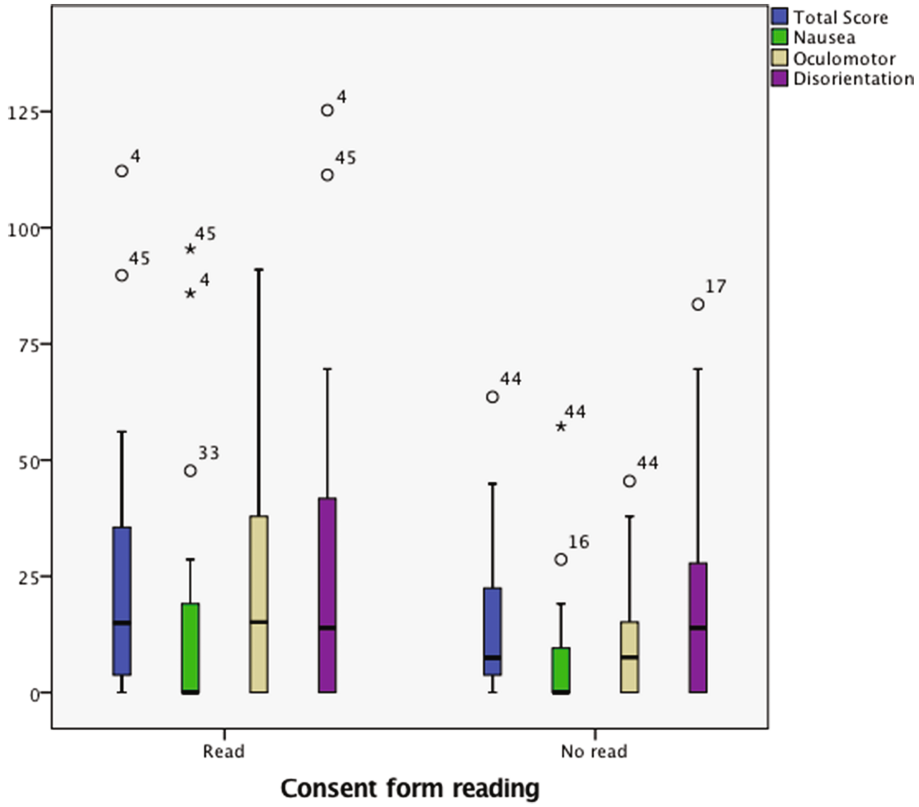

Fig. 1. Box plots for scores of SSQ.

Observation of Table 1, data reveals in the group that read carefully the consent forms (readers), higher average values and more variability of results. The mean of total score for *readers* was 25.7 and for the other group (no readers) 13.8. The values for *readers* in nausea, oculomotor and disorientation was 15.8, 24.1 and 28.5 respectively. The *no readers* group had minor mean values with 8.4, 11.5 and 17.9 respectively for nausea, oculomotor and disorientation scores. Nonetheless higher values for mean scores in the *readers* group, there was not obtained statistically significant differences using a nonparametric test for two independent samples ($p < 0.05$ for all independent tests). Only in the oculomotor score test, a p value near 0.05 was obtained ($p = 0.0069$).

Results for the 16 symptoms evaluated are illustrated in Table 2 and Fig. 2. Table 2 present means and standard deviations obtained from each symptom, as well the p value of a non-parametric test for independent samples. In the 14 of the 16 symptoms averages and standard deviation are higher for *readers* group. Exception is the *blurred vision* symptom in which standard deviation is higher for *no readers*, and *burping* symptom in which mean was higher for *no readers*. This tendency is clearly illustrated in Fig. 2 that shows average values for *readers* and *no readers*. Nonetheless this tendency for higher values for symptoms in the *readers* group, there was only a statistically significant difference in the *fatigue a*nd *sweating* symptoms.

Table 2. SSQ symptoms, mean and standard deviation.

	Readers		NO readers		p value
	Mean	StDev	Mean	StDev	
General discomfort	0.435	0.843	0.080	0.277	0.080
Fatigue	0.739	0.864	0.080	0.277	0.001**
Headache	0.217	0.518	0.120	0.332	0.567
Eyestrain	0.870	0.757	0.560	0.651	0.147
Difficulty focusing	0.435	0.662	0.280	0.458	0.499
Increased salivation	0.217	0.518	0.120	0.332	0.567
Sweating	0.304	0.559	0.040	0.200	0.031*
Nausea	0.304	0.703	0.240	0.523	0.952
Difficulty concentrating	0.130	0.344	0.120	0.332	0.914
Fullness of head	0.435	0.662	0.240	0.436	0.336
Blurred vision	0.348	0.487	0.280	0.678	0.304
Dizziness (eyes open)	0.217	0.518	0.160	0.374	0.848
Dizziness (eyes closed)	0.174	0.388	0.040	0.200	0.133
Vertigo	0.130	0.458	0.040	0.200	0.491
Stomach awareness	0.174	0.388	0.080	0.277	0.331
Burping	0.087	0.288	0.200	0.500	0.429

**sig < 0.005; *sig < 0.05

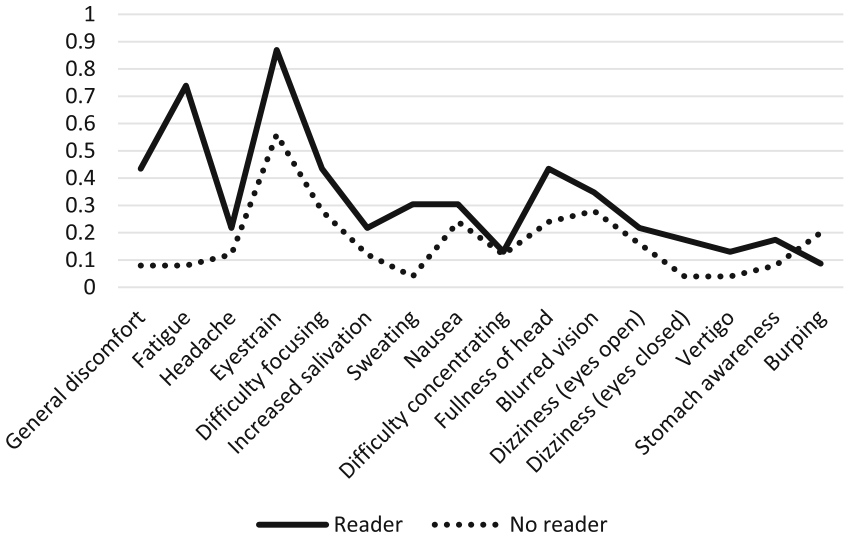

Fig. 2. Scores for SSQ symptoms for *readers* and *no readers* of the consent form.

4 Discussion and Conclusions

Although we do not have statistically significant differences, there is a clear tendency that knowledge of the side effects of VR causes a higher level of symptoms, suggesting in some way a self-induced effect of cybersickness. Significant differences appeared only in the variables fatigue and sweat, which, for Bouchard and colleagues, [24] are associated with anxiety. These authors found the same symptoms in clinical populations that used VR and had anxiety induced to confront feared stimuli. Indeed, it can be assumed that knowledge of possible side effects of VR can generate anxiety and trigger these symptoms. However, this suggestion obtained from these results will have to be confirmed with a larger sample and with a methodological approach developed for this objective.

One of the fundamental rules of ethics in science is the non-deception of subjects; however, as these results seem to point out, the knowledgement of possible adverse effects seems to increase the symptoms of cybersickness. On the one hand this is also unethical, because in this way we are increasing the symptoms so as not to cause non-deception of subjects. To solve this ethical conflict between deception and generate symptoms, one most try to study the individual characteristics better and try to predict, before the experiment, which subjects are most susceptible to cybersickness to start avoiding their inclusion in these samples.

This observation, reported here, began when data from the RV experiments were collected from a state public service (Lisbon Municipality). The coincidence of these participants (n = 5) have more time available for the experience and have read the consent form in detail, and consequently had more cybersickness was the reason for a

more detailed, but still incomplete, analysis of the differences in self induction of cybersicness by knowledge of the side effects of immersion in RV.

In addition to the ethical issues related to the consent form, where participants often lacked the patience to read the information, we encountered other ethical issues in our experiences. It is known that the participant must be informed about the objectives of the study before starting the experiment. However, this procedure is incompatible with the objectives of our tests, where we want to evaluate the behavioral compliance with safety warnings. Knowledge of this objective compromises the effectiveness of this kind of study. In order to not disappoint and motivate the participant, we inform that the objective is the evaluation of a game in VR, that has a history and a goal to fulfill to obtain a reward.

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