Clinical and physiological characteristics of cybersickness

Submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy (Human Physiology)

School of Biomedical Sciences and Pharmacy

Faculty of Health and Medicine

University of Newcastle, Australia

This research was supported by an Australian Government Research Training Program (RTP) Scholarship.

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I hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision. The thesis contains no material which has been accepted, or is being examined, for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made. I give consent to the final version of my thesis being made available worldwide when deposited in the University's Digital Repository, subject to the provisions of the Copyright Act 1968 and any approved embargo.

Alireza Mazloumi Gavgani

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I hereby certify that some parts of the work embodied in this thesis have been done in collaboration with other researchers. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

Alireza Mazloumi Gavgani

Acknowledgment

I dedicate this work to my wife, Parastou, who has supported me all the way throughout my study and helped me overcome the doubts and fears. Also I dedicate this work to my beloved parents Seddighe and Samad. Although physically you have not been beside me but I have felt your presence to support me in every step of my journey.

I would like to extend my deepest gratitude to Associate Professor Eugene Nalivaiko whom not only been a supportive and knowledgeable principle supervisor but also, a dear friend that whose door has always been open for me and has been there to help in any circumstance. Further thanks to my other supervisory team co-supervisors Dr Keith Nesbitt and Professor Deborah M. Hodgson for thier help and support.

And finally, I am extremely thankful of my family Maryam, Fatemeh, Fahimeh, Mohsen, Jake, Omid and Arman for supporting me in this journey and whose persuasion and support helped me to overcome obstacles in my path.

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List of Abbreviations

ANOVA	Analysis of variance
BA	Brodmann area
BP	Blood pressure
CBF	Cerebral blood flow
CI	Confidence interval
DAP	Diastolic arterial pressure
ECG	Electrocardiography
HR	Heart rate
HRV	Heart rate variability
HMD	Head mounted device
HbO2	Oxygenated haemoglobin
MCA	Middle cerebral artery
MSSQ	Motion sickness susceptibility questioner
MSAQ	Motion sickness assessment questioner
MS	Motion sickness
NIRS	Near Infrared spectroscopy
PCA	Posterior cerebral artery
RMSSD	Square root of the mean squared differences
RMS	Root Mean Square
RC	Rotating chair
SDRR	Standard deviation of R-R intervals
SAP	Systolic arterial pressure
SCL	Skin conductance level
SEM	Standard error of the mean

TCD	Transcranial Doppler
VIMS	Visually induced motion sickness
VR	Virtual reality

Abstract

In the last two decades there have been substantial advances in the development of virtual reality (VR) technology for various applications such as entertainment, education and training. However, limited knowledge is available about the side effects of this technology including cybersickness - a form of motion sickness that is caused by immersion in VR. My present study is aimed at providing an insight into cybersickness in order to better understand the physiological characteristics of this averse phenomenon. In this study, a total of 79 healthy volunteers (41 females, 38 males) were exposed to cybersickness provoking VR content (virtual ride on a rollercoaster using Oculus Rift head-mounted display) in four independent research experiments.

In the first experiment (described in Chapter 2), we investigated the symptom profile of cybersickness and explored if desensitization can occur with repetitive exposure. We found that gastrointestinal symptoms such as nausea are the most common symptoms associated with cybersickness followed by other - central, peripheral and sopite-like symptoms. We found that these symptoms can last over 3 hours after exposure. Our results clearly demonstrate that repetitive exposure to virtual environments can result in habituation to cybersickness. Our findings demonstrate that forehead sweating increases significantly with increasing nausea and therefore, forehead sweating can be a reliable biomarker for cybersickness in general and nausea in particular.

In the second experiment (described in Chapter 3), we examined the effects of visual content on the intensity of cybersickness symptoms. We found that changes in the direction of visual flow of the same VR content has a significant effect on the severity of sickness such that moving forward in a virtual environment is more provocative than moving backward.

In the third experiment (described in Chapter 4), two different imaging modalities were used to analyse brain hemodynamic during cybersickness. We found that cybersickness is associated with variations in brain activity (region-specific increases and decreases) in a complex network in numerous cortical regions related to the cognitive, evaluative and sensory discriminative aspects of this syndrome. Our results demonstrate that overall sensitivity to cybersickness was significantly higher in females than males.

In the fourth experiment (described in Chapter 5), we compared the subjective symptoms and physiological effects of cybersickness induced by virtual reality and “classic” motion sickness triggered by vestibular stimulation (Coriolis cross-coupling). We found that despite fundamental differences in provoking stimuli, cybersickness and motion sickness are clinically identical. We conclude that cybersickness is a complex syndrome, and that its symptoms and physiological effects are far beyond the common gastrointestinal symptoms.

My work represents detailed characterisation of symptoms and physiological changes that accompany cybersickness. The major impact of my work is, firstly, in the identification of a selective and sensitive biomarker that will allow detection, monitoring and quantification of cybersickness in future studies. Secondly, my finding of similarity between cybersickness and “classical” motion sickness opens opportunity for translational work, namely developing of a simple test for assessing motion sickness susceptibility, and a novel approach for motion sickness desensitization.