The Effects of Visual Stimulus Oscillation Frequency on Postural Disturbance in Roll and in Fore-and-Aft Direction

E. H.C. Chow[1], J.T.T. Ji[1], R.H.Y. So[1] and R.T.F. Cheung[2]

[1]Department of Industrial Engineering and Logistics Management, The Hong Kong University of Science and Technology, Hong Kong, PRC.

[2]Department of Medicine, University of Hong Kong, Hong Kong, PRC.

[1]echow@ust.hk

Keywords: Postural Disturbance, Oscillating Visual Scene.

Abstract. The current study examines the relationship between visual scene oscillation frequency and postural disturbance. Twelve subjects participated in the study, in which postural disturbance due to viewing oscillating visual scene (frequency ranges from 0.1Hz to 1.0Hz) in viewer's roll direction and fore-and-aft direction were measured. Preliminary results on four test subjects indicate that postural disturbance inversely relates to stimulus frequencies in both fore-and-aft and roll directions.

Introduction

Visual motion experiments involving the viewers' roll axis had been performed in numerous past studies. In the linear regime (along the roll axis, or the viewer's fore-and-aft direction), Cunningham (2006) showed in their virtual "swinging room" experiment that moving visual environment in viewer's fore-and-aft direction produced compensating postural response. Other recent "swinging room" experiments studied the relationship between postural sway and visual scene oscillation (in fore-and-aft direction) frequency. Oullier et. al (2002) showed that viewer's ankle angle displacement magnitude decreased as room oscillation frequency increased. In the rotation regime, Van Asten (1998) showed that rotational visual stimulus about viewer's roll axis induce lateral body sway, and is inversely related to scene oscillation frequency. Duh et. al. (2004) also reported similar decreasing relationship between postural disturbance and rotating scene oscillation frequency. They made an interesting comparison of their data (rotational direction) with those on linear self-motion perception by Berthoz's et. al (1974) in (linear fore-and-aft direction), and found a very similar trend between the two.

However, all aforementioned studies had different viewing conditions (namely, field-of-view and viewing distance), display types, and visual contents. To our knowledge, no previous work has looked at the relationship between postural disturbance and visual scene oscillation frequency for both linear and rotational direction within the same study. To this end, the current study attempts to verify the inverse relationship between postural disturbance magnitude and visual scene displacement oscillation frequency in both roll and fore-and-aft directions.

Experiment Design

Objectives: Two experiments were performed to study how postural disturbance relates to scene oscillation frequency. Experiment 1 examined this relation in the roll direction, while Experiment 2 focused on the fore-and-aft direction. It is hypothesized that postural disturbance due to both linear and rotation scene oscillation is inversely related to frequency of scene oscillation.

Variables: The independent variable was the frequency of the sinusoidal oscillating visual scene and the dependent variable was postural disturbance along the anterior-posterior (A-P) and lateral direction. The control variables were the field-of-view (FOV), viewing distance, display type and visual contents (random square star-field patterns).

Apparatus and Stimuli: In both experiments, a white projection screen (Da-Lite® Screen Company, USA) provided a 1.0 neutral gain projection surface for an NEC LT-380 projector (800 x 600 pixels). A head-mounted display was not used because of the potential effects of time delays during head movements (So and Griffin, 1991, 2000; So *et al.*, 1999). Visual stimuli were generated by Microsoft® DirectX® version 9 programming library and Microsoft® Visual Basic 2005 Express Edition on a PC (Intel Core2 2.40GHz CPU, 2GB RAM, NVidia® GeForce 7600GT graphic card). The computer-generated stimuli were displayed via the projector onto the white screen at a FOV of 70º (horizontal) x 52º (vertical). The stimuli consisted of an array of white squares against a dark background scattered in a simulated star-field manner (Figure 1). Five hundred white squares were displayed on the screen. The 500 white square objects were randomly distributed in a three-dimensional virtual space of 65m visible range (with respect to the viewer). This virtual space was programmed in DirectX®. Due to physical space constraint, the projector was placed at a height which provided a projection image with the center raised 10cm above the viewer's eye level.

In Experiment 1, the star-field patterns oscillated linearly along the fore-and-aft axis through the center of projection. To keep spatial content consistent at all time, there were always 500 squares in the virtual space at any given moment during the linear motion; objects disappeared as it went off the screen in the nearest foreground would immediately appear again in the farthest background, and vice versa. Similar oscillating stimulus has been reported to cause linear self-motion perception (Bonato *et. al.*, 2006). Although Bonato and his colleagues used blue squares in their experiment, we employed white squares. Previc et. al. (1992) reported that color does not affect the level of perceived self-motion. The peak oscillation displacement was kept at approximately 12.5m (with respect to the viewer) across all frequency conditions.

In Experiment 2, the star-field rotated about the center of projection display. The rotation followed a pattern of sinusoidal oscillation. Visual content was again kept at 500 white square scattered in the same star-field pattern. Peak oscillation displacement was kept at 70 degree across all frequency conditions. Such displacement magnitude was used in Duh *et. al* (2004) and had been shown to cause significant increases in postural disturbance to the viewers.

In both experiments, subjects stood at one meter away from the projection screen. Subjects viewed the oscillating stimuli while standing in upright posture. Two Polhemus 3-SPACE sensors were attached to the subjects' head and shoulder to record (sampling rate 80Hz) the amount of head and shoulder movements due to postural disturbance. Subjects also wore a goggle that restricted the field-of-view to approximately 70º (horizontal) x 52º (vertical). The purpose of the goggle was to restrict the view of the subjects to only the projected image of the star-field so as to minimize visual distraction from rest of the visual background. Figure 1 illustrates the photograph of a subject viewing the star-field stimulus.

Subjects: Twelve subjects were recruited to participate in the experiment. All subjects reported good health, with no past history of diabetics or epilepsy, and were not under any medical treatment or illness. All participants were paid HKD50/hr, and completed a subject consent form.

Figure 1: A subject viewing the oscillating star-field stimuli.

Methods: In both Experiments 1 and 2, the start-field visual scene oscillated in sinusoidal movement at six different frequencies: 0.1Hz, 0.2Hz, 0.4Hz, 0.6Hz, 0.8Hz and 1.0Hz. The order of presenting oscillating scene of different frequencies was randomized and counterbalanced with Latin square designs to avoid sequential learning effect (Bradley, 1958). Three successive dependent repeated trials were performed for each visual stimulus condition and the date collected were average to obtain better mean estimations. All subjects participated in both Experiments 1 and 2 and a within-subject design was used. A minimum of 24 hours elapsed between the two experiments.

For each trial, all lights in the experimental area were switched off. Subjects were first asked to stand upright, wearing sport socks provided by the experimenter, with their heels pressed together and arms in the pocket (or on their sides if there was no pocket on their clothing). Subjects were asked to fix their lines of sight on a blank screen for 10 seconds while stabilizing their balance (the pre-exposure period). After this, the subjects were asked to remain in the same stance position and were exposed to the appropriate oscillating visual stimulus for 10 seconds (the exposure period). Subjects were instructed not to move their feet and arms throughout the pre-exposure and exposure period. The instruction provided to the subjects during pre-exposure and exposure period was adopted and slightly modified from Stoffregen and Smart (1999).

After visual stimulus exposure, subjects were asked to close their eyes and assume the Sharpened Rhomberg (SR) stance for 30 seconds. SR stance is typically used for static postural test in postural disturbance experiments (Kennedy *et. al.*, 1993; Duh, 2004), which requires the subjects to stand with one foot in front of the other and their arms folded across the chest. Subjects were asked to maintain their balance the best they could during the 30-second SR stance period. These exposure and SR stance periods were repeated three times to obtain better mean estimations of the data.

Before each condition, subjects were also asked to look at a blank screen for 10 seconds, and then assume SR stance for 30 seconds. This provided baseline data of the subject's sway during SR stance without any visual perturbation.

Between each trial, lights in the experiment area were turned back on, and subjects were provided with a chair to rest for at least 4 minutes in order to reduce physical fatigue, eye strain, or nausea effect typically arises from viewing of moving images in VE. The experiment conformed to the requirement of the HKUST University Research Human Subject and and Ethic Committee.

Results

Head position data were analyzed for each condition. For each trial, squared deviations about mean head position were computed in both A-P and lateral direction during the SR stance period. The mean squared deviations of three trials represented the score for that condition (frequency). Each score is normalized by dividing the data with the average SR stance baseline data for that participant. Preliminary results collected from the first four test subjects show that as the oscillating frequencies increase, the deviation scores reduce (See Figure 1 and Figure 2). The full set of results will be presented at the symposium in December. This trend is consistent with the findings of Duh *et al.* (2004) and Berthoz *et al.* (1979). This finding is important when confirmed with the full data set because the results for both the rotating and translating visual motions had been collected from a homogeneous setting for the first time. Future work to integrate this study with previous research on visually induced motion sickness is desirable (Kiryu and So, 2007; Lo and So, 2001; So and Lo, 1999, So *et al.*, 1999, 2001, 2002).

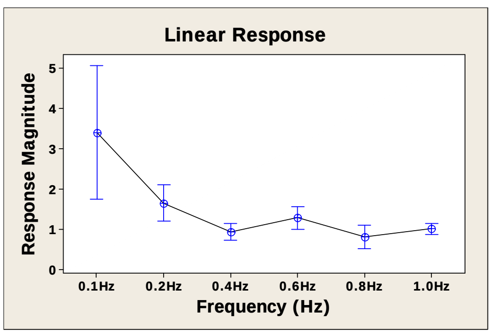

Figure 2: Mean condition score (±1 S.D.) as a function of fore-and-aft scene oscillation frequency (Hz).

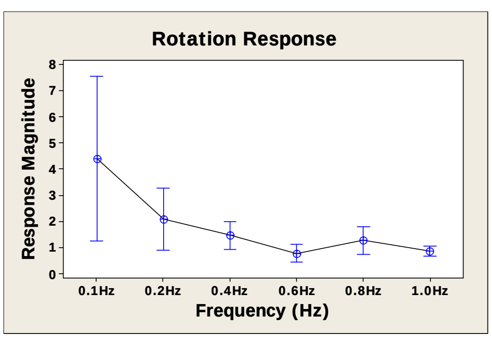

Figure 3: Mean condition score (±1 S.D.) as a function of scene roll oscillation frequency (Hz)

Acknowledgment

This study was partially supported by Hong Kong Research Grants Council through the Earmarked projects HKUST6154/04E, HKUST619706 and DAG05/06.EG20.

References

Berthoz A, Lacour M, Soechting JF, Vidal PP. The role of vision in the control of posture during linear motion. *Prog Brain Res*. 1979,50, pp. 197–209

Bonato, F., Bubka, A., Palmisano, S., Phillip, D., Moreno, G., Vection Change Exacerbates Simulator Sickness in Virtual Environments. (In Press)

Bradley, J. V., Complete counterbalancing of immediate sequential effects in a Latin square design. J. Amer. Statist. Ass., 1958, 53, pp. 525-528

Cunningham, D.W., Nusseck, H., Teufel, H., Wallraven, C. & Bülthoff, H.H., A psychophysical examination of swinging rooms, cylindrical virtual reality setups, and characteristic trajectories. Proceedings of IEEE Virtual Reality, 2006, pp. 111-118

Duh H.B., Parker D.E., Philips, J.O., Furness, T.A., "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

Kennedy, R.S., Stanney, K.M.: Postural instability induced by virtual reality exposure: Development of a certification protocol. International Journal of Human-Computer Interaction, 1996, 8 (1), pp. 25-47.

Kiryu, T. & So, R.H.Y. (2007) Sensation of Presence and Cybersickness in applications of Virtual Reality for Advanced Rehabilitation. Journal of Neuro Engineering and Rehabilitation, 4:34.

Lo, W.T. & 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.

Oullier, O., Bardy, B.G., Stoffregen, T.A. and Bootsma, R.J. Postural coordination in looking and tracking tasks. Human Movement Science, 2002, 21 (2), pp. 147-167

Previc, F. H., Varner, D. C., & Gillingham, K. K. Visual scene effects on the somatogravic illusion. Aviation, Space, and Environmental Medicine, 1992, 63 (12), pp. 1060-4

Stoffregen T A. & Smart L J. (1999) Postural instability precedes motion sickness. Brain Research Bulletin, 47(5), pp. 437-448.

So, R.H.Y., Chung, K.M. & Goonetilleke, R.S. (1999) "Target-directed head movements in a head-coupled virtual environment: predicting the effects of lags using Fitts' law". Human Factors, Vol.41, No.3, 1999, pp. 474-486.

So, R.H.Y., Finney, C.M. & Goonetilleke, R.S. (1999) Motion sickness susceptibility and occurrence in Hong Kong Chinese. Contemporary Ergonomics 1999, Taylor & Francis, pp.88-92.

So, R.H.Y. & Griffin, M.J. (1991) Effects of time delays on head tracking performance and the benefits of lag compensation by image deflection." Proceedings of Flight Simulation Technologies Conference, New Orleans, Louisiana, 12-14 August, 1991, pp.124-130.

So, R.H.Y. & Griffin, M.J. (2000) "Effects of target movement direction cue on head-tracking performance". Ergonomics, Vol.43, No.3, pp. 360-376.

So, R.H.Y., Ho, A.T.K. & Lo, W.T. (2001) A proposed metric to quantify virtual scene movement for the study of cybersickness: definition, implementation and erification". PRESENCE, 10, pp. 193-216.

So, R.H.Y. & 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, Houston, Texas, USA, pp.237-241.

So, R.H.Y., Lo, W.T. & Ho, A.T.K., (2002) Effects of navigation speed on the level of cybersickness caused by an immersive virtual environment. Human Factors, 43, 2002, pp.452-261.

Van Asten W. N. J. C., Gielen C. C. A. M., Denier van der Gon J. J. Postural movements induced by rotations of visuals scenes. J. Opt. Soc. Am. A, 1998, 5 (10), pp. 1781-1789