

VISUALLY INDUCED MOTION SICKNESS AFTER WATCHING SCENES OSCILLATING AT DIFFERENT FREQUENCIES AND AMPLITUDES

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Background: Viewers reported different vection (an illusion of self-motion) when watching scenes oscillating at similar velocities but at different frequencies and amplitudes. **Hypothesis:** It was hypothesized that different levels of VIMS would be reported after watching scenes oscillating at similar velocity but with different frequencies. **Method:** Ten participants were exposed to a checker board pattern expanding and contracting at five frequencies (0, 0.05, 0.1, 0.2, 0.8Hz). The motions differed in amplitudes but had similar spatial content and r.m.s. velocities. **Results:** Preliminary data indicated that vection reduced significantly as frequency increased but nausea did not change. Velocity, rather than frequency (or amplitude), dominated the provocation of VIMS.

Introduction

Visually induced motion sickness and why it is important?

Prolonged exposure to visual motion with wide field of view could induce illusion of self-motion (referred to as vection). Without corresponding and appropriate physical motion, about 33% of viewers experience vection and suffer the symptoms of motion sickness (So *et al.*, 1999; Lo and So, 2001). This type of motion sickness has been referred to as visually induced motion sickness (VIMS: Bos *et al.*, 2008, 2010; Diels and Howarth, 2011; So and Ujike, 2010). Nowadays, with the availability of low-cost virtual reality displays and wide field-of-view HDTVs, concerns for visual stress associated with exposure to video games have been raised in the International Workshop Agreement 3 on image safety (IWA, 2005). During the workshop, VIMS has been highlighted as

one of the safety issues for video games and more studies to determine the causes of VIMS are urged.

Importance of frequency responses of VIMS

Duh *et al.* (2004) reported a cross-over frequency model for VIMS and predicted that watching visual motion oscillating at about 0.06 Hz would provoke the highest levels of VIMS. In their paper, Duh and his colleagues followed the sensory conflict theory (Reason, 1978) and argued that for self-motion perception, humans are becoming less sensitive to visual motion above 0.06 Hz and physical motion below 0.06 Hz. Consequently, when presented with 'conflicting' visual and physical motion cues at 0.06 Hz, people would be most likely to be confused and experience the highest level of VIMS due to the conflict brought by the greatest mismatch of visual and physical motion under the same frequency. Though it is not the objective of this paper to comment on the validity of Duh's cross-over frequency model for VIMS, it is critical to mention Duh's work, which clearly pointed out the relationship between frequency of scene movement and VIMS. This paper focuses on the measurement of the frequency responses of VIMS to translational visual oscillations.

Motivation for the current study and the hypothesis

A cybersickness dose value (CSDV) has been developed to predict levels of VIMS among 150 viewers of visual motion with a R-Squared greater than 0.8 (Chen *et al.*, 2004; So, 1999; So *et al.*, 2001a; Yuen *et al.*, 2002). CSDV comprises three parameters: (i) the exposure duration, (ii) the spatial complexity of the scenes, and (iii) the r.m.s. velocity of the scene movement. It can be inferred from this CSDV that viewers exposed to scenes oscillating at the same velocity but with different amplitudes (hence, frequencies) will report similar levels of VIMS as long as both the scene complexity and exposure duration were kept the same. However, Chow *et al.* (2007) reported that, when exposed to scenes oscillating at the same velocity but with different amplitudes (hence, frequencies), viewers' vection sensations changed significantly even though the scene complexity and exposure duration were kept the same. Based upon the correlation relationships between vection and VIMS (Ji *et al.*, 2009; So and Lo, 1999; Stern *et al.*, 1990), it was hypothesized that both vection and nausea would be significantly reduced with increasing frequencies of oscillation.

Method and Design

Objectives and hypothesis

The objectives of this study were two-fold: (i) to study the frequency response of vection and VIMS after exposure to a visual stimulus oscillating along the fore-and-aft direction, and (ii) to study how VIMS will change when viewers are exposed to scenes oscillating in different amplitudes (hence, frequencies), but with the same r.m.s. velocity.

As explained in the introduction section, we hypothesized that viewers exposed to visual scenes oscillating at higher frequencies would report higher levels of vection and VIMS.

Independent, dependent, and control variables

Frequency has been chosen as the independent variable. Stimuli at five levels of frequency (i.e., 0, 0.05, 0.1, 0.2, and 0.8 Hz) were displayed to the participants. Feelings of self-motion (vection), nausea, sickness symptoms, and postural sway were taken as the dependent variables. The viewing distance was controlled to be one metre. All participants were screened to have attained 20/20 binocular visual acuity using a vision tester (Model 2000, Stereo Optical CO., INC.). Adaptation effect was also controlled by balancing the presentation order of the conditions and separating each exposure by at least one week.

Design of experiment

The experiment was a single factor (five levels) full factorial within-subject experiment, with the order of presentation of conditions following two 5x5 balanced Latin Squares.

Participants, Stimulus, Apparatus and Procedure

Ten university students, 4 females and 6 males, aged 19 to 24 years' old, participated in the experiment. Their susceptibility was measured using a motion sickness history questionnaire. Each participant was exposed to all five conditions.

Under each condition, participants were required to stand in front of a curved screen (DaMatt, Da-Lite Screen Company, Inc., Indiana). The screen was illuminated by three projectors (NEC LT-380 LCD projectors, refresh rate: 60 Hz) with a field of view of 220° (horizontal) x 56° (vertical). Viewing distance was 1 metre. Edge blending was applied to smooth out the overlapping areas between projections of adjacent projectors.

The visual stimulus was created and rendered frame by frame in 3D Studio Max 6.0. The virtual environment consisted of a long circular tunnel decorated in a black and white checkerboard pattern. A virtual camera was used to capture the view point frame by frame. For each condition, a virtual camera was programmed to move according to the designated sinusoid oscillation waveform. The rendered frames were first processed by our edge blending software and then they were played back at 60 Hz refresh rate (1920 pixels by 480 pixels). Figure 1 illustrates a snapshot of the visual stimulus. The average luminance of the white stripes was 450 lm / m² and luminance of the black stripes was 15 lm / m² (RS 180-7133 light meter, RS Components Ltd., Hong Kong).

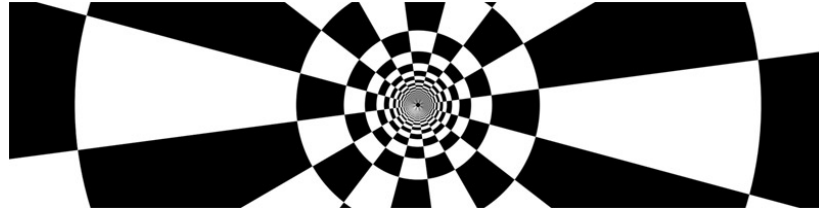


Figure 1: Sample frame of the checkerboard patterned tunnel visual stimulus (adapted from Chow *et al.*, 2007 with permission)

During the 30 minute exposure, participants were asked to look straight ahead at the stimulus with their eyes fixated at the center of the stimulus (normal blinks were allowed). The position and the movements of their eyes and head were recorded. At 5-minute intervals, participants were asked to verbally rate their sensation of vection and nausea respectively. Nausea was measured using a 7-point Likert scale adopted from Golding and Kerguelen (1992). The scale ranged from '0 – no symptom' to '3 – mild nausea' and to '6 – moderate nausea and want to stop'. Vection was also measured using a 7-point Likert scale adopted from Chow (2008) and Webb and Griffin (2003). It ranged from '0 – I perceive that the only thing oscillating is the visual stimulus and I remain stationary', to '2 - I perceive that the visual stimulus to be oscillating but also experience weak feeling of self-motion' to '4 - I perceive that the visual stimulus to be oscillating but also experience strong feeling of self-motion' and to '6 - I perceive that the visual stimulus is stationary, and a strong feeling that I am oscillating'. Before and after the exposure, participants completed a pre-exposure and post-exposure simulator sickness questionnaire (SSQ) adopted from Kennedy and Fowlkes (1993). The experiment was approved by the Human Subject Committee at the Hong Kong University of Science and Technology.

Results

Preliminary data of the first seven participants are reported in this paper. Full results will be presented at the conference.

The vection ratings taken immediately after 30 minutes of exposure are plotted in Figure 2. As the data were not normally distributed, median and inter-quartile ranges are shown. Inspections of the figure indicate that viewers did not report any vection during the 0 Hz condition. This was not surprising as there was no visual motion in this condition. As the visual patterns oscillated, vection reported by viewers reduced as the frequency of oscillation increased. The difference between the vection reported at 0.05 Hz and 0.8 Hz was significant ($p < 0.05$, Wilcoxon signed rank test).

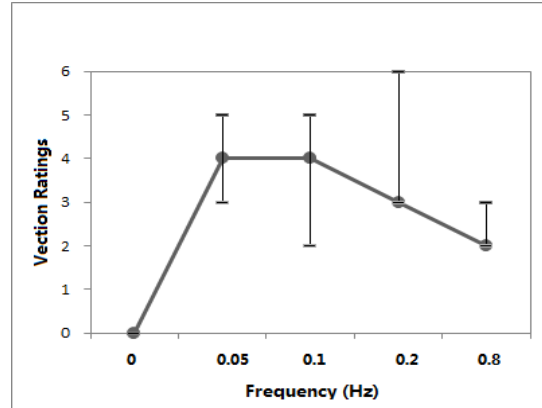


Figure 2: Vection Ratings taken at 30 minutes (median±inter-quartile ranges of the first seven participants)

The median nausea data taken immediately after the 30-minute exposure are plotted in Figure 3. Inspection of the figure show that nausea reported during the 0 Hz condition was near zero (not zero because some viewers did report some slight symptoms). As the visual scene oscillated at frequencies other than 0 Hz, significantly higher nausea ratings were reported ($p < 0.01$, Wilcoxon signed rank tests). However, there was no significant difference in rated nausea ratings collected from all of the four conditions with scene oscillations at frequencies of 0.05, 0.1, 0.2, and 0.8 Hz (Friedman, $p = 0.5$).

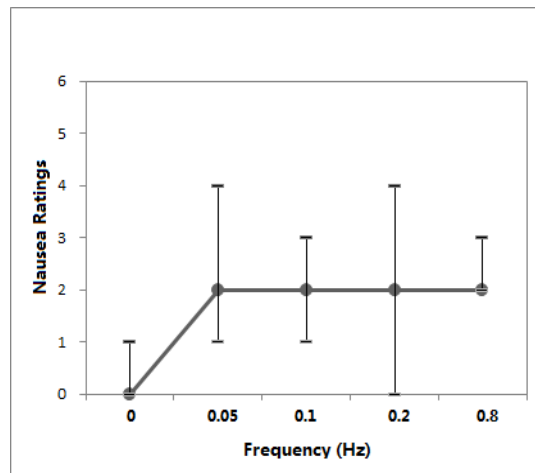


Figure 3: Nausea Ratings taken at 30 minutes (median±inter-quartile ranges of the first seven participants)

Discussion

Vection

In this experiment, vection decreased as frequency increased, confirming the results of previous studies (Chow, 2008; Chow *et al.*, 2007). This confirmation of the vection results is important because our hypothesis relied on significant changes in vection with increasing frequencies.

Motion Sickness

In contrary to our hypothesis, viewers did not report significantly different nausea ratings when exposed to visual oscillations with different frequencies (0.05 Hz to 0.8 Hz). Further analyses indicated that vection and nausea data were not significantly correlated in this study ($p > 0.2$, Spearman).

Although our hypothesis is not supported, it does however confirm the findings of So *et al.* (2001a) that watching moving scenes of similar velocities and complexity would provoke similar levels of VIMS. This finding has important implications on the reporting of frequency responses of VIMS as frequencies can be manipulated with changing velocity (keeping amplitude constant) or changing amplitude (keeping velocity constant).

In this study, watching a checker board pattern expanding and contracting at 0.05, 0.1, 0.2, and 0.8 Hz resulted in significant increases in levels of nausea ($p < 0.001$, Friedman). However, the reported levels of nausea at different frequency conditions were not significantly different. One possible reason is that the r.m.s. velocity was kept the same across conditions of different frequencies. Combining the current results with a past finding that changing navigating velocities through the same virtual environment could significantly change the reported levels of VIMS (So *et al.*, 2001b), we could conclude that velocity of a moving scene is the dominant factor, rather than its temporal frequency and displacement, in terms of provoking VIMS. In other word, velocity determines human perceptions of visual motion, rather than temporal frequency and displacement. With the availability of wide field of view displays at lower costs, more and more video game players will be exposed to VIMS provoking stimuli. Findings of this study can help game developers to identify factors that are more influential to the generation of VIMS.

Limitations, Conclusion, and Future Work

Watching visual oscillations with a wide field of view can cause vection sensation and symptoms of nausea. As the oscillation frequency increased from 0.05 Hz to 0.8 Hz, reported vection reduced significantly but the rated nausea remained similar. The results suggest that the frequency-dependence characteristics of VIMS may vary depending on how the frequency is manipulated. In particular, whether the velocity is kept constant may make a significant difference to the findings. The results of this present study suggest

that velocity of a moving visual stimulus may be the dominating factor affecting its ability to cause VIMS. This paper contains only the preliminary data. The full results will be presented and discussed in the conference.

Acknowledgement

The study was partially supported by the Hong Kong Research Grant Council through GRF 619907 and GRF 620009.

Relevance

Visual oscillations of different frequencies will provoke similar levels of motion sickness when the velocities are kept constant. This is useful for game designers.

References

- Bos, J.E., Bles, W. and Groen, E.L. (2008) A theory on visually induced motion sickness. *Displays*, 29, pp.47-57.
- Bos, J.E., de Vries, S.C., van Emmerik, M.L. and Groen, E.L. (2010) The effect of internal and external fields of view on visually induced motion sickness. *Applied Ergonomics*, 41, pp.516-521.
- Chen, R., Ho, A., Lor, F. and So, R. (2004) *Enhancing the predictive power of cybersickness dose value (CSDV) to include effects of field-of-view and binocular views*. Proceedings of the 7th International Conference on Working With Computing Systems 2004, 29 June to 2 July, KL, Malaysia.
- Chow, E.H.C. (2008) *Postural disturbance and vection when viewing visual stimulus oscillating in roll and fore-and-aft directions: effects of frequency and peak velocity*. Unpublished MPhil thesis. Department of Industrial Engineering and Logistics Management, the Hong Kong University of Science and Technology.
- Chow, E.H.C., Ji J.T.T., So R.H.Y. and Cheung, R.T.F. (2007) *The Effect of Visual Stimulus Oscillation Frequency on Postural Disturbance in Roll and in Fore-and-Aft Direction*. Proceedings of the First International Symposium on Visually Induced Motion Sickness, Fatigue, and Photosensitive Epileptic Seizures (VIMS2007), 10-12 Dec., Hong Kong. pp.165-170.
- Diels, C. and Howarth, P.A. (2011) Visually induced motion sickness: Single-versus dual-axis motion. *Displays*, 32, pp.175-180.
- Duh H.B., Parker D.E., Philips, J.O., Furness, T.A. (2004) *Conflicting" motion cues to the visual and vestibular self-motion systems around 0.06 Hz evoke simulator sickness*, *Human Factors*, 2004, 46 (1), pp.142-153.
- Golding, J. and Kerguelen, M. (1992). *A comparison of the nauseogenic potential of low-frequency vertical versus horizontal linear oscillation*. *Aviation, Space, and Environmental Medicine*, 63, 491-497.

- Ji, T.Y., So, R.H.Y. and Cheung, R.T.F. (2009) *Isolating the Effects of Vection and Optokinetic Nystagmus on Optokinetic Rotation-Induced Motion Sickness*. Human Factors, 51(5), pp.739-751.
- Ji, J.T.T., Lor, F.W.K. and So, R.H.Y. (2004) *Integrating a computational model of optical flow into the cybersickness dose value prediction model*. Proceedings of the 48th annual meeting of the Human Factors and Ergonomics Society, 20-24 September, New Orleans, LA, USA.
- IWA (2005) *ISO International Workshop Agreement-IWA3 Image Safety - reducing the incidence of undesirable biomedical effects caused by visual image sequences*. IWA 3:2005(E). ISO copyright office, Case postale 56, CH-1211 Geneva 20.
- Kennedy, R. S., Lane, N. E., Berbaum, K. S., and Lilienthal, M. J. (1993). *Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness*. The International Journal of Aviation Psychology, 3, 203-220.
- Lo, W.T. and So, R.H.Y., (2001) *Cybersickness in the presence of scene rotational movements along different axes*. Applied Ergonomics, Vol.32, No.1, 2001, pp. 1-14.
- So, R.H.Y. (1999) *The search for a Cybersickness Dose Value*. Proceedings of the 8th International Conference on Human-Computer Interaction. August 22-27, 1999, Munich, Germany.
- So, R.H.Y., Finney, C.M. and Goonetilleke, R.S. (1999) *Motion sickness susceptibility and occurrence in Hong Kong Chinese*. Contemporary Ergonomics 1999, Taylor & Francis.
- So, R.H.Y., Ho, A.T.K. and Lo, W.T. (2001a) *A proposed metric to quantify virtual scene movement for the study of cybersickness: definition, implementation and verification*. PRESENCE, 10, 2001, pp. 193-216.
- So, R.H.Y., Lo, W.T. and Ho, A.T.K., (2001b) *Effects of navigation speed on motion sickness caused by an immersive virtual environment*. Human Factors, 43, 2001, pp.452-461.
- So, R.H.Y. and Lo, W.T. (1999) *Cybersickness: An Experimental Study to Isolate the Effects of Rotational Scene Oscillations*. Proceedings of IEEE Virtual Reality '99 Conference, March 13-17, 1999, Houston, Texas. Published by IEEE Computer Society, pp.237-241.
- So, R.H.Y. and Ujike, H. (2010) *Visually induced motion sickness, visual stress and photosensitive epileptic seizures: what do they have in common? - Preface to the special issue*. Applied Ergonomics, 41(4), pp.491-393.
- Stern, R.M., Hu, S., Anderson, R.N., Leibowitz, H.W. and Koch, K.L. (1990) *The effects of fixation and restricted visual field on vection-induced motion sickness*. Aviat Space Environ Med, 61. pp.712-5.
- Webb, N.A. and Griffin, M.J. (2003) *Eye movements, vection and motion sickness with foveal and peripheral vision*. Aviat Space Environ Med, 74, 622-625.
- Yuen, S.L., Chen, R.W. and So, R.H.Y. (2002) *A progress report on the quest for a cybersickness dose value*. Proc. of 46th HFES Annual Meeting, Baltimore, MD, pp.2189-2192.