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published in
Displays
2015

DOI (link to publisher)
10.1016/j.displa.2015.03.001

document version
Publisher's PDF, also known as Version of record

Displays 38 (2015) 55–61

Contents lists available at ScienceDirect

Displays

journal homepage: www.elsevier.com/locate/displa

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

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ARTICLE INFO

Article history:
Received 30 July 2014
Received in revised form 4 March 2015
Accepted 19 March 2015
Available online 26 March 2015

Keywords:
Visually induced motion sickness
Postural sway
Detrended fluctuation analysis
Motion images
Sensory conflict
Vection

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.

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http://dx.doi.org/10.1016/j.displa.2015.03.001
0141-9382/

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.

Table 1
Misery scale (MISC) after Bos et al. [18].

Symptom	Severity	Score
No problems		0
Uneasiness (no typical symptoms)		1
Dizziness, warmth, headache, stomach awareness, sweating, and other symptoms	Vague	2
	Slight	3
	Fairly	4
	Severe	5
Nausea	Slight	6
	Fairly	7
	Severe	8
Retching		9
Vomiting		10

In one session participants were exposed to motion images, and in another session to still images. First, participants were informed about the experimental procedure, were familiarized with the MISC, practiced once the CoP measurements, and signed an informed consent. The introduction was directly followed by baseline measurements consisting of CoP measurements (eyes open and eyes closed), a MISC rate and filling out the SSQ.

The exposure phase was subdivided into three 12 min blocks during which images (motion or still) were presented, while participants sat on a chair, in an otherwise darkened room. Each block was followed by a three minute period in which participants had to report a MISC rate and stepped on to the force plate for a 60 s measurement with their eyes closed. If participants reported to be fairly nauseated or worse while watching the images (MISC rate of 7 or higher), exposure was paused and participants took a three minute rest, after which exposure was again started until the end of the block. Irrespective of these possible interruptions, the duration of the experiment and number of measurement moments was fixed for all participants, i.e. participants took part in a measurement moment before exposure (pre), two measurement moments during exposure (M1 and M2 respectively), and a measurement moment directly after exposure (post). Measurement moments M1 and M2 were included to get a better insight into the time courses of VIMS and postural sway characteristics. After exposure, participants again filled out the SSQ.

2.5. Data analyses

IBM SPSS Statistics 20 was used for the statistical analyses. For the SSQ and MISC data, effects of image type and measurement moment were examined with non-parametric two-tailed Wilcoxon 2-related samples tests. Considering SSQ total score (TS) data, for each image type the pre- and post-measurement moments were compared and for each measurement moment the two image types (motion and still) were compared, resulting in 4 tests. In addition, a between-subject factor (sickness level) was created based on the SSQ TS. First, participants were ranked based on their SSQ TS (obtained directly after exposure to motion images), followed by definition of the median as a cut off. Participants with a score equal or larger than the median were classified as the high-SSQ group ($n = 8$), participants with a score lower than the median were classified as the low-SSQ group ($n = 7$), respectively. We chose this division, because only three participants (all assigned to the high-SSQ group) reported nausea (VIMS $\geqslant 6$) next to other VIMS symptoms, which was not sufficient for statistical analysis. To test whether the SSQ TS values were actually higher after exposure compared to before exposure for the high-SSQ group four Bonferroni corrected ($p = .0125$) non-parametric two-tailed Wilcoxon 2-related samples tests were conducted; the pre-measurement moment was compared to the post-measurement moment for the high- and low-SSQ group and for the still and motion images condition, resulting in four tests. Considering the MISC data, for each image type the measurements during exposure (M1 and M2) and after exposure (post) were compared to the measurement before exposure (pre) and for each measurement moment the two image types (motion and still) were compared, resulting in 10 tests. A Bonferroni correction was applied to correct for the multiple comparisons leading to a significance level of $p = 0.0125$ (SSQ) and $p = 0.005$ (MISC), respectively.

The relationship between the MSSQ, the SSQ and the MISC was also examined in order to test for the predictive validity of the MSSQ and the validity of the MISC. In order to study these relationships, a one-tailed Spearman's correlation was calculated. Positive correlations between these measures were expected; hence a one-tailed test was performed. Only MISC rates and SSQ TS obtained at the post-measurement moment in the motion images session were included, because the scores obtained at baseline were over-represented with 0-scores, while directly after exposure to motion images the largest spread in both SSQ- and MISC scores was observed.

Effects of image type (motion and still images), measurement moment (pre- M1, M2 and post-measurement) and SSQ TS (high and low) on all postural sway measures (SPL, SD, α_s, α_l) were examined with a three-way mixed-design ANOVA. When appropriate, simple contrasts (i.e., differences with respect to the first level) were used to identify where specific differences occurred. Partial eta^2 (η_p^2) was calculated to determine effect size. All variables appeared to meet the assumption of normality as checked with Kolmogorov–Smirnov tests and by visual inspection of boxplots and q–q plots.

3. Results

3.1. Subjective misery

MSSQ scores obtained prior to the experiment ranged from 0 to 101. The 50th percentile in this population was a MSSQ of 41, suggesting that the average susceptibility of this group of participants was comparable to the susceptibility of the general population. One-tailed Spearman's correlations revealed that SSQ TS and MISC rates, obtained directly after exposure, correlated significantly, $r_s = .67$, $p = .003$. Furthermore, significant correlations between the MSSQ and MISC rates and MSSQ and SSQ TS were found, with $r_s = 0.52$, $p = .024$ and $r_s = 0.72$, $p = .001$, respectively.

No significant differences were found on the subscales of the SSQ and so only the total scores will be reported here. Average SSQ TS values are shown in Fig. 1a. After exposure to motion images participants reported significantly higher SSQ TS values compared to before exposure, $Z = 2.81$, $p = .005$, $r = 0.51$, as well as compared to the scores reported after exposure to the still images, $Z = 2.77$, $p = .006$, $r = 0.51$. The SSQ TS did also increase in the still images condition, but this increase was not significant ($p = .046$, notice that the Bonferroni corrected significance level is $p = .0125$). In addition, after exposure to the motion images the high-SSQ group did show a significant increase on the SSQ TS ($Mdn_{pre} = 0$, $Mdn_{post} = 33.66$), $Z = 2.53$, $p = .011$, $r = 0.89$, while no such increase was found for the low-SSQ group ($Mdn_{pre} = 0$, $Mdn_{post} = 3.74$). In the still-images condition SSQ scores after exposure were not different for the low-SSQ group ($Mdn_{pre} = 0$, $Mdn_{post} = 0$) and borderline significant increased for the high-SSQ group ($Mdn_{pre} = 0$, $Mdn_{post} = 7.48$), $Z = 2.05$, $p = .041$, $r = 0.72$ (notice that the Bonferroni corrected significance level is $p = .0125$). For the MISC, similar results were found (Fig. 1b). Participants reported significantly higher MISC rates after the second block of exposure (M2), and after the third block of exposure (post) to motion images compared to pre-exposure, $Z = 2.98$, $p = .003$, $r = 0.77$ and $Z = 2.96$,

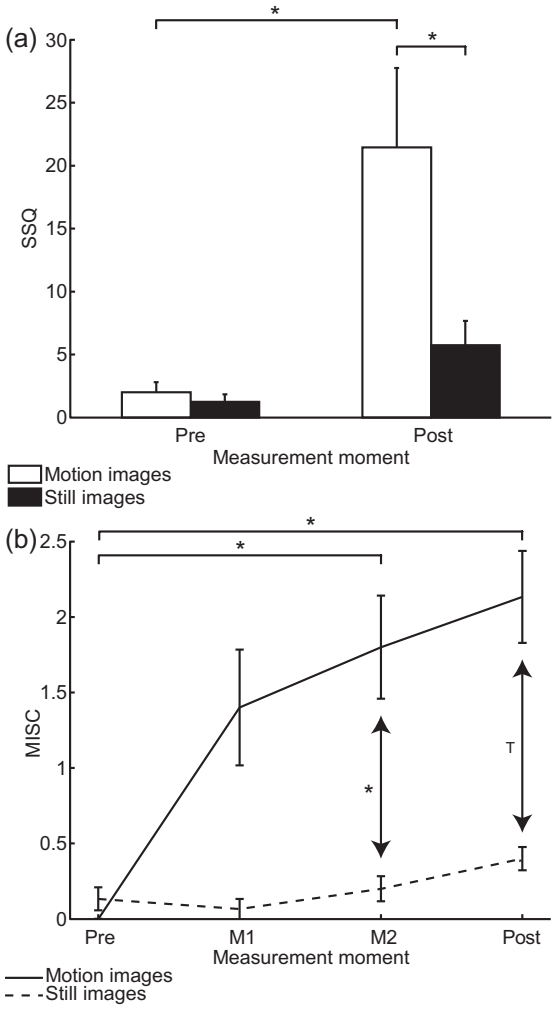

Fig. 1. (a) Mean SSQ (±SE) scores on two measurement moments for still images (black bars) and motion images (white bars). The pre-measurement moment indicates the measurement moment before exposure to images. The post-measurement moment indicates the measurement moment after exposure to images. Note that the *p*-values are Bonferroni corrected. Significant differences at $p < .0125$ are indicated with an *. (b) Mean MISC rates (±SE) for measurement moments and both image types. Data points indicate the mean MISC rates for still images (dotted line) and motion images (solid line). MISC rates at M1 and M2 were obtained during exposure. Note that the *p*-values are Bonferroni corrected. Significant differences at $p < .005$ are indicated with an *. The near significant difference is indicated with a *T*.

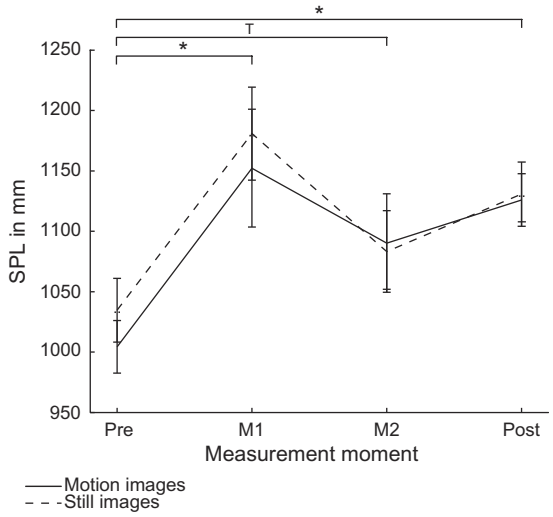

Fig. 2. Mean SPL (mm, ±SE) for all measurement moments, separate for still images (dotted line) and motion images (solid line). The pre-measurement moment indicates the measurement moment before exposure to images. Data points at M1 and M2 were obtained during exposure. The post-measurement moment indicates the measurement moment after exposure to images. Significant simple contrasts for measurement moments at $p < .05$ are indicated with an *. The near significant contrast is indicated with a *T*.

$p = .003$, $r = 0.76$ respectively. In the still images condition MISC rates were increased after exposure compared to before, but this increase was not significant, $Z = 1.63$, $p = .102$. MISC rates given at M2 and the post-measurement in the motion images condition were also (near) significantly higher compared to the still images condition, $Z = 3.02$, $p = .003$, $r = 0.78$ and $Z = 2.70$, $p = .007$, $r = 0.69$.

3.2. Postural sway

3.2.1. Global measures of postural sway

The time courses of the SPL and SD in AP and ML direction are depicted in Figs. 2 and 3, respectively. The division into a high- and low SSQ TS did not yield a significant main, or interaction effect in any of these postural sway measures. Therefore, we present all postural sway measures for the high- and low SSQ TS groups together. Image type did not result in significant differences in SPL's or SD's in both directions. There was a significant main effect of measurement moment on SPL, $F(3, 39) = 6.91$, $p = 0.001$, $\eta_p^2 = 0.347$. Simple contrasts revealed that the SPL was significantly higher directly after the first block of exposure (M1) compared to before exposure, $F(1, 13) = 29.11$, $p = .000122$, $\eta_p^2 = .691$, and remained (near) significantly elevated after the second and third block of exposure with $F(1, 13) = 4.07$, $p = .065$, $\eta_p^2 = .239$ and $F(1, 13) = 7.49$, $p = .017$, $\eta_p^2 = .365$, respectively.

Also, a main effect of measurement moment on the SD in AP direction was found, $F(3, 39) = 3.69$, $p = .020$, $\eta_p^2 = 0.221$ (Fig. 3a). Simple contrasts showed that the SD in AP direction was significantly increased after all blocks with exposure compared to before exposure, with $F(1, 13) = 7.20$, $p = .019$, $\eta_p^2 = .356$, $F(1, 13) = 8.66$, $p = .011$, $\eta_p^2 = .40$ and $F(1, 14) = 6.58$, $p = .024$, $\eta_p^2 = .336$, for M1, M2 and the post measurement, respectively. The SD in ML direction was during and after exposure not different from pre-exposure (Fig. 3b).

3.2.2. Structural measure of postural sway

All differentiated CoP time series were classified as fGn with a scaling component between 0 and 1, showing that the scaling components are equal to the Hurst exponent [20]. The short-range scaling components, α_s-AP and α_s-ML, were above 0.5 and lower than 1, implying persistent postural behavior. For long-range scaling components, α_l-AP and α_l-ML, values below 0.5 were found, indicating anti-persistent behavior. The division into a high- and low-SSQ TS did not yield a significant main, or interaction effect in any of the scaling components. Therefore, results for the scaling components are presented for the high- and low SSQ groups together. For image type no significant effects were found. Both α_s-AP and α_s-ML were significantly affected by the measurement moment, $F(3, 39) = 4.70$, $p = .007$, $\eta_p^2 = .27$ and $F(2.19, 28.47) = 7.36$, $p = .002$, $\eta_p^2 = .362$, respectively (Fig. 4a and b). Simple contrasts revealed that α_s-AP was significantly increased after the first and third block of exposure compared to before exposure, $F(1, 13) = 12.88$, $p = .003$, $\eta_p^2 = .50$, and $F(1, 13) = 6.39$, $p = .025$, $\eta_p^2 = .329$ respectively. Also the α_s-ML was significantly increased as a result of exposure to the images. The α_s-ML was significantly increased after the first and third block of exposure with $F(1, 13) = 24.36$, $p = .000184$, $\eta_p^2 = .652$ and $F(1, 13) = 7.77$, $p = .015$, $\eta_p^2 = .374$, respectively. For the long-term scaling components, α_l-AP and α_l-ML, neither image type, nor the division into a

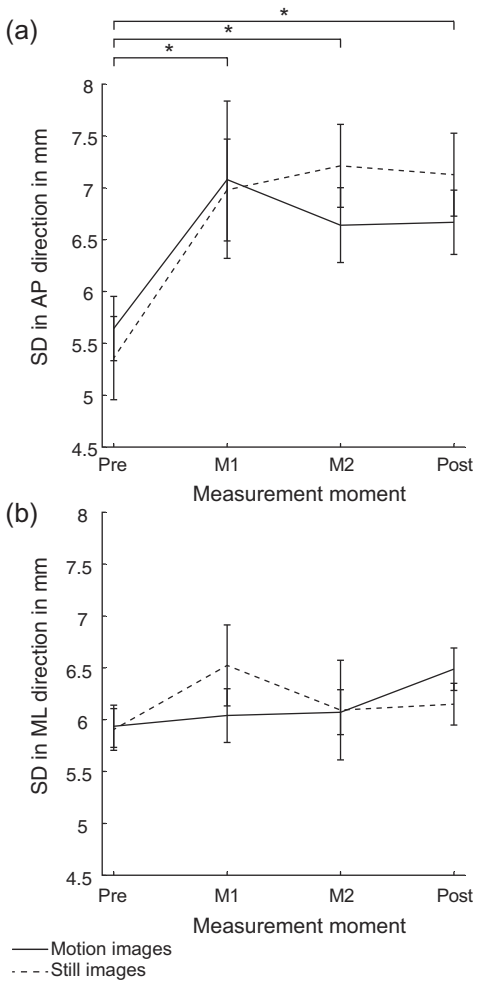

Fig. 3. Mean SD (mm, ±SE) in (a) AP direction and (b) ML direction for all measurement moments, separate for still images (dotted line) and motion images (solid line). The pre-measurement moment indicates the measurement moment before exposure to images. Data points at M1 and M2 were obtained during exposure. The post-measurement moment indicates the measurement moment after exposure to images. Significant simple contrasts for measurement moments at $p < .05$ are indicated with an *.

high- and low-SSQ TS group, nor measurement moment had a significant effect (Fig. 4c and d).

To sum up, all postural sway measures consistently showed that postural control was equally affected by watching a sequence of still images as by watching motion images, irrespective of the experienced VIMS severity.

4. Discussion

In this study we examined the effect of motion in images on visually induced motion sickness and postural control, explicitly including a condition with comparable images without motion. We hypothesized that visual motion would be necessary to cause an increase in subjective reports of VIMS and in postural sway. In addition, the relationship between the MSSQ, SSQ and MISC was examined in order to gain better insight in the relationship between these outcome measures and their (predictive) validity.

The MSSQ, rating motion sickness susceptibility observed in the past, significantly correlated with both the total SSQ scores and MISC rates obtained after exposure to motion images. Therefore, the MSSQ has good predictive validity for the subjective report of VIMS symptoms during exposure to motion images. Also, total SSQ scores and MISC rates obtained after exposure to motion images were highly correlated. It therefore seems that a single MISC score reflects VIMS as measured with the SSQ, and so can be used to measure VIMS, at least in conditions as reported in this experiment.

VIMS provoked by motion images has been studied extensively before; however, the perhaps obvious control condition with still images has not yet been studied so far. In line with our hypotheses, significantly worsening symptoms were reported during and after exposure to motion images as (1) compared to scores reported before exposure and (2) to scores reported during and after exposure to still images. We therefore argue that motion in these images is essential for the occurrence of VIMS and that the nomenclature thereof is appropriate for the phenomenon at issue.

The occurrence of VIMS after exposure to motion images can be explained with the sensory conflict theory [25–27]. According to this theory, motion sickness arises when there is a conflict between sensory signals – originating from the visual, vestibular and proprioceptive systems – and/or the anticipated sensory signals [25–28]. In case of exposure to motion images while sitting or standing still, the visual system registers motion that may be interpreted as self-motion, whereas the vestibular system registers no such self-motion. This discrepancy between visual and vestibular input causes a sensory mismatch that is believed to provoke sickness [27,28]. Such a mismatch was not present while watching still images, thus also not causing VIMS as has been observed here too.

In contrast to VIMS, motion- and still images induced comparable amounts of postural sway. We therefore conclude that visual motion affects VIMS different from the way it affects postural sway. This conclusion is supported by the observation that both global (SPL, SD) and structural (scaling components) parameters of postural sway were equally affected. The SPL showed that participants swayed more and the SD revealed that participants swayed further to the front and back. The increased short-range scaling components revealed that postural sway became more persistent during exposure to both motion and still images, i.e. when exposed to either motion or still images, it became more likely that the CoP velocity continued into the same direction with increasing speed in the future as it did in the past on a short time scale (0.2–0.8 s). Concluding, it seems that the a-specific act of watching images (irrespective still or in motion) may already affect postural control.

Two explanations may account for the increase in postural sway after exposure to both still- and motion images. First, the game Mirror's Edge is known for its multiple full-screen effects and multiple depth structures that were added as an attempt to improve the sensation of self-motion [15]. Several of these features are also present in the still images, possibly causing the comparable increase in postural sway. More research has to be done on the consequences of the full-screen effects, as used in this game, in order to draw firm conclusions on cause and effect.

Second, also a lack of sustained, oscillating or unidirectional (typically low frequency) flow in the whole visual scene may explain why no difference between the motion- or still images condition has been found on any of the considered postural sway characteristics. Vection, a visually-induced illusion of self-motion, occurs when exposed to sustained, oscillating or unidirectional flow in the whole visual scene [29,30]. Several experiments have shown that such vection inducing patterns can influence postural sway [29,31,32]. Although vection was not measured in this study, the nature of movement of the visual scene does provide information about the vection inducing capacity. In the game Mirror's Edge, from which the images were taken, movement of the visual scene is multidirectional and often high-frequency with a great deal of changes in both direction and frequency. Due to these characteristics it does not contain many prolonged periods with

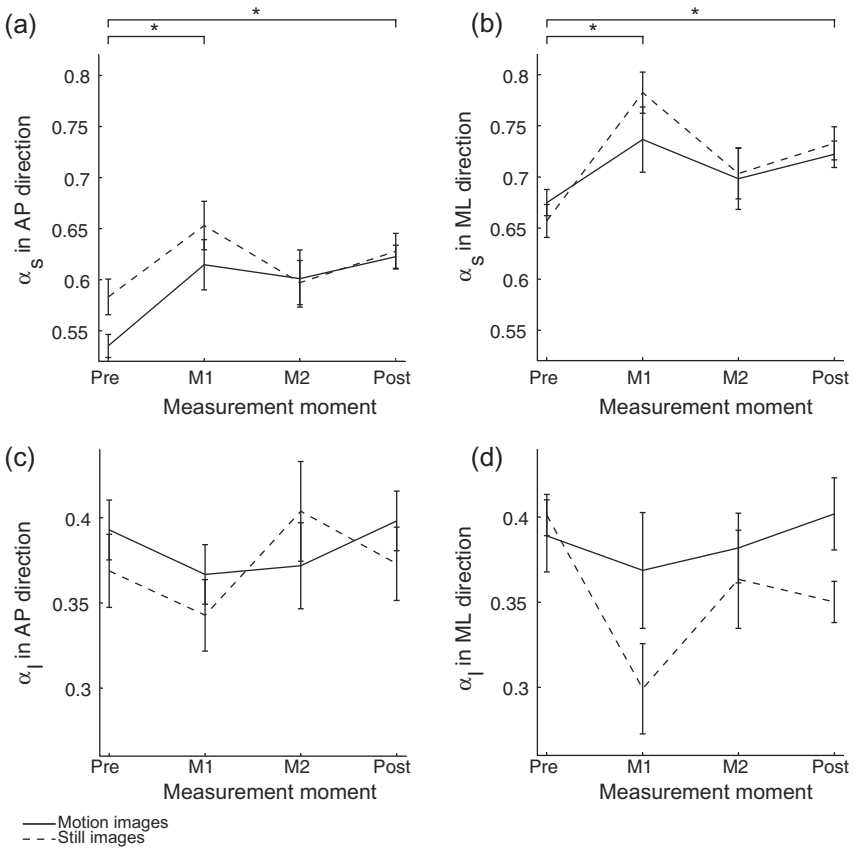

Fig. 4. (a) Mean(±SE) α_s in AP direction, (b) α_s in ML direction, (c) α_l in AP direction and (d) α_l in ML direction for all measurement moments, separate for still images (dotted line) and motion images (solid line). The pre-measurement moment indicates the measurement moment before exposure to images. Data points at M1 and M2 were obtained during exposure. The post-measurement moment indicates the measurement moment after exposure to images. Significant simple contrasts for measurement moments at $p < .05$ are indicated with an *.

unidirectional or oscillating flow. It can therefore be assumed that these characteristics of the optic flow in the motion images will have resulted in only a limited amount of vection which in turn led to a comparable increase in postural sway after exposure to motion and still images.

The measurement moments during the exposure phase gave insight into the time courses of VIMS and postural sway. VIMS, as measured with the MISC, showed a continuing increase lasting longer than the first 15 min in the motion images condition. In contrast to VIMS, postural sway showed only an increase after the first 15-min block of exposure to motion- and still images, and did not increase any further after the following exposure blocks. These findings could imply that postural sway is a predictor for VIMS, as has been suggested in the literature (see, e.g. [5,10,33,34]). Our data, however, suggest this cannot be true in general, for the current data show that still images may also cause increased postural sway, not being accompanied by a significant increase in VIMS.

Finally, we did not find a difference between the high- and low SSQ groups on any of the postural sway measures. However, numerous studies have reported differences on several postural sway measures before onset of nausea [5,10,12,14,33,34]. Two possible differences between these studies and this study may account for the distinction. First, we measured postural sway with eyes closed before and after blocks of exposure and not during exposure with eyes open. Second, because only three participants reported nausea (i.e. a MISC rate > 6) we divided participants based on their SSQ TS into a high- and low SSQ TS group. This division may have masked a possible difference between nauseated and well participants as reported in previous studies.

Summarizing, we conclude that motion in images seems not to be necessary to cause an increase in postural sway, while it is essential for the occurrence of VIMS. Stated differently, we can be moved by still images, but only experience VIMS from motion images.

Acknowledgements

This study is part of the PhD project titled “Standing Well” and is financed by the Netherlands Organisation for Scientific Research (NWO; No. 406-11-020). The Netherlands Organisation for Scientific Research had no involvement in any part of the study.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.displa.2015.03.001.

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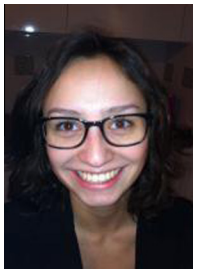

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