VISUALLY INDUCED MOTION SICKNESS DURING COMPUTER GAME PLAYING

C.T. Guo, Chi Wai Tsoi, Yiu Lun Wong, Kwok Chun Yu & R.H.Y. So

Department of Industrial Engineering and Logistics Management, Hong Kong University of Science & Technology, Hong Kong

The objective of this study is to examine the effects of active control verses passive watching on visually induced motion sickness (VIMS) during game playing, as well as the types of eye motions. Two experiments are reported: Experiment one compared sickness levels in active and passive conditions and Experiment two studied the effects of eye fixation during passive watching. Preliminary results show that: (i) rated nausea levels during passive watching were significantly higher than active playing ($p < 0.05$) and (ii) nausea level during passive watching was significantly suppressed by eye fixation ($p < 0.05$).

Introduction

Motion sickness can be characterized by a series of symptoms like nausea, sweating, dizziness, vomiting, etc. Study of motion sickness dated back more than one hundred years ago (Reason, 1978). Levels of motion sickness reported by individuals can be affected by susceptibility, age, gender, type of motion stimulus, frequency of exposure, etc. (e.g., Kennedy *et al.*, 2010; So and Ujike, 2010). Stimulus that can provoke motion sickness, according to the sensory organs being explicitly involved, can be categorized into three types: (i) visual motion, (ii) vestibular motion, and (iii) combined visual and vestibular motions. Motion sickness that is purely provoked by visual motion is called visually induced motion sickness (VIMS). With the development of virtual reality (VR) technique, incidences of VIMS when watching movies, VR simulation or computer games have been reported in recent years. Over eighty percent of individuals exposed to VR simulations of 20 minutes reported increases in sickness symptoms (e.g., Cobb *et al.*, 1999; Kennedy and Stanney, 1998; Wilson *et al.*, 2000). Incidents of VIMS have also been reported among users of various immersive video game systems, such as Xbox, PlayStation, and Wii (e.g., Merhi *et al.*, 2007; Stoffregen *et al.*, 2008). No doubt, the occurrence of VIMS can reduce the joy of entertainment. More importantly, efficiency and accuracy of performance can be reduced in scientific applications of VR technology. Hence, research to study factors affecting VIMS is desirable and meaningful.

Active playing and passive watching

The sensory conflict theory is widely cited as a theory to describe the needed conditions for motion sickness to occur (Reason, 1978). The theory explains that motion sickness is likely to occur when there is conflict among signals coming from different sense organs, or when there is conflict between real and expected forms of these signals. Since the "conflict" as defined in the theory is a neural psychological signal that is difficult to quantify, direct verification of this theory can be difficult. However, its ability to describe situations that can provoke motion sickness has been widely accepted. One such example is that a taxi driver should experience less motion sickness than the passengers. Rolnick and Lubow (1991) reported a "driver" and "passengers" experiment. The drivers executed a planned series of vehicle rotations and the passengers just watched and experienced the motion. Results showed that those who had controls of the rotations reported less symptoms of motion sickness than those who just experienced the motion. Xiao *et al.* (2011) extended the hypothesis to see whether the "control effect" was just limited to physical motion or could be extended to visual motion. One group of subjects drove (the driver) a computer driving simulation game and another group of subjects watched the video (the passenger). Results showed that the influence of control on motion sickness incidence is not limited to vehicle controls. It also applied to the control of virtual environment. Given the importance of eye motion in the generation of VIMS (e.g., Ebenholtz *et al.*, 1994, Ebenholtz, 2001; Hu *et al.*; Ji *et al.*, 2009; Yang *et al.*, 2011; Guo *et al.*, 2011), we hypothesized that eye motions of active and passive gaming is different and this difference could be related to the occurrence of VIMS.

Eye motions and VIMS

The presence of eye motion had been shown to increase VIMS (e.g., Ji *et al.*, 2009; Yang *et al.*, 2011). However, eye motions in these studies were provoked by watching rotating striped patterns on optokinetic drums. Studies related to eye movements and their effects on VIMS during game playing could not be found. g In other words, although eye fixation has been shown to significantly reduce VIMS when watching rotating drums, its effect on VIMS among players of computer games is not known. If, indeed, eye fixation can be verified to reduce VIMS among game players, it would provide a way to design a VIMS-free computer game.

Objectives and hypothesizes

The objectives of the first experiment were: (1) to compare VIMS levels between subjects who were actively playing computer games and subjects who were passively watching recorded videos; (2) to compare eye motions under these two modes of playing; and (3) to study effects of eye motion by using eye fixation on VIMS during active game playing. The objectives of the second experiment were: (1) to study types of eye motion during passive viewing conditions; and (2) to investigate whether eye fixation can reduce VIMS during passive viewing conditions. VIMS levels provoked by passive watching are hypothesized to be higher than those provoked by active game playing (Hypothesis I), and VIMS levels are hypothesized to be reduced by eye fixations (Hypothesis II).

Methods

3 males and 9 female, participated in the first experiment; 3 males and 4 females, participated in Experiment two. All of the subjects were undergraduate students or postgraduate students at the Hong Kong University of Science & Technology. They all signed subject consent forms and passed eye acuity tests before participating the experiment. They received money compensation of 50 HKD/hour. The experiment had been approved by the human subject committee of the Hong Kong University of Science & Technology.

Design of experiment

The video game named Mirror's Edge, developed by EA Digital Illusions CE (DICE) was used in our experiment. Mirror's Edge is a single-player first person action-adventure video game allowing for a wide range of actions. Players enjoy great freedom of movement. In this study, subjects used mouse and keyboard to control the avatar in the game from a first-person perspective. Due to rapid visual motion involved in the game, players have reported incidences of motion sickness (http://forums.steampowered.com/forums/showthread.php?t=1683987). All subjects in experiment one and two did not have experience in the game before training.

Experiment one used a within-subject design with 3 conditions: (A) active game playing with no eye fixation; (B) active game playing with eye fixation; and (C) passive viewing of recorded videos of game playing. Participants rested for at least 7 days between two successive conditions to avoid adaptation. A training session one week before the first condition was conducted to help the participants to be familiar with the game. The 12 participants were equally divided into 2 groups. The video that subjects watched in the passive viewing condition were recorded by another subjects during their active game playing conditions. Procedures were followed to match the game playing styles of these two groups of subjects. In short, the frequencies of pressing keys during the training were recorded to classify participants into "fast" moving players and "slow" moving players. In this study, a "fast" player would watch recording from another "fast" player during the passive viewing conditions. Similarly, "slow" players would watch recordings from another "slow" players during passive viewing conditions. Experiment two also used within subject design with two conditions: (A) passive watching without eye fixation; and (B) passive watching with eye fixation.

Procedure and apparatus

The procedure and apparatus of experiment one and two was the same. The game Mirror's Edge was run in a computer with Windows 7 Enterprise System and a 27-inch LCD monitor 50 cm away from subjects' eyes. During the exposure, all light was turned off except that from the stimulus. Subjects' eye motions were measured by a 16-mm eye tracker VT1 produced by Eye Tech Digital System.

During each session, participants were required to place their heads on a chin-rest stand to minimize head motion (Stoffregen and Smart, 1994). At the beginning, each subject went through the calibration of the eye tracker and fill in a pre-exposure simulator sickness questionnaire (SSQ: Kennedy *et al.*, 1993). Subjects were then exposed to the respective conditions according to a balanced presentation order and with 7-day rest in between. During the 30 minutes exposure, rated levels of nausea were measured using a 7-point nausea rating adopted from Golding and Kerguelen (1992) at every five minutes. Each player's performance in terms of mouse position and keystrokes was recorded by software named Macro Recorder, and their screenshot of playing were recorded in the form of "avi" video by software named PlayClaw. Also, their head positions were recorded by a webcam to verify that their heads did not move. After the 30-minute exposure, all participants were instructed to fill in the post-exposure SSQ.

Results

Pearson correlation test results show that there was significant correlation between the two dependent variables: post SSQ total score (SSQT) and the average 7 point nausea rating across 30 minutes, in both active (*Pearson Corr.*: $0.715, p = 0.009$) and passive conditions (*Pearson Corr.*: $0.812, p = 0.001$).

In Experiment one, the average 7 point nausea rating across 30 minutes in passive watching (mean: 2.2) was significantly higher than active playing (mean: 1.7) ($t = -3.592, p < 0.01$) and the same significant result was found in 8-people sub-group where all subjects' susceptibility rating were equal, or lower than, 3 ($t = -3.173, p < 0.05$, left part of Figure 1); the 7 point nausea rating at 30 minute in passive watching (mean: 3.5) was significantly higher than active playing (mean: 2.7) ($z = -2.232, p < 0.05$, right part of Figure 1), and the same significant result could also be found in low susceptibility sub-group ($z = -2.041$, $p < 0.05$). The average 7 point nausea data were verified to be normal and with equal variance, so the significant results were based on paired t-test, and the 7 point nausea data at 30 minute was non-normal and also failed to apply Box-cox transformation, so the significant results were based on Wilcoxon Signed Rank Tests. For sub-groups with higher sickness susceptibility (>=4), no significant difference between the active and passive conditions was found. By adding eye fixation, neither sub-groups nor the whole group's data showed significant reduction on 7 point nausea rating. For post SSQ scores, no significant result was found.

In Experiment two, the post SSQ sub-scores of nausea (SSQN) was significantly reduced by eye fixation (nfix: 40.4, fix: 27.2, $t = -2.8, p < 0.05$, Figure 2) based on paired t-test result. There was no other significant result between fixation and

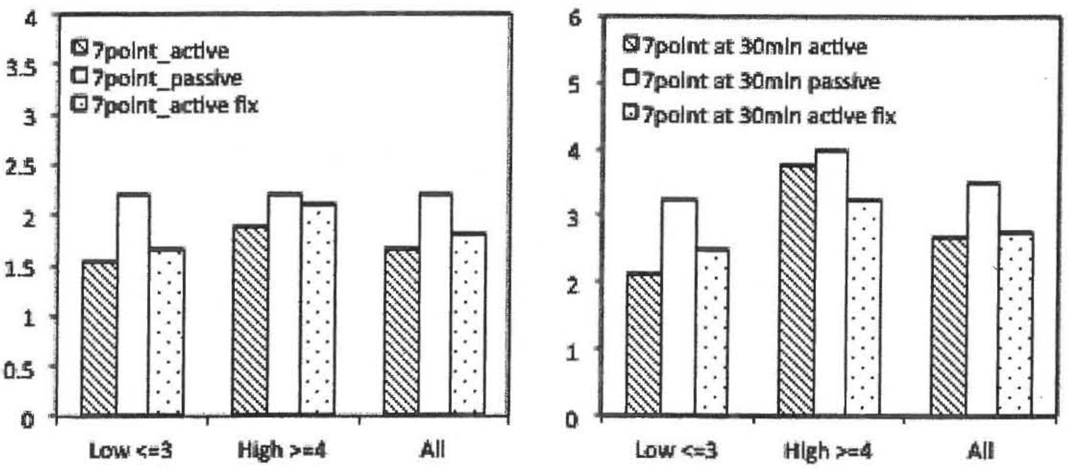

Figure 1. The left figure is the average 7 point nausea data across 30 minutes, and the right figure is the 7 point nausea data at 30 minute.

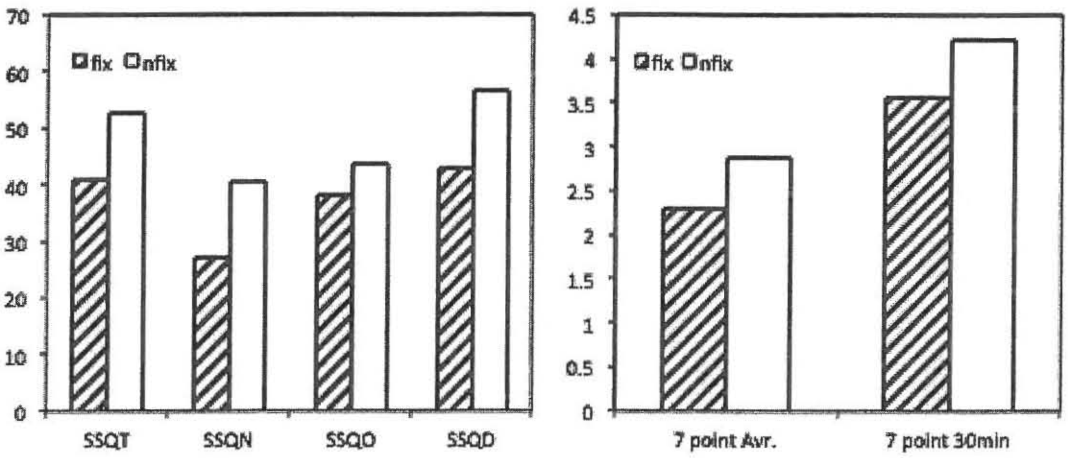

Figure 2. Left part the figure is the average SSQ total score (SSQT), SSQ nausea score (SSQN), SSQ oculomotor score (SSQO) and the SSQ disorientation score (SSQD) of all subjects. The right part of the figure is the average 7 point nausea rating across 30 minutes and the rating at 30 minute of all subjects.

non-fixation conditions. However, a trend could be observed for all the dependent variables that eye fixation did reduce VIMS.

The eye tracker recorded both the left and right eye position in terms of pixels. Base upon the individual calibration data, linear regressions were conducted to obtain the gaze positions in degrees using left and right eye data. Regression results showed that linear model was valid to predict the gaze position, with left eye (x, y) and right (x, y) explained more than 95% of the variance (RSS > 95%).

For Experiment one, overall variance of eye motion during active game playing conditions and passive viewing conditions were statistically the same. We would like to remind the readers that participants did not watch their own recorded videos but videos of another game players with similar playing styles. For the active game playing condition with eye fixation, which was supposed to suppress eye motions, no significant reduction in variance of eye motion was found. This indicated that even with an eye fixation pointer placed at the centre of the screen and with instructions to fixate ones' eyes, it was difficult to fixate ones' eyes while actively playing the game.

For Experiment two, eye fixation significantly reduced eye motion in both horizontal and vertical directions. A Matlab program was run to identify duration of stop ($<=2$ dps), smooth pursuit ($<=40$ dps and >2dps) and saccadic eye motion (>40 dps). On average, 62% of the time, eye motion was categorized as "stop", 37% of the time categorized as "smooth pursuit" and no more than 1% of the time categorized to "saccadic". There was no significant correlation between these durations and sickness level.

In both experiments, there is not significant difference in VIMS score between genders.

Discussion and conclusion

Hypothesis I was supported by the nausea data from sub-group with low motion sickness susceptibility and the whole group. In other words, VIMS levels among participants with low sickness susceptibility were significantly lower when they were actively playing the game than when they were watching recorded videos of the same game. This could be explained by a ceiling effect on participants with high susceptibility, in which subjects already got very sick in the active condition, and even there is still room for them to get higher sickness in the passive condition, the difference between the two cases could be small.

Hypothesis II was supported only by SSQ nausea sub-scores. In other words, eye fixation was only associated with significant reduction in post-exposure nausea sub-scores. Compared with past studies (Ji *et al.*, 2009; Yang *et al.*, 2010; Guo *et al.*, 2011, 2012) in which OKN (optokinetic nystagmus, a type of eye motion produced by large screen moving scene) occurred nearly 100% during the whole 30-minute period when participants were watching rotating drums, OKN period in Experiment two was lower than 40% of the time. Subjects tended to relax their eyes on the screen most of the time. These observations raised a possible relationship between OKN and VIMS. Further studies are desirable.

In summary, the comparison between active and passive condition with more subjects are needs to further verify the hypothesis. Besides, further investigation on eye motion in terms of retinal slip in the passive condition, as well as the types of eye motion needs to be done.

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