Applied Ergonomics 45 (2014) 521–527

Contents lists available at ScienceDirect

Applied Ergonomics

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

Pleasant music as a countermeasure against visually induced motion sickness

Behrang Keshavarz [a,b,*], Heiko Hecht [a]

[a] Johannes Gutenberg-University Mainz, Psychological Institute, Department of General and Experimental Psychology, Wallstrasse 3, 55099 Mainz, Germany
[b] Toronto Rehabilitation Institute, Department of Research, Technology Team/iDAPT, 550 University Avenue, Toronto, ON M5G 2A2, Canada

ARTICLE INFO

Article history:
Received 24 January 2013
Accepted 20 July 2013

Keywords:
Visually induced motion sickness
Music
Countermeasures
Motion sickness
Simulator sickness

ABSTRACT

Visually induced motion sickness (VIMS) is a well-known side-effect in virtual environments or simulators. However, effective behavioral countermeasures against VIMS are still sparse. In this study, we tested whether music can reduce the severity of VIMS. Ninety-three volunteers were immersed in an approximately 14-minute-long video taken during a bicycle ride. Participants were randomly assigned to one of four experimental groups, either including relaxing music, neutral music, stressful music, or no music. Sickness scores were collected using the Fast Motion Sickness Scale and the Simulator Sickness Questionnaire. Results showed an overall trend for relaxing music to reduce the severity of VIMS. When factoring in the subjective pleasantness of the music, a significant reduction of VIMS occurred only when the presented music was perceived as pleasant, regardless of the music type. In addition, we found a gender effect with women reporting more sickness than men. We assume that the presentation of pleasant music can be an effective, low-cost, and easy-to-administer method to reduce VIMS.

1. Introduction

Motion sickness is a well-known phenomenon not only when traveling, but also in virtual environments. In the latter case, motion sickness typically occurs in the absence of real physical motion, thus, motion sickness in simulators, cinemas, video-games, or virtual reality is usually referred to as being visually induced. Typical symptoms during an acute phase of visually induced motion sickness[1] include, but are not limited to, pallor, cold sweat, dizziness, disorientation, fatigue, or nausea.

The genesis of VIMS is not fully understood. Arguably the most prominent explanation for VIMS is described by the sensory conflict theory (Reason, 1978; Oman, 1990). Following this approach, a mismatch between or within the visual, vestibular, and/or the proprioceptive system is the origin of VIMS. For instance, users of fixed-base driving or flight simulators frequently experience the illusion of self-motion—so-called vection (see Hettinger, 2002; for an overview)—although they remain physically unmoved. Thus, the signals delivered by the visual system (indicating vection) and the vestibular organs (indicating the observer's veridical, stationary position) are at variance with each other. If this visual-vestibular mismatch is unfamiliar to the user VIMS might occur as a potential side-effect. Note that for good reasons, the sensory conflict theory has been discussed controversially over the past years. Alternative approaches include the sensed vertical hypothesis (Bles et al., 1998), the postural instability hypothesis (Riccio and Stoffregen, 1991), or the eye-movement theory (Ebenholtz, 1992). Unfortunately, none of these theories is capable of explaining all nuances of the multi-faceted nature of VIMS, hence, the precise genesis of VIMS still remains ambiguous.

Despite the lack of a profound theory, several countermeasures against motion sickness and VIMS do exist. A variety of drugs have been tested over the past years (for an overview see Sherman, 2002; Shupak and Gordon, 2006), and two drug classes have gained special popularity, namely antihistamines and anticholinergics (Hoyt et al., 2009). Antihistamines (e.g. meclozine, cyclizine, or promethazine) are designed to inhibit histaminergic H-receptors and might affect the H1-receptors in the vestibular nuclei (Golding, 2006). In contrast, the purpose of anticholinergic substances is to block muscarinic receptors in the brain and to subdue the input from the vestibular organs to the vestibular nuclei. Currently, scopolamine is probably the most common anticholinergic medication used against motion sickness (Murray, 1997; Sherman, 2002). Although medical drugs can reliably reduce motion sickness, serious temporary side-effects – such as drowsiness, fatigue,

* Corresponding author. Toronto Rehabilitation Institute, Department of Research, Technology Team/iDAPT, 550 University Avenue, Toronto, ON M5G 2A2, Canada. Tel.: +1 416 597 3422x7846; fax: +1 416 597 3027.
E-mail addresses: behrang.keshavarz@uhn.ca, behrang.keshavarz@uni-mainz.de (B. Keshavarz), hecht@uni-mainz.de (H. Hecht).

[1] Visually induced motion sickness, VIMS.

0003-6870/$ – see front matter
http://dx.doi.org/10.1016/j.apergo.2013.07.009

or cognitive impairment – frequently occur and pose a serious limit to the application of anti-motion sickness drugs. Note that most drugs have been designed to ease classical, travel-related motion sickness. It remains uncertain whether such drugs can also be assessed to successfully diminish VIMS. For instance, Furman and Marcus (2009) showed that rizatriptan—a tryptamine-based drug used to treat migraine—can reduce classical motion sickness but is less effective in preventing VIMS.

Additionally, several behavioral techniques have been introduced in the past to counteract both motion sickness and VIMS. The most efficient method to prevent VIMS is adaptation or habituation, respectively. VIMS typically subsides in most people with repeated exposure to the same nauseating stimuli (Cowings and Toscano, 2000; Young et al., 2003; Cheung and Hofer, 2005). Although some behavioral techniques have delivered promising results, they come at a price or may be impractical in many situations. For instance, adaptation to VIMS is very time-consuming and cost-intensive, hence, it is not the method of choice in many cases.

Yen Pik Sang et al. (2003a) highlighted the role of music as a potential countermeasure against classical motion sickness that does not have the disadvantages outlined above. The authors asked their participants to perform head movements in off-vertical directions during full-body rotation along the earth-vertical yaw-axis. This procedure typically causes Coriolis effects and is known to be highly nauseating. Relaxing background music turned out to significantly prolong the onset time of motion sickness compared to a control group that did not listen to music. However, several questions were left unanswered. The authors used physical movement to create motion sickness, but did not focus on VIMS. Also, the music was only introduced after the onset of sickness symptoms. This could have been later than optimal, as motion sickness can rapidly increase once the first signs appear. Furthermore, the authors analyzed the onset delay of MS rather than its magnitude. Finally, the effect of several types of music and the relation between the music's pleasantness and its effect on VIMS has not been addressed.

Thus, the aim of the present study was to determine the effectiveness of different music types as suitable countermeasures against VIMS. We exposed our participants to a nauseating video of a bicycle ride and either added relaxing (instrumental music), neutral (mainstream pop music), or stressful music (fast speed electronic music). A control group received no music. We assumed that relaxing music would effectively reduce the severity of VIMS compared to stressful or no music. Additionally, gender was added as further factor as previous research showed higher VIMS-reports for women compared to men (Flanagan et al., 2005; Klosterhalfen et al., 2005).

2. Methods

2.1. Participants

All participants gave written consent to their participation prior to the experiment and assured to be in a normal state of health. Two participants were eliminated from data analyses due to severely increased sickness scores prior to the beginning of the testing (measured by the simulator sickness questionnaire, SSQ; Kennedy et al., 1993). Thus, 50 female ($M_{age} = 24.16$, $SD_{age} = 4.40$) and 43 male ($M_{age} = 25.72$, $SD_{age} = 5.17$) young adults were randomly assigned to one of the four experimental groups (see also Table 3). All subjects had normal or corrected-to-normal vision and were naïve with respect to the purpose of the study. The stimuli were administered in accordance with the Declaration of Helsinki to ensure research ethics in human experimentation. Participants were free to abort the experiment at any time without negative consequences and were rewarded with partial course credit. Twenty participants (4 in the relaxing group, 4 in the neutral group, 5 in the stressful group, and 7 in the control group) chose to abort the experiment prior to stimulus offset due to severe sickness or strong discomfort.

Table 1
Overview of the chosen songs' characteristics for each music category.

Music	Artist	Song	Duration	BPM
Relaxing	Blank and Jones	Lullaby (Les Yeux Fermes)	6 min 33s	116.39
	Blank and Jones	City of Angels	4 min 57s	156.10
	Elmara	Training	4 min 52s	160.22
Neutral	The Overtones	Second Last Chance	3 min 39s	111.99
	Avalanche City	Ends In The Ocean/Oh Life	5 min 11s	102.01
	Brooke Frasier	Coachella	3 min 32s	104.01
	Regina Spektor	All The Rowboats	3 min 34s	166.00
Stressful	Crookers	Il Brutto (Original Mix)	3 min 56s	130.00
	Crookers	Il Brutto (Bloody Beet Roots Remix)	4 min 20s	130.10
	Crookers	Il Buono (Original Mix)	4 min 52s	133.46
	Crookers	Il Cattivo (Original Mix)	4 min 53s	136.12

Note. BPM = beats per minute (measured using MixMeister Beat Analyzer, http://www.mixmeister.com/download-bpmanalyzer.php).

2.2. Design, apparatus, and stimuli

We chose a one-factorial between subjects design including the factor music type (relaxing, neutral, stressful, no music). Gender was counterbalanced for all groups. The stimuli consisted of a video (14 min 15 s long) showing a first-person view of a bicycle ride through the city of Mainz, Germany. The bicycle ride was mainly performed on a flat terrain, including sequences of even pavement and cobble stone roads, thus providing a mixture of smooth and shaky video images. The driver navigated the bicycle through a crowded area of the city center of Mainz, thus, navigation speed was moderate, and a number of turns and stops (e.g., caused by traffic lights) were included. Note that the rider used to create the stimuli was not a subject in this study. The video was captured with a Sony video camera, which was mounted on the handle-bars of a bicycle. Participants were seated in dimly lit room in a height-adjustable chair 200 cm in front of a 191 cm $\times$ 144 cm large screen, resulting in a field of view of 51° horizontally and 40° vertically. A chinrest was used to minimize participants' head movements and was fixed 116 cm above the ground with eye-height adjusted to the center of the screen. The video had a resolution of 600 $\times$ 480 Pixels with a refresh rate of 60 Hz. Depending on the experimental group, participants were either exposed to easy-listening instrumental music, mainstream pop music, or fast speed electronic music. Prior investigations among the subjects' peer group (personal comments) labeled the chosen songs as *relaxing* (instrumental music), *neutral* (pop music), and *stressful* (electronic music). Table 1 shows detailed information regarding the chosen songs. The loudness of each music style varied between 60 and 70 dB. No music and no other sounds were presented for the control group. For each music category, the transitions between songs were blended to avoid noticeably break points. The last song of each category was shortened and faded out to correspond to the length of the video.

Table 2
Mean (SD) SSQ-pre scores separated by music type.

SSQ-pre subscale	Music type			
	Relaxing	Neutral	Stressful	No music
Nausea	16.70 (12.66)	17.49 (13.09)	10.73 (11.36)	18.63 (13.98)
Oculomotor	17.69 (13.72)	22.74 (16.12)	15.48 (14.22)	24.18 (16.37)
Disorientation	6.38 (10.84)	8.12 (12.93)	8.12 (11.55)	11.93 (14.12)
Total-score	13.25 (8.89)	15.43 (10.07)	11.53 (9.42)	17.63 (11.29)