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Motion in images is essential to cause motion sickness symptoms, but not to increase postural sway

Astrid J.A. Lubeck [a,*], Jelte E. Bos [a,b,1], John F. Stins [a,2]

[a] Research Institute MOVE, Faculty of Human Movement Sciences, VU University Amsterdam, Netherlands
[b] TNO Perceptual and Cognitive Systems, Soesterberg, Netherlands

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ABSTRACT

Objective: It is generally assumed that motion in motion images is responsible for increased postural sway as well as for visually induced motion sickness (VIMS). However, this has not yet been tested. To that end, we studied postural sway and VIMS induced by motion and still images.
Method: 15 Participants were exposed to motion- and still images in separate sessions. Motion images consisted of video clips taken from a first person shooter game. Still images consisted of stills taken every 10 s from these same clips. Before, during, and after exposure, VIMS was rated and postural sway was measured. Sway path length, standard deviation and short- and long-term scaling components of the centre of pressure were calculated as measures of postural sway.
Results: VIMS scores obtained during and after exposure to motion images were significantly higher compared to scores obtained before, and directly after exposure to still images. The sway path length, standard deviation in anteroposterior direction and short-term scaling components in mediolateral and anteroposterior direction increased significantly during exposure to motion and still images.
Conclusion: In this experiment motion- and still images caused different levels of VIMS, but comparable increases in postural sway. We assume VIMS was caused by a mismatch between visual and vestibular motion cues. The increase in sway during exposure to still images can be explained by visual effects present in still images. The lack of vection in the motion images may explain why sway was not larger when viewing these motion images as compared to viewing the still images.

1. Introduction

Motion sickness symptoms may be induced not only by physical motion, as in car-, sea-, or airsickness, but also by watching motion images or dynamic displays [1]. In the latter case, the phenomenon is generally referred to as visually induced motion sickness (VIMS). Also postural control, i.e., "the act of maintaining, achieving or restoring a state of balance during any posture or activity" [2], is known to be affected when exposed to motion images [3–8].

The effect of motion images on VIMS and postural sway characteristics has been studied extensively over the years. During passive viewing conditions, it has repeatedly been found that VIMS and postural sway significantly increased during [5–9] or directly after exposure to motion images [3,9]. However, some studies did report no increase, or even a decrease, in postural sway during exposure to motion images, while VIMS increased [10,11].

Although motion images are known to have the ability to induce VIMS and increase postural sway, both phenomena can also occur when participants are looking at stationary objects [12], or are unaware of the imposed visual motion [13,14]. Regarding exposure to motion images, to the best of our knowledge, no research has directly addressed whether motion in these images is the factor inducing VIMS and increasing postural sway. Therefore, we made a comparison between watching motion images and still images under otherwise equal circumstances.

Two earlier studies did address the effect of motion in images on VIMS and postural sway, however this was not their primary objective [7,8]. Moreover, the exposures were limited to 100 s and the results were contradicting. Freeman et al. [8] found a significant effect of motion on VIMS and postural sway, while Ijsselsteijn et al. [7] only found a small effect of motion on VIMS.

* Corresponding author at: Vrije Universiteit (VU) – Faculty of Human Movement Sciences, Van der Boechorstraat 9, 1081BT Amsterdam, Netherlands. Tel.: +31 20 59 88533.
E-mail addresses: astrid.lubeck@vu.nl (A.J.A. Lubeck), jelte.bos@tno.nl (J.E. Bos), j.f.stins@vu.nl (J.F. Stins).
[1] Address: TNO Perceptual and Cognitive Systems, P. O. Box 23, 3769 ZG, Soesterberg, Netherlands. Tel.: +31 88 86 65925.
[2] Address: Vrije Universiteit (VU) – Faculty of Human Movement Sciences, Van der Boechorstraat 9, 1081BT Amsterdam, Netherlands. Tel.: +31 20 59 88543.

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Thus, whether prolonged exposure to motion in these images is the factor inducing VIMS and increased postural sway still remains uncertain.

In this study we therefore exposed participants to motion images and still images from a first-person view for a prolonged duration (up to 36 min) in otherwise equal circumstances. If motion would be the factor causing both increased VIMS and postural sway we would expect to find a significant increase in VIMS and sway only when exposed to motion images, with still images affecting neither VIMS nor postural sway.

2. Methods

2.1. Participants

Fifteen participants ($N = 15$) voluntarily took part after signing an informed consent form. Participants were PhD students at the Faculty of Human Movement Sciences of the VU University, 6 males and 9 females with a mean age of 29.5 years ($SD = 5.9$ years). This study was approved by the Ethics Committee of the same faculty, in accordance with the Declaration of Helsinki.

2.2. Materials

In two different sessions, participants watched motion images and still images taken from "Mirror's Edge" (EA Sports Inc., Canada), a first-person shooter game showing ample linear and angular motion in all dimensions [15]. The motion images consisted of pre-recorded 12 min episodes with a frame rate of 60 Hz (Supplementary video 1). The still images were taken every 10 s from these motion images (0.1 Hz; Supplementary video 2). We chose for changing the still images every 10 s over showing a single image for the entire duration, because it allowed participants to follow the storyline, that by itself may already affect the level of arousal, which in turn may affect postural control [16]. The images were projected 1.44 m wide and 1.08 m high with a resolution of 1024 × 768 pixels onto a projection screen, viewed while sitting from a distance of 1.2 m, yielding a visual angle of 62 × 24°.

2.3. Measurements

2.3.1. Subjective misery

Prior to the experiment, participants filled out a motion sickness susceptibility questionnaire (MSSQ) [17]. This questionnaire assesses previous occurrences of motion sickness in cars, buses, trains, aircrafts, boats, swings, roundabouts and theme park rides up to the age of 12 and for the last 12 years. MSSQ-ratings range from 0 (no problems whatsoever) tot 222 (severe problems in all situations). A value of 37 corresponds to the 50th percentile of a normal population [18].

During the experiment, VIMS was assessed using the simulator sickness questionnaire (SSQ) [19] and the misery scale (MISC) [18]. VIMS is considered a condition in which not only symptoms of nausea are experienced, but also oculomotor and disorienting symptoms by only viewing visual motion, i.e., while being physically stationary [1,19–21]. Both the SSQ and the MISC assess these symptom clusters [18,19]. The SSQ rates the severity of 16 symptoms on separate 4-point scales from 0 to 3 (none, slight, moderate, severe) [19] and consists of three subscales that represent the distinct symptom clusters of VIMS, labelled nausea (N), oculomotor (O) and disorientation (D). A summation of the three subscales results in a total score (TS) representing overall VIMS.

Due to the assessment of 16 symptoms, the SSQ cannot be administered in a short period of time, and therefore the MISC was also included. The MISC (Table 1) also takes into account the three symptom clusters, but exploits the knowledge that symptoms of nausea are generally preceded by symptoms from the oculomotor and disorientation subscale [18]. The MISC is an 11-point scale ranging from 0 to 10. Absence of symptoms is represented by 0, severity of any VIMS symptom except nausea by 1–5, severity of nausea is represented by 6 and up, and 10 represents vomiting [18]. After participants are familiarized with the scale, its employment only consists of asking for a single number typically taking a few seconds, and can therefore be applied repeatedly.

2.3.2. Postural sway

Centre of Pressure (CoP) time series were collected at 100 Hz using a custom made 1 × 1 m strain gauge force plate with a resolution of 0.28 N/bit. Participants stood barefoot with their arms alongside their torso on the force platform. During each measurement moment first a CoP measurement on a solid surface was conducted, which was followed by a second CoP measurement on foam. Only data obtained during the measurements with eyes closed while standing on the solid platform surface will be reported here. In case of measurements on foam, we observed differences in the distance between the point of application and the force transducers between participants. This difference was not captured, impeding a reliable CoP calculation.

To get a more complete insight into the changes in postural sway, we calculated global properties of postural sway as well as structural or fractal properties from the CoP time series. As global measures of postural sway we calculated (a) sway path length (SPL), defined as the length the CoP travelled over the measurement interval, and (b) the standard deviation (SD) in anteroposterior (AP) and mediolateral (ML) direction. As a structural or fractal measure we calculated (c) scaling components of the differentiated CoP time series, i.e. CoP velocity, for ML and AP directions using a detrended fluctuation analysis (DFA) [22,23]. We made a further distinction between short-range (α_s; 0.2–0.8 s) and long-range (α_L; 1.5–8 s) timescale effects, as reported by Collins and De Luca [24] and Delignières et al. [23]. These scaling components provide insight into the serial correlation properties of the signal [23]. A scaling component above 0.5 represents positively correlated or persistent behavior, meaning that a high velocity (the rate of change of the position) at a certain moment presumably will be followed by more high velocities, and a low (or negative) velocity by more low (or negative) velocities. A scaling component below 0.5 represents the opposite, also referred to as anti-persistent behavior typically to and fro (left to right) CoP displacements [23].

To ignore onset-effects, the first 5 s of all CoP time series were excluded, leaving 55 s of the time series for further analyses. All CoP measures were calculated using Matlab R2011a. In order to calculate the SPL and SD in AP and ML direction, the time series were filtered with a 2nd order low-pass Butterworth filter with a cut-off frequency of 5 Hz.

Scaling components, α_s and α_l were calculated for AP and ML direction separately using raw differentiated CoP time series (CoP velocity). If the differentiated time series can be classified as fractional Gaussian noise (fGn), then the scaling component α is equal to the Hurst (H) exponent [20], $\alpha = \hat{H}$. Based on results of Collins and De Luca [24], who found a mean transition point from persistent to anti-persistent behavior around 1 s, short-range scaling components were calculated over a time scale of 0.2–0.8 s, and long-range components over a time scale of 1.5–8 s. Window sizes ($n = 1000$) were calculated on a logarithmic scale.

2.4. Procedure

Participants took part in two sessions in a counterbalanced order and on separate days with at least one day between sessions.