Effects of Short Exposure to a Simulation in a Head-Mounted Device and the Individual Differences Issue

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Abstract. Virtual Reality (VR) displays have been developed for years; lots of technological challenges are still remaining to improve presence and hopefully avoid oculomotor trouble, eyestrain and sickness. Although the technology is not mature enough to avoid discomfort, the market already proposes devices to a large public, especially head-mounted devices. Many questions arise: Will customers adapt to those unnatural technologies? Could exposure to those kinds of devices be a public health trouble? Is it safe to drive a real vehicle afterwards? Motion sickness, simulator sickness and cyber sickness in VR are symptoms linked to a wrong (biased) multisensory integration, where visual fluxes and vestibular information are not coherent. As the VR images differ from real world by focus, anamorphic fluxes, image characteristics (rate of flickering, luminance….), vision, balance and oculomotor issues may be involved. Our concerns are focused on short time exposure (less than 10 min) to a VR display. We developed a brief test battery to quickly evaluate 3 dimensions: cognitive style using Rod and Frame Test (RFT), oculomotor modification (AC/A) and balance (vestibular tests). Here we present a pilot study to evaluate the hypothesized influence of a short time exposure to a roller coaster simulation using Oculus Rift DK1™. Participants were tested before and after 3 cycles of roller coaster simulation, they were allowed to freely move head and body. A few number of participants asked to stop the experiment before the third cycle of roller coaster, some of the participants felt a bit uncomfortable after the exposure. Global data analysis showed no significant effect of short time exposure on a series of tests but individual differences remain.

Keywords: Perception · Virtual Reality · Vision · Vestibular · Multisensory integration · Test · Head-mounted display

1 Introduction

Head-mounted devices (HMD) are in the focus of market for a couple of years but they are studied for decades in laboratories [1]. Cybersickness induced by those devices was classified as a sort of Visual Induced Motion Sickness [2]. The main hypothesis proposed to explain this sickness is based on the "sensory conflict theory" of Reason and

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Brand [3], which considers that the sickness is due to the mismatch between sensory information from visual, vestibular and somatosensory systems. If the brain is able to deal with new sensory interaction rules (multisensory reweighting process) [4], those new rules could afterwards produce wrong perception in the real world (disorientation, reminiscence, negative training…). Facing the large diversity of environments inducing this sickness, researchers have mainly used the Simulator Sickness Questionnaire to psychometrically evaluate simulation side effects [5]. In this questionnaire participants have to rate their feelings (dizziness, nausea, cold sweating, disorientation and eye-strain), however those feelings could be biased by motivation and the will to adapt. Subjective evaluation alone may not be enough when security and life span health are at stake. Question is about evaluating synthetic environment effects on multisensory integration without subjective filter. Nalivaiko et al. [6] studied cybersickness provoked by HMD focusing on physiological online reaction. They were also interested about effects on cognitive performance and noticed the lack of publications addressing this issue. Yet, it is of tremendous importance to provide a reliable and fast test battery to objectively evaluate undesirable impacts of synthetic environment on human perception in order to help prevent side effects linked to VR exposure. Here we propose and tested a brief test battery to measure VR exposure effects on basic perceptions.

2 Methods

2.1 Participants

14 volunteers (2 women, mean age = 40.7, range = [22–56]) participated in the study. Participants were instructed not to drive during the 3 h following the experiment. Five participants had already experienced a VR head mounted device before, but only to try. For participants wearing glasses, the head mounted device was adjusted using one of the provided lenses (A, B, C from Oculus Rift DK1).

2.2 Tests Battery

To assess the effect of VR exposure four tests were selected. SSQ focuses on three main effects of VR exposure: nausea, oculomotors and disorientation. We selected our tests to investigate the influence of VR exposure on oculomotors effects, balance (supposed to take part of disorientation) and cognitive style.

Oculomotor tests consisted in measuring the accommodation/vergence ratio (at far & near distances) to evaluate the amount of the oculomotor modification. The participants viewed the Bernell Muscle Imbalance Measure (MIM) card with a Maddox plate in front of their right eye. They had to report the position of the Maddox red rod produced by the flashing spotlight (2 Hz) placed at the center of the MIM card [7]. This heterophoria assessment was done before and after exposure for near (40 cm) and far (3.05 m) viewing distance.

Balance board tests consisted in measuring the balance with a platform of a seesaw (stabilometer, SATEL balance board) when participants were standing upright static or standing on a cylindrical curved base board (pitch: forward/backward or roll: left/right) with their eyes open or closed [8]. Balance ability was assessed using the surface area (in cm^2) of the mass center's movements. In static conditions participants had to stand without moving for 51.2 s, in dynamic conditions they had to stand without moving for 25.6 s.

WOFEC i.e. Walk On Floor Eyes Closed, test consisted in «walking» heel-to-toe steps with eyes closed and arms folded against chest [9] The WOFEC score is calculated on 30 points corresponding to 3 times 10 perfect steps over 5 trials of 10 steps.

Rod-and-Frame test: This test measures the effect of frame orientations on the perception of the vertical subjective. It consisted in putting a rod vertically relative to gravity in a square frame displayed in different orientations to evaluate field dependence/independence considered as the cognitive style [10].

Tests orders were the same for all participants: they first completed oculomotor tests, then balance tests, then the WOFEC and finally the Rod and Frame test. Participants passed all the tests before and started again the series immediately (less than 30 s) after the VR exposure.

2.3 Head-Mounted VR Device

The VR exposure used an Oculus Rift DK1 TM. This device permits to display image over a 110° horizontal field of view, the resolution per eye is 640 × 800 pixels, the refresh rate is at 60 Hz and the persistence around 3 ms. Sensors (Gyroscope, Accelerometer, Magnetometer) are update at 1000 Hz. Three types of lens were provided in order to cope with participant's ametropia. We used a VR software a replica of the Helix roller coaster of Liseberg amusement park created by ArchiVision. The software is free online (Virtualrealityreviewer 2014) [11].

2.4 Exposure Scenario

The VR software scenario was the same for each participant; before the roller coaster simulation sequence started, the avatar was sitting on a sofa with a popcorn box and a drink on the left side and glasses on the right side. At this time, the experimenter invited the participant to move the head around to feel how the head mounted display works. Participants were sitting on a rotating chair. The experimenter asked them to first look at the popcorn box, then at the glasses and to turn themselves to look at a written sentence on the wall behind them. Then, participants were invited to turn the head 45° towards the right hand side to activate a green button which triggers the roller coaster sequence. To enhance the experience a head set was put on the ears of the participant to improve presence sensation with a loud music and sounds of the rollercoaster; the experimenter could keep on talking to the participant but needed to speak louder.

Then, the roller coaster sequence started. During the ride, participants were free to do what they wanted and to comment on their own free will. At the end of the first roller coaster round, the trolley slows down. At this moment, the experimenter checked how the participant was feeling, and invited him/her to turn his head around. The experimenter also asked the participant about the other characters in the trolley in order to improve presence. If the participant was fine, he/she was invited to launch another round. At the end of the 3rd round participant was invited to quit the game.

3 Results

3.1 Oculomotor Results (AC/A)

Results showed no significant differences (Paired T-Test, p = 0.2622) (Fig. 1a). At individuals level pre-post differences were very small (Fig. 1b).

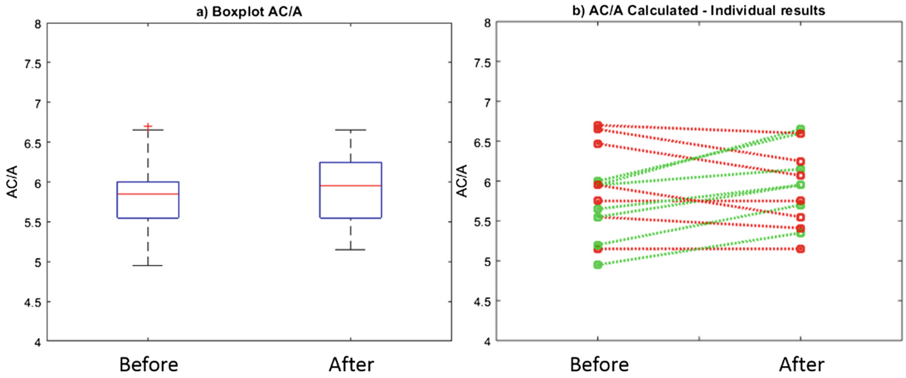

Fig. 1. AC/A Scores. (a) Boxplot before and after exposure. (b) Individual scores before and after exposure, decreasing scores in red, increasing scores in green. (Color figure online)

3.2 Balance Board Tests Results

Due to technical problem for one participant, data analysis was done on 13 participants only.

Differences of surface area between static and dynamic conditions were large (static: 207.38 cm^2; dynamic: 1008.2 cm^2). In static condition (Fig. 2a), mean surface area increased after exposure whether the participants were eyes opened (before: 148.71; after: 233.46) or closed (before: 188.2; after: 259.1). However differences were not significant in the eyes opened condition (paired T-Test p = 0.1185) and only tended to be significant in the eyes closed condition (paired T-Test p = 0.0559). In the pitch condition (Fig. 2b), mean surface area increased after exposure when the participants were eyes opened (before: 271.4; after: 299.7) but not when they were eyes closed (before: 1410.9; after: 1202.6). However, in both cases pre-post differences were not significant (eyes opened: paired T-Test p = 0.5296; eyes closed: paired T-Test p = 0.4787). In the roll condition (Fig. 2c), mean surface slightly decreased after exposure when the participants were eyes opened (before: 634.15; after: 520.15) and slightly increased with eyes closed (before: 1818.4; after: 1908.4). The pre-post differences were significant only in the eyes opened condition (paired T-Test p = 0.0467; eyes closed: paired T-Test p = 0.7318).

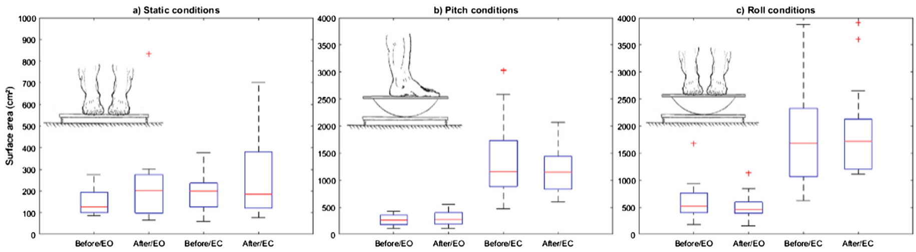

Fig. 2. Surface area boxplot before and after exposure, eyes opened (EO) and eyes closed (EC). (a) standing static, (b) standing on a moving board in pitch rotation, (c) standing on a moving board in roll rotation. Note the scale difference between static and dynamic conditions.

3.3 WOFEC

Pre-post VR exposure differences were not significant (before: 21.61 (SD: 6.4); after: 21.23 (SD: 6.8)). Paired T-test showed no significant difference due to the exposure ($p = 0.7419$) (Fig. 3a).

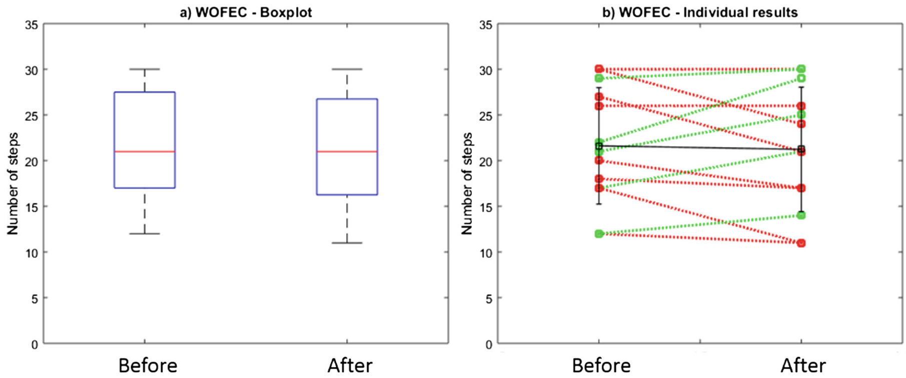

Fig. 3. WOFEC scores. (a) Boxplot before and after exposure. (b) Individual scores before and after exposure, decreasing scores in red, increasing scores in green. (Color figure online)

Looking at individuals scores, two types of participants can be grouped, some improve their scores, others decline (Fig. 3b). The fact that five individuals improved their scores compensates the global decrease of the other participants' scores. It is worth noting that this test is very simple for a non-pathological population. Thus, with repetition effect the scores should have increased for everyone if the exposure had no effect.

3.4 Cognitive Style Results (RFT)

Due to technical problem one participant was not able to perform this task. Data analysis was performed on 13 participants.

Mean results are coherent with literature; vertical subjective estimation varies with frame orientation (Fig. 4). Before VR exposure the main effect of the frame orientation was at ±28°. In contrast, after the exposure the curve is smoother and the largest effect is observed when the frame was tilted at ±18°. After VR exposure, response variability got smaller and frame effect weaker, participants seem to be less sensitive to the orientation of the frame but differences were not statistically significant.

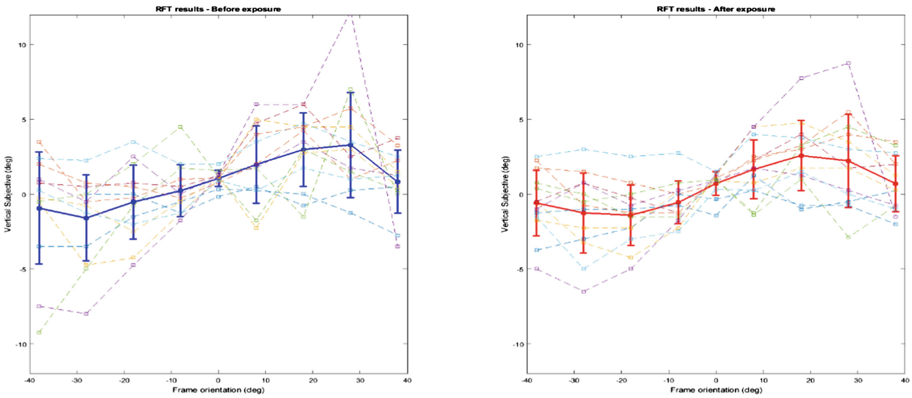

Fig. 4. RFT test results, individual (dash) and mean (plain) data. Vertical subjective estimation varies with frame orientation for tests before and after exposure to VR.

3.5 Behavioral Observations

During the first part of the exposure the participants were invited to move and enjoyed possibilities of HMD. Participants were free to move during the rest of the exposure time. Some participants really enjoyed all the VR exposure, they moved their head and chest (still sitting on the chair) to follow the track, they made noises, they smiled. A part of the participants enjoyed the first round but the good feelings decreased with time and they expressed bad sensations during the remaining exposure. A third part of participants moved the head only when the experimenter invites them to explore around, otherwise they stayed still. Most of the discomforts feelings raised by participants were linked to gastrointestinal sensations (only one felt real nausea), sweat and vertigo during the exposure.

4 Discussion

Our goal was to easily assess the main sensory systems involved in the sensory conflict theory proposed by Reason and Brand. The present tests battery duration is less than 25 min and participants performed all the tests easily. Results showed no large differences due to a 10 min VR rollercoaster simulation exposure using an HMD. It is known that HMD devices produce dissociation between convergence and accommodation [12]; but 10 min exposure seems to have no significant effect on oculomotors parameters tested here. RFT results showed also no significant effect of exposure but it is also a tool to characterize participants and investigate interindividual differences. With more participants we would be able to define field dependency groups and look at score differences to the other tests. We could prefer long duration exposure [13] to reveal stronger effects, but we assumed that subtle consequences could happen as participants already report discomfort within 10 min. In addition our tests are probably biased by learning effects. In the dynamic conditions (roll, eyes opened) the mean surface area and variance significantly decreased after exposure. Standing upright on a moving board is not a common condition; improvement on second run could be due to a learning effect. On the other hand, standing upright on a static plan is quite easy; in those conditions surface area and variance increased after exposure and differences are close to be significant. Increasing score is also found for WOFEC test although this test is probably strongly dependent on learning effect also.

Even though our study does not evidence any significant effect of short VR exposure, the findings indicate several directions of interest. By enlarging our sample of participants, we could link the interindividual differences in the response to multisensory conflict linked to VR exposure with behavioral differences during exposure.

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