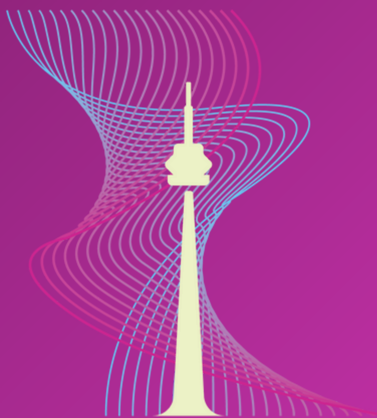
VIMS 2024

UHN Toronto Rehabilitation Institute
The Kite Research Institute

8TH INTERNATIONAL CONFERENCE ON

VISUALLY INDUCED MOTION SENSATIONS



NOV 20-22, 2024
TORONTO, CANADA

General Information

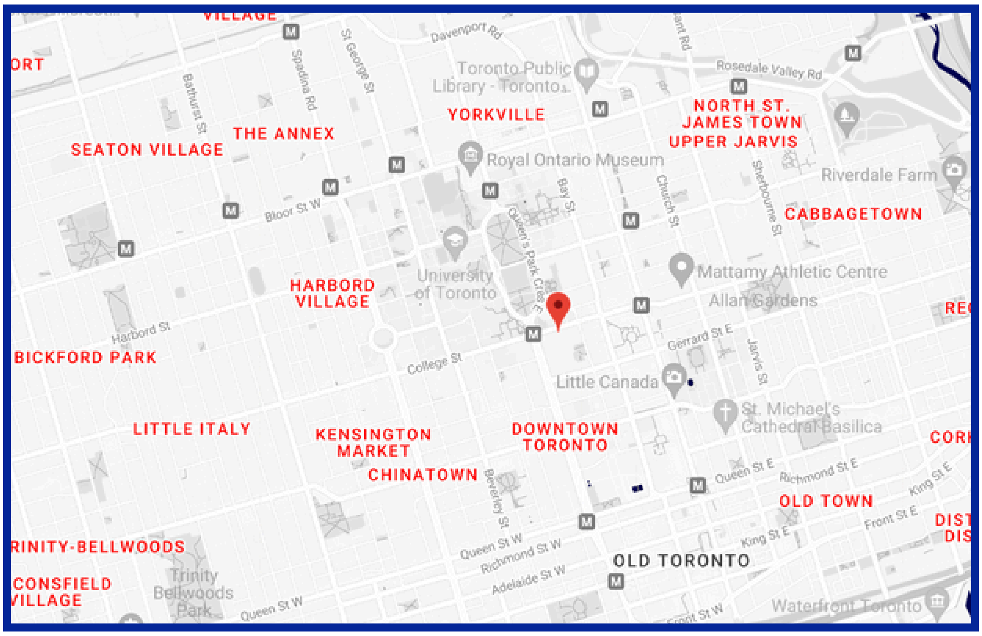
Host:

The KITE Research Institute, University Health Network (UHN). https://kite-uhn.com

UHN Toronto Rehabilitation Institute
The Kite Research Institute

Location:

MaRS Discovery District – **Room CR-3**
101 College St
Toronto ON M5G 1L7
Canada



Wifi Info:

Name: MaRS Guests
No password needed

Contact:

Behrang Keshavarz, KITE Research Institute - UHN, 550 University Ave, Toronto ON M5G 2A2, Canada

e-mail: behrang.keshavarz@uhn.ca

Greetings from the organizers

We are excited to welcome you to the 8th International Conference on Visually Induced Motion Sensations (VIMS). Traditionally, VIMS has been a bi-annual conference, dating back to the first decade of this millennium. However, fueled by the Covid-19 pandemic and other unforeseeable events, the last VIMS conference was held (virtually) in 2020. In fact, the last time VIMS brought together researchers in person was right here at the KITE Research Institute in Toronto in 2017. Welcome back!

The KITE Research Institute – the research arm of the Toronto Rehabilitation hospital and part of the University Health Network (UHN) – is a world leader in rehabilitation research. Our research focuses not only on optimizing patient care, but also on preventing injuries and the promotion of aging well. In the Challenging Environment Assessment Laboratory (CEAL), we use immersive VR technologies to measure perception and performance under highly realistic conditions with the goal of improving mobility and safety. Being aware of the potential side-effects of VR, we seek effective solutions to optimize simulated experiences. We are therefore particularly excited to host the 8th VIMS conference in Toronto.

Many things have changed since the early VIMS meetings. Existing and new visual technologies and developments such as VR/AR/XR continue to emerge and significantly influence our daily lives. Despite the increase in technological advances, our understanding of the physiological and psychological effects of these visual technologies has not grown proportionally. VIMS will serve a key role in helping to find ways in which to optimize engagement and improve the perceptual aspects of these technologies and mitigating potentially adverse effects.

Starting in 2017, we decided to widen the scope of VIMS by including topics from research fields that are relevant to traditional motion sickness, but also have their own empirical tradition. Keeping up this tradition, VIMS 2024 will cover a broad spectrum of research topics including vection, eye-movements, and postural control. We believe that the best way to address the challenges we are facing is to integrate elements from the various interdisciplinary and interprofessional sectors in this research field. We have also engaged industry partners who have extensive experience with the increasingly pervasive use and explosive development of these technologies in the context of art, design, healthcare, entertainment, and training, and who can help to prioritize and identify new research objectives. We hope that the 8th VIMS conference will reflect this diversity and will facilitate new collaborations for exciting, innovative, and unique research in the future.

Behrang Keshavarz, Jennifer Campos, Katharina Pöhlmann
The KITE Research Institute, Toronto Rehab-University Health Network

VIMS 2024

35% discount on the APC fee for conference attendees

Special Issue

Visually Induced Motion Sensations

Multisensory Research (Brill)

Guest Editors:

Dr Behrang Keshavarz
Senior Scientist, KITE, Professor
Department of Psychology,
Toronto Metropolitan University.
behrang.keshavarz@uhn.ca

Dr Jennifer Campos
Senior Scientist, KITE, Professor
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Dr Katharina Pöhlmann
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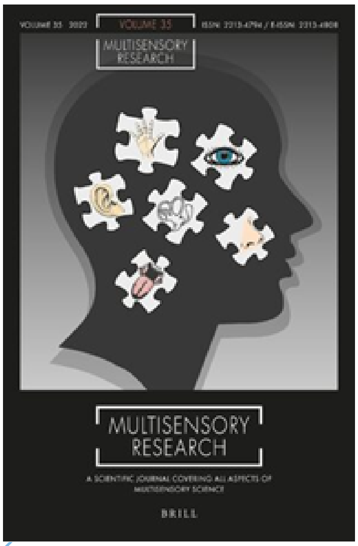
Deadline for Manuscript submissions:
June 27,2025



Message from the Guest Editors

The use of modern display technologies is strongly driven by stimulation of the visual system. Mobile phones, tablets, computers and virtual reality interfaces are only few of the many visual display devices that occupy (or may soon occupy) our everyday lives. Visually-induced motion sensations often accompany the use of these technologies. These sensations can lead to intended and desirable outcomes (e.g. vection) or unintended and undesirable outcomes (e.g. simulator sickness, photosensitive seizures, and visual discomfort). This special issue aims to bring together international research findings and opinions in this complex and multifaceted area of study and application. Participants of the 8th International Conference on Visually Induced Motion Sensations (VIMS 2024, Toronto, Canada) are strongly encouraged to submit the work they present at the conference for consideration in this special issue.

We invite authors to submit high quality papers addressing research topics including, but not limited to, the following:

- Visually Induced Motion Sickness (e.g., Simulator sickness, VR sickness)
- Visual discomfort (e.g., visual fatigue, visual stress – asthenopia)
- Illusory self-motion (vection)
- Optic flow
- Display factors and designs
- Photosensitive seizures (visually induced epilepsy)
- Neurophysiological mechanisms
- Pharmaceutical and non-pharmaceutical countermeasures
- Virtual Reality and simulators
- Serious gaming
- Social aspects
- Civil and military applications
- Regulation and standardization

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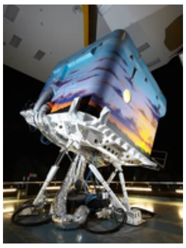
Program at a Glance

TIME	NOV 20	NOV 21	NOV 22
9:00 AM		Registration and Breakfast Welcome Address	Registration and Breakfast Welcome Address
10:00 AM		Keynote - Angus Rupert	Keynote - Julie Smithson
11:00 AM		Break Presentation Session I	Break Presentation Session III
12:00 PM		Lunch	Lunch
1:00 PM	Tour of KITE-UHN research facilities	Panel	Plenary Session
2:00 PM		Break	Break
3:00 PM		Presentation Session II	Presentation Session IV
4:00 PM	Visit to Arcadia Earth		Closing Remarks
5:00 PM	Welcome Reception at the Lulu Bar	Visit to the Museum of Illusions	
6:00 PM			
7:00 PM		Conference Dinner at the Flat Iron Firkin	
8:00 PM			

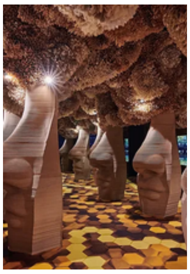
KITE-UHN tours | Social Events | Presentation Sessions | Special Presentations | Breaks

Social Events



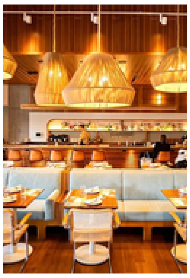
Tour of KITE-UHN (Nov 20, 1:30pm)

Tours of the unique simulation technologies located at KITE-Toronto Rehab, UHN.
Address: 550 University Ave, M5G 2A2 Toronto



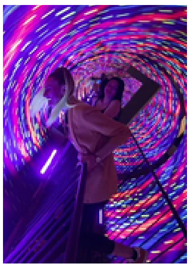
Visit: Arcadia Earth (Nov 20, 4:00pm)

Arcadia Earth is an immersive, multi-sensory experience designed to promote environmental awareness and inspire climate action with cutting-edge technologies such as augmented reality (AR), virtual reality (VR), and projection mapping.
Address: 486 Front St W building C, M5V 0V2 Toronto



Reception @ Lulu Bar (Nov 20, 5:00pm)

Join us for drinks and tasty bites.
Address: 427 Wellington St W, M5V 1E7 Toronto



Visit: Museum of Illusions (Nov 21, 5:00pm)

Step into a world of deception and wonder at the Museum of Illusions with exhibits like a vortex tunnel and anti-gravity room!
Address: 132 Front St E, M5A 1E2 Toronto

Dinner @ Flatiron Firkin (Nov 21, 6:30pm)

Have dinner in one of Toronto’s most iconic buildings - The Flat Iron Building!
Address: 49 Wellington St E, M5E 1C9 Toronto

Keynote Speakers

Angus Rupert

Embry-Riddle Aeronautical U

(Nov 21, 10-11:00am)

Angus is a research professor working on a variety of ERAU affiliated research projects. Following a PhD in Neurophysiology from the University of Illinois and MD from the University of Toronto, he joined the US Navy in 1985. He served operationally as a Navy flight surgeon in the Azores before joining the Naval Aerospace Medical Research Laboratory (NAMRL) in Pensacola Florida. At NAMRL he developed programs to explore vestibular psychophysics and the neurophysiological responses to unusual acceleration experienced by pilots, astronauts and operators of high-performance military platforms.

In 2008, he retired from the Navy to join the U.S. Army Aeromedical Research Laboratory in Ft Rucker where he continued to develop practical multisensory solutions to the problems faced by personnel operating in sensory deprived or altered acceleration environments. He has transitioned his tactile cueing device, originally developed for aerospace environments, to balance rehabilitation technologies for personnel suffering balance dysfunction associated with mild traumatic brain injury.

For the past 18 years, Angus has provided perceptual modeling expertise to all branches of the U.S military and the NTSB in support of aviation mishap investigations. In 2017 the U.S. State Department awarded him the 2016-17 Fulbright Distinguished Chair in Advanced Science and Technology to provide the opportunity to transition the TSAS to Australian aviation assets. In 2020, he accepted a position as Research Professor at Embry-Riddle Aeronautical University in Daytona where he continues his aviation research activities.

Julie Smithson

METAVRSE, XR Women

(Nov 22, 10-11:00am)

Julie is CoFounder & CEO of METAVRSE, a 3D creation tool & game engine for the spatial web. Over 14+ years, she has led the production of several world-first interactive experiences across use cases; touchscreens, 360° Photo Booths, Interactive & LMS integrated maintenance & repair training labs, retail consumer gamification engagement (Web3), product showcases and immersive collaboration.

Julie is the Co-Founder of XR Women, the world's largest global community dedicated to connecting, empowering, and supporting women's success in virtual platforms. Over four years, Julie and her team have organized more than 185 immersive events featuring women speakers from the industry, serving a diverse and growing community of over 1,000 members worldwide, with weekly Wednesday attendance exceeding 30 participants across 8+ countries.

Julie leverages spatial awareness and perseverance to improve and support how we learn, teach, and adapt in a rapidly digitizing, post-AGI world. Julie and her team produce cutting edge awards shows featuring never-before done immersive content. This team also produces MetaTr@versal, a global tour focused on learning about best practices, ethics, standards and governance with particular focus on interoperability.

Prior to her pioneering work in spatial computing, Julie was COO & Co-Founder at SmithsonMartin, creators of the world's first multitouch system for the music industry. Their flagship immersive product for music performance won the coveted DJ Mag Award for Most Innovative Product in 2011.

Paper Sessions I & II

Thursday, Nov 21

SESSION I (11:15AM-12:30PM) *Sensory and Neurophysiological Factors in VIMS Perception (Session Chair: Dr. Robert Allison)*

Individual Differences in Cybersickness: Sensory Reweighting and Neural Plasticity
Michael Barnett-Cowen

A Novel Virtual Reality Program for Oculomotor Deficits After Concussion: Considerations for Sex and Gender, and Technology
Melissa Biscardi

Neurophysiological Responses to Vection-Inducing Stimuli
Polina Andrievskaia

Integrating Non-Visual Cues in Perceiving Travel Distance Using Central versus Peripheral Optic Flow
Ambika Bansal

Optic Flow Motion Parameters Explain Visual Disturbance from VR-HMD Pupil Swim
Phoebe Lim Ching

SESSION II (3:00-4:15PM) *Assessing and Predicting VIMS Susceptibility (Session Chair: Dr. Mara Baljan)*

Norms and Correlations of the Visually Induced Motion Sickness Susceptibility Questionnaire short (VIMSSQ-short)
John Golding

Mitigate and Predict Cybersickness Susceptibility - A Systematic and Transparent Evaluation of Working Mechanisms
Judith Josupeit

Predicting (Visually Induced) Motion Sickness: The Role of Lifestyle, Sex, and Racial Identity – An Online Survey Study
Narmada Umatheva

Assessing Cybersickness Susceptibility: The Impact of User-Related Factors
Zahra Moussavi

Is Simulator Sickness Related to Differences in Visual-Vestibular Self-Motion Perception?
Jelte Bos

Panelists

(Nov 21, 1:30-2:45pm)

Stephanie Greenall, Tilt Five

With a passion for video games and XR, Stephanie has transformed her hours logged in-game into real life XP. She is currently the Head of Marketing at Tilt Five, an AR gaming system that takes new and existing games and turns them into tabletop holograms. She has co-produced VRTO – The Spatial Media World Conference and FIVARS – Festival of International Virtual & Augmented Reality Stories, advocated for the interactive digital media (IDM) industry with Interactive Ontario, acted as selection committee/judge for Canada Game Awards, VR Rhythm League, and FIRST Robotics Canada, and has consulted on projects and programs for universities including, University of Toronto, York University, Schulich School of Business, and Harvard University. She graduated from McMaster University and Seneca@York, received a Producer's certificate from Raindance Festival and an Esports specialization from University of California.

Craig Perlmutter, Arcadia Earth

Meet Craig Perlmutter, the President of Arcadia Earth Toronto. With a degree in Economics from the University of Pennsylvania, Craig's leadership style blends detail-oriented focus with a passion for the outdoors, entertainment, and outstanding customer service. His journey from the promotions and marketing industry to owning one of Canada's top overnight summer camps for 20 years showcases his diverse expertise. Having discovered Arcadia Earth in New York in 2020, Craig's entrepreneurial spirit drove him to establish the exhibit's first Canadian location. His commitment to environmental consciousness and sustainability aligns perfectly with the mission of Arcadia Earth, fostering a community of like-minded individuals. Craig's fusion of experiences in promotions, marketing, and events helped create a unique and enriching venture in Toronto with a great team around him. Witness Arcadia Earth's innovative approach to merging entertainment, education, and hospitality in downtown Toronto, located at The Well (Front and Spadina).

Tanya Kelen, Kelencontent

Seasoned C-Suite media executive with 20+ years advising CEOs and C-Suite teams across production, marketing & global licensing / distribution in media, education, digital & creative tech sectors. Supervising innovative teams of 3 - 75 people to deliver premium content in Film, TV, Games via KCI's high-impact partnership development services to meet KPI's. Ms. Kelen is a serial entrepreneur, advisor & futurist who is founder & Ceo at Kelencontent (KCI). The company offers creative product-market fit and go-to-market services to scale B2B-B2G-B2C products via KCI's established marketing and distribution networks. KCI's services include collaborating in co-designing high-growth marketing and distribution plans to scale innovative media, tech and educational products & incubator services across North America & global markets. KCI works with multi-sector innovation teams and product leads and develops partner relations managing quality control from inception to delivery. Skilled at managing multicultural, neurodivergent and BIPOC teams who perform 30% better than average. Committed to offering all stakeholders more value, visibility & market share that delivers greater ROI as well as optimal wellbeing outcomes for all.

Paper Sessions III & IV

Friday, Nov 22

SESSION III (11:15AM-12:30PM) — *Perception and Control of Self-Motion (Session Chair: Dr. Jelte Bos)*

Flow Parsing Gain Depends on Self-Motion and Object Motion Directions
Hong Yi Guo

Where am I heading? Steady and Foggy
Richard So

Validation of Visualization Hardware in a VR-based Driving Stimulation with Focus on Simulator Sickness
Melina Bergen

Postural Responses After Gain Adaptation in VR
Xue Teng

A Repulsive Bias in Perceived Heading Away from the Straight-Ahead as Determined by Continuous Psychophysics
Bjorn Jorges

SESSION IV (3:00PM-4:30PM) — *Influences on VIMS (Session Chair: Dr. Richard So)*

Short-term Subjective Recovery from Visually Induced Motion Sickness
John Golding

Optical See-through Augmented Reality can Induce Severe Motion Sickness
Mara Baljan

An Assessment of Cybersickness Caused by Augmented Reality Head-Mounted Display for At-Sea Use by the Royal Canadian Navy
Ramy Kirollos

Static and Dynamic Visual Fields Influence Object Orientation Estimates in a Different Way
Anna Reuten

Exploring the Effects of Delayed Visual Feedback on Dynamic Postural Control
Nora Pourhashemi

Plenary Speakers

(Nov 22, 1:30-2:45pm)

Stephen Palmisano, University of Wollongong, AU

Stephen Palmisano is a Professor of Psychology at the University of Wollongong (UOW). He received his PhD from the University of New South Wales in 1997 under the supervision of Scientia Professor Barbara Gillam, and then worked as a post-doctoral fellow with Distinguished Professor Ian P Howard from 1998-2000 at the Centre for Vision Research in York University, Canada. Afterwards he returned to Australia to start his own "Perception and Action Laboratory" (PAL) at UOW. His research investigates how we perceive and control our own self-motions (such as walking as well as traveling in cars, trains and even planes) and role that binocular vision plays in our perception of depth (so called stereoscopic perception). Much of his research now examines head-mounted display based virtual reality (HMD VR) - looking at experiences of vection, presence and cybersickness during immersive simulations and gameplay.

Yoon-Hee Cha, University of Minnesota, MN

Dr. Cha is an Associate Professor in the Department of Neurology with subspeciality training in neurotology. She joined the faculty of the department in July 2019 as a MnDRIVE Scholar to pursue research on the application of non-invasive brain stimulation methods on the modulation of motion perception, treatment of vertigo, and enhancement of gait and balance. She developed the first neuromodulation based clinical trials in a motion entrainment disorder called mal de debarquement syndrome (MdDS) in which individuals who are exposed to passive oscillation, such as on a boat, develop a persistent oscillating vertigo as if they are still on the boat when they return to stable ground. The study of MdDS revealed the importance of brain regions not traditionally thought to be part of the vestibular system in the creation of motion perception. Understanding how motion entrainment can affect multiple resting state brain networks provided insights into why migraine, anxiety, and cognitive dysfunction are frequently comorbid with vestibular disorders. Besides research on the use of non-invasive brain stimulation tools such as transcranial alternating current stimulation and transcranial magnetic stimulation, Dr. Cha sees patients in the neurology clinic with a focus on chronic headache, vertigo, and gait dysfunction.

Stephen Brewster, University of Glasgow, UK

Stephen Brewster Is a Professor of Human-Computer Interaction in the School of Computing Science at the University of Glasgow. He is a member of the GIST research section and within that, he lead the Multimodal Interaction Group doing world-leading research in human-computer interaction (mig.dcs.gla.ac.uk). His research focuses on multimodal HCI, or using multiple sensory modalities and control mechanisms (particularly audio, haptics and gesture) to create a rich, natural interaction between human and computer. His work has a strong experimental focus, applying perceptual research to practical situations. He currently holds an ERC Advanced Grant on virtual and augmented reality (the ViAjeRo project). He also works on interfaces for mobile devices and in-car interactions. He Is a Fellow of the Royal Society of Edinburgh, a member of the ACM SIGCHI Academy and an ACM Distinguished Speaker.

Abstracts

NOV 21 - SESSION I

Sensory and Neurophysiological Factors in VIMS Perception

Individual Differences in Cybersickness: Sensory Reweighting and Neural Plasticity

Michael Barnett-Cowan[1]
[1]Department of Kinesiology and Health Sciences, University of Waterloo, Canada

Conflicting sensory information can lead to disorientation and discomfort. Virtual and augmented reality (VR/AR) create conditions where sensory conflict occurs between stimuli from the real environment and those from virtual environments. This conflict can result in cybersickness, with symptoms like motion sickness and visually induced motion sickness (VIMS). In the sickness literature, there are significant individual differences in susceptibility to cybersickness, motion sickness, and VIMS. Some research has suggested that these individual differences may relate to differences in reliance on one sensory modality over others. We approach the problem of cybersickness by hypothesizing that exposure to VR/AR environments has the potential to provoke neuroplastic changes in the relative contribution of sensory cues for perception, action, and decision-making. In this talk, I will highlight studies from our lab showing that participants who experience more sickness while playing VR games are less likely to adjust their relative reliance on visual, bodily, and vestibular cues for the subjective visual vertical and perceptual upright. Our results suggest that individual differences in sickness susceptibility may be related to differences in sensory reweighting and short-term neural plasticity, the nervous system's capacity to reorganize itself by changing neural connections in response to sensory input. I will conclude by highlighting some future research approaches using brain stimulation, brain imaging, and genomic techniques to further assess this theory, aiming to enhance our understanding of the neural mechanisms underlying sensory reweighting and its role in cybersickness susceptibility.

A Novel Virtual Reality Program for Oculomotor Deficits After Concussion: Considerations for Sex and Gender, and Technology

Melissa Biscardi[1], Mark Bayley[2], Angela Colantonio[3], Tatyana Mollayeva[4]
[1]University of Toronto, Canada [2]Toronto Rehabilitation Institute University Health Network, Canada
[3]University of Toronto, Canada [4]University of Toronto, Canada

Concussion rehabilitation is an evolving field, with oculomotor deficits emerging as key early indicators of prolonged recovery. These deficits, including disruptions in visual tracking and gaze stability, are particularly relevant as evidence suggests individuals with concussion may develop visual dependence to compensate for potentially less reliable vestibular inputs. Virtual reality (VR) technology offers a promising avenue for rehabilitating such oculomotor impairments by providing reproducible and adaptable exercises that can be easily delivered. However, as VR-assisted rehabilitation for concussion continues to advance, it is essential that protocols are designed with consideration for sex and gender. Given that females are more likely to report a greater number of symptoms, experience more severe symptoms, and take longer to recover than males, any differences in interest and responses to VR-based interventions should be thoroughly explored. This presentation will discuss the current knowledge of sex- and gender-specific factors influencing concussion recovery, the argument that VR may carry inherent biases, and the development and testing of a novel VR-based oculomotor intervention. This intervention includes phone application-based oculomotor exercises for home-based reinforcement by adults post-concussion. Preliminary observations related to study engagement and simulator sickness during initial exposure to the VR-based system will also be discussed.

Neurophysiological Responses to Vection-Inducing Stimuli

Polina Andrievskaia[1 2], Julia Spaniol[1], Stefan Berti[3], Behrang Keshavarz[1 2]
[1]Toronto Metropolitan University, Canada, [2]The KITE Research Institute – University Health Network, Canada, [3]Johannes Gutenberg-Universität Mainz, Germany

Vection refers to the sensation of self-motion elicited in the absence of corresponding physical movement and is a common phenomenon in application such as Virtual Reality technology. Although this is a well-studied phenomenon, little is known about the underlying neurophysiological processes of vection. Previous studies have used EEG measures to identify the early processing stages (e.g., N2, P3) of this experience, yet our understanding of the neurophysiological differences between the states of vection and non-vection remains unclear. The purpose of this study was to address this gap. 34 participants were exposed to moving bars on a three-screen setup at two different speeds (slow and fast), reporting episodes of vection via button presses and releases during 40 seconds of visual stimulation. Vection was experienced during both speed conditions, but more intense and longer lasting vection was reported during faster moving stimuli than during slower moving stimuli. Time-frequency analyses revealed a suppression of activity across all frequency bands during vection, with an increase in activity in all frequency bands following vection offset. Consistent with earlier work, we found the alpha band to be sensitive to vection. However, our results also suggest that neurophysiological correlates of vection can be observed in several other frequency bands as well. We were therefore unable to establish a clear pattern of changes in the EEG signal associated with vection, even though EEG was found to be sensitive in capturing vection-related neuro-cortical processing.

Integrating Non-Visual Cues in Perceiving Travel Distance Using Central versus Peripheral Optic Flow

Ambika Bansal[1]
[1]York University, Canada

Continuously evolving modes of moving people challenge the brain's self-motion processing ability. Previous research from our lab has shown that optic flow presented in the far periphery results in people feeling they moved further than when the same motion was presented full field or in only the central field. Although others have shown that non-visual cues are generally weighted higher than visual cues when estimating travel distances, it is unknown how non-visual cues might affect the use of optic flow in the far periphery. Here, we used a large-field edgeless display to either visually “move” participants while they were physically stationary, performing a blind walking task on a treadmill, or visually “moving” while walking on a treadmill. Optic flow was presented either full field, in the central field, or in the far periphery. Participants judged travel distances by stopping at the location of a previously seen target (Move-To-Target Task) or adjusting a target to indicate the distance of a previous movement (Adjust-Target Task). Preliminary results (N=11) show that in the Move-To-Target task, peripheral optic flow led to higher gains (perceived travel distance / actual travel distance) than the central field and full-field conditions during both the visual-only and visual-and-treadmill conditions. In the same task, the blind walking condition also led to higher gains than the visual-only or visual-and-treadmill conditions. In the Adjust-Target task, there were no significant differences between conditions. These findings highlight the importance of the far periphery in self-motion processing and emphasize the importance of multisensory processing.

Optic Flow Motion Parameters Explain Visual Disturbance from VR-HMD Pupil Swim

Phoebe Lim Ching[1], Tsz Tai Chan[2], Richard H. Y. So[3], Jerry Jia[4]
[1]York University, Canada, [2]Hong Kong Polytechnic University, HKSAR, [3]Hong Kong University of Science and Technology, HKSAR, [4]Guardian Glow Limited (Hong Kong), HKSAR

Virtual scenes viewed from contemporary VR-HMDs are distorted by pupil swim: the combined effect of eye movement and image distortion from the HMD lens. Users perceiving pupil swim feel different levels of disturbance depending on the VR-HMD lens design characteristics. We characterized pupil swim from various VR-HMD designs based on its similarity to the optic flow pattern observed when viewing the translation and/or rotation of a hypothetical 2D plane. Our method decomposed pupil swim cases into a set of descriptive motion parameters, namely rotation axis position, rotation angle, and translation distance. The values of these motion parameters were mathematically optimized to create optic flow approximating image distortion from a specific pupil swim case, differentiated by the mode of eye movement and VR-HMD lens design. This method was applied to 42 commercial and conceptual VR-HMD lens designs. We then examined whether or not the motion parameters could explain the visual disturbance felt by users by analyzing the relationship between the fitted parameter values and data on user perception of pupil swim from a diverse set of VR-HMD designs. Pupil swim from VR-HMDs have some optical characteristics that cannot be represented by motion alone as determined by our earlier work on the subject. Nonetheless, this motion-based framework of analysis for pupil swim links it to the larger body of work on Visually Induced Motion Sickness. This work was done while one of the authors, Jerry Jia, was working in Meta Reality Labs and was partially supported by Meta.

NOV 21 - SESSION II *Assessing and Predicting VIMS Susceptibility*

Norms and Correlations of the Visually Induced Motion Sickness Susceptibility Questionnaire short (VIMSSQ-short)

John F Golding[1] and Behrang Keshavarz[2 3]
[1]Psychology, School for Social Sciences, University of Westminster, London, UK.
[2]KITE-Toronto Rehabilitation Institute, University Health Network, [3]Toronto Metropolitan University, Toronto, Canada.

Background: Motion Sickness Susceptibility Questionnaires (MSSQ), also called Motion History Questionnaires, predict individual differences in motion sickness. The MSSQ-short was optimised for classic motion sickness provoked by transport motion in boats, cars, planes, etc. Visually Induced Motion Sickness (VIMS) shares many characteristics of classic motion sickness. But symptoms such as eyestrain, headache assume greater salience. Increasing use of visual technologies prompted development of a questionnaire optimised for predicting individual differences in VIMS. Methods: Development used repeated item analysis, and various scoring methods. This produced the 97-item VIMSSQ-long and the 6-item VIMSSQ-short, which were developed in parallel. Norms and percentiles for the VIMSSQ-short are presented here based on survey (n=920). Relationships were explored with classic motion sickness susceptibility of the MSSQ-short, migraine susceptibility, dizziness susceptibility impact, and syncope susceptibility. Predictive validity used a validated wide field provocative moving visual stimulus (n=30). Results: VIMSSQ-short mean +SD=7.2+4.2; median=7.0, 25th percentile=4.0, 75th percentile=10.0. Cronbach's alpha was 0.80. Females had non-significantly higher VIMSSQ-short scores than males (males=6.9+4.6, females=7.4+3.9, p=.09). Susceptibility declined slightly with age (r=-0.12, p<.001), but with an increase above ages 70 years. VIMSSQ-short correlated (p<.001) with MSSQ-short r=0.55, with Migraine r=0.48, with Dizziness r=0.35, with Syncope r=0.31. Exploratory Factor Analysis suggested two latent variables: Nausea related; Ocular-motor related. Predictive validity for sickness induced by provocative visual motion was r =0.58 (p<.01). Discussion: VIMSSQ-short provides reliability with efficient compromise between length (reduced time cost) and validity (predicted VIMS susceptibility). It can be used alone, or with other questionnaires, the most useful being MSSQ-short and Migraine Screen.

Mitigate and Predict Cybersickness Susceptibility - A Systematic and Transparent Evaluation of Working Mechanisms

Judith Josupeit[1]
[1]TU Dresden / Engineering Psychology and Applied Cognitive Research, Germany

Virtual reality (VR) can cause visually induced motion sickness also known as cybersickness. Not only these two but various terms are used interchangeably for cybersickness, potential working mechanisms for cybersickness are overgeneralized, or VR-specific characteristics are neglected. Therefore, the current approach aimed at validating the potential working mechanisms more systematically using a reference VR environment. For systematization, the working mechanisms were attributed to either the VR environment, the user, or the interaction between the former two. Exemplary one study for each factor is presented: In the first study, the design of the VR environment was manipulated through additional rest frames which should mitigate cybersickness. The second study tested whether the participants' performance in a field dependency test allowed for screening for susceptibility. Neither the reference frame nor the field dependence was associated with cybersickness as hypothesized. Still, both studies found supporting evidence for mitigation through descriptively self-reported as well as experimentally manipulated immediate previous VR experience. The third study aimed at predicting the mean expected cybersickness severity by respecting the virtual camera transform and the participant's controller input for locomotion: The interaction between the VR environment and the behavior allowed for a prediction of cybersickness severity. Further, a synoptical comparison of all three studies stressed the environment-specificity of symptom reports. In conclusion, a holistic consideration of all three factors is important to classify research results; for an integrative comparison between cybersickness studies, clear definitions, and transparent research methods are required.

Predicting (Visually Induced) Motion Sickness: The Role of Lifestyle, Sex, and Racial Identity – An Online Survey Study

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Visually induced motion sickness (VIMS), a type of motion sickness (MS), is a common side-effect of visual devices and Virtual Reality usage. Due to its complexity, individual lifestyle factors may be possible predictors of experiencing VIMS/MS. This study aimed to (1) explore the association between lifestyle factors (e.g., video game use, physical activity, diet, substance use) and self-reported VIMS/MS, and (2) investigate the impact of sex and ethnicity on VIMS/MS prevalence in young adults. An online survey with over 700 healthy adults aged 18-49 was conducted. The survey had three main sections: (1) general demographics (age, sex, ethnicity), (2) VIMS/MS susceptibility, and (3) habits on video game use, physical activity, diet, and substance use. Most participants reported experiencing VIMS symptoms when using visual displays, with eyestrain (72%) and headaches (62%) being the most common, followed by fatigue (53%), dizziness (28%), and nausea (23%). Multiple regressions showed that sex, ethnicity, and lifestyle factors explained only 2-8% of VIMS/MS susceptibility variance. Significant sex differences were observed for VIMS/MS susceptibility, with females reporting higher scores than males. Additionally, significant differences were noted between specific ethnic groups for MS susceptibility, with South Asians reporting lower MS scores compared to East Asians. However, no ethnic differences were found for VIMS. Overall, lifestyle factors are not prominent predictors of VIMS/MS susceptibility. However, we found that females are more susceptible to VIMS/MS than males and that ethnic origin may be a possible predictor of MS. Our findings also support the notion that VIMS is a prevalent issue.

Assessing Cybersickness Susceptibility: The Impact of User-Related Factors

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Introduction: Cybersickness refers to the discomfort and motion sickness-like symptoms that may be experienced in virtual reality. Symptoms considered in this study include nausea, dizziness, and 14 others as outlined in the Simulator Sickness Questionnaire (SSQ). Literature identifies several user-related factors, such as age, sex, motion sickness susceptibility, sleep disturbances, and anxiety that increase cybersickness likelihood. We analysed data collected over 10 years to evaluate which factors significantly impact likelihood of experiencing cybersickness in an immersive environment. Method: 258 qualitative data points with assessor notes, were coded for presence of cybersickness based on the SSQ criteria. Of these, 197 data points included additional information on sleep disturbances, history of motion sickness, and stress/anxiety. These three factors were used as themes for further coding of assessor notes. Logistic regression was applied to these 197 complete data points to assess the impact of these factors, along with age and gender, on cybersickness likelihood. Results: Logistic regression revealed an odds ratio (OR) of 4.21 for previous motion sickness experience ($p=0.025$). Sex factor approached significance, while other factors were not statistically significant. Analysis of the full dataset ($n=258$) with sex and age information alone found both to be significant predictors: males had an OR of 0.4 ($p=0.015$), and age of 1.02 ($p=0.019$), likely due to the larger sample size. Conclusion: A history of motion sickness increases the likelihood of cybersickness by 4.21 times. Males have 60% lower odds of experiencing cybersickness than females, and each one-year increase in age raises the odds by 2%.

Is Simulator Sickness Related to Differences in Visual-Vestibular Self-Motion Perception?

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Simulator sickness can be explained by a conflict between visual and vestibular self-motion cues. In everyday life retinal image and physical self-motion are equal but opposite. Most moving base simulators, however, apply less physical motion than visually displayed, the ratio between visual and vestibular motion or gain being fixed. Correia Gracio et al. (2014) showed that for linear motion the optimal gain was about two on average, but ranged individually from less than one to over 14. We accordingly posed the question whether this gain could explain individual differences in simulator sickness severity. Similar to Correia et al., we exposed subjects to a continuous physical linear sinusoidal motion with fixed amplitude on a sled, and presented the corresponding visual motion in a virtual environment delivered by VR goggles. This visual motion was in phase with the physical motion of the sled, except for its amplitude that subjects had to adjust by in- and/or decreasing two buttons on a handheld numerical keypad until it matched their perceived physical motion. After determining each subject's preferred gain, we then exposed them to separate experimental sessions using their preferred gain and a three times smaller gain while rating motion sickness scores. Results confirmed the reported large individual variability in preferred gains as observed by Correia et. al., but did not show an effect of the visual-vestibular gain on their sickness scores. This poses a new question whether this was due to a true lack of an effect or due to our experimental conditions.

A Repulsive Bias in Perceived Heading Away from the Straight-Ahead as Determined by Continuous Psychophysics

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Perceived heading has been shown to be biased either away from the straight-ahead or towards it, depending on the task specifics such as whether judgements are made allocentrically or egocentrically. In this study, we used a novel, continuous psychophysics paradigm to provide further evidence to the debate. We immersed 30 participants into a virtual 3D environment in which they perceived visual self-motion with continuously changing heading angles. Participants had to continuously indicate in which direction they felt they were moving using a joystick, and in separate runs we manipulated how informative the optic flow was that participants experienced. We found compelling evidence that angles close to the straight-ahead were repelled from it, i.e., participants tended to overestimate small angles to the right and the left of the straight-ahead. This bias tended to be larger in the presence of less informative optic flow, which suggests a Bayesian mechanism in which a repulsive prior (i.e., away from the straight-ahead) biased performance more when immediate sensory input was less reliable. An important caveat is that we did not measure motor performance separately from perceived heading, i.e., this bias could theoretically also have originated in the motor aspect of the task.

Flow Parsing Gain Depends on Self-Motion and Object Motion Directions

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When we move through the environment, the egocentric direction of objects changes producing an optic flow. Optic flow must be decomposed to perceive object motion during self-motion (Rushton & Warren, Current Biology, 15(14), 542–543, 2005), a process called flow parsing. Most real and realistic VR environments contain abundant depth and distance cues, including size and binocular disparities. Little is known about their roles in flow parsing. We designed two experiments with our wide-field stereoscopic environment. Participants observed target motions during visually simulated self-motion and indicated the direction of target motion with respect to the scene depicting a large room (Experiment 1) or a cluster of 3D objects (Experiment 2). Both sagittal and lateral target motions and self-motions were simulated. During lateral locomotion through both environments, flow parsing gains were significantly lower for laterally compared to sagittally moving targets. However, during sagittal locomotion, laterally moving targets had much higher flow parsing gains than sagittally moving targets. Geometrically, collision with an eccentric target is only possible if they move orthogonally to the direction of self-motion, which might explain the sensitivity toward these motions. The perception of possible contact stems from the visual cues of distance and depth, such as binocular disparity and object size, and the change in these signals (e.g. looming, change in disparity, interocular velocity difference). This means that depth and distance cues such as binocular disparity and object size may have important roles in perceiving world-relative object motion during self-motion.

Where am I heading? Steady and Foggy

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Humans integrate visual and vestibular cues to perceive heading directions. Past studies reported a Bayesian model to predict the combined HDTs as functions of visual and vestibular HDTs but suffered a prediction bias. The overweighting of vestibular signals (vestibular overweighting, VesO) had been offered as an explanation (Fetsch et al., 2009; de Winkel et al., 2010). However, the model has not been tested when vestibular stimuli are weak (peak acceleration of vestibular stimuli < 45 mg). This talk will present a series of experiments conducted to examine HDTs and model prediction with different combinations of weak visual cues (none and 8% coherence) and weak vestibular cues (0, 9, 14 and 19 mg). Only a few subjects could extract heading information correctly from the vestibular cues confirming that the cues tested were around the thresholds. HDTs with combined visual and vestibular cues were significantly higher (i.e., less sensitive) than the Bayesian model predictions ($p<0.05$) indicating that prediction biases still existed. Both the frequency and peak acceleration of the vestibular cues significantly affected vestibular HDTs. The lowest mean HDT was found in (0.5 Hz, 30 mg) condition. Visual HDTs significantly increased with decreasing visual coherence. Results will be discussed towards the possibility of "Visual Misestimation (VisM)" (de Winkel et al. 2010; Fetsch et al. 2010) an alternative explanation to the prediction bias.

Exploring the Effects of Delayed Visual Feedback on Dynamic Postural Control

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BACKGROUND: Vision provides essential sensory feedback for upright stance. Delayed visual feedback can affect postural control by creating a mismatch between one's motor actions and visual responses. This study examined the relationship between visual delay, postural responses, and visually induced motion sickness (VIMS) during dynamic balance tasks. METHODS: Twenty young adults stood on a force plate mounted to a motorized platform that continuously translated in the anteroposterior (AP) direction for 60s while wearing a virtual reality head-mounted display. Full body kinematics, centre of pressure (COP) displacements, and surface electromyography (EMG) from the right medial gastrocnemius (MGast), tibialis anterior (TA) and soleus (Sol) muscles were recorded. Trials for each delay condition (0ms, 250ms, 500ms) were randomized and performed twice. Following each trial, questionnaires were completed to assess perceived stability and VIMS. AP and mediolateral (ML) root mean square (RMS), mean muscle activity, and co-contraction between antagonistic muscles were used to quantify postural responses. RESULTS: As visual delay increased, AP/ML COP, Head, and Trunk RMS, along with TA and MGast activity, and TA/SOL co-contraction significantly increased. Perceived stability significantly decreased, while VIMS remained unaffected with increased visual delay. Perceived stability increased, while postural responses decreased during repeated exposure. CONCLUSIONS: Overall, increasing visual delay resulted in larger postural responses but did not affect VIMS. However, upon repeated exposure, postural responses returned to baseline levels, similar to conditions without visual delay. Therefore, participants demonstrated adaptability, integral for developing fall risk interventions. Acknowledgements: Funded by NSERC and VISTA at York University, and Canadian Foundation for Innovation.

Postural Responses After Gain Adaptation in VR

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A common source of discrepancy between the motion in Virtual Reality (VR) environments and the equivalent physical world is a gain difference between visual and kinesthetic motion. Previous studies have shown that the gain perceived as corresponding to a stationary environment during self-motion did not shift following prolonged adaptation to non-unity gain. In the current study, we asked whether observers show adaptation in spontaneously and visually-elicited synchronous postural responses when immersively viewing a moving room oscillating back and forth sinusoidally. During adaptation observers continuously walked to pick up and post objects while their virtual motion was scaled by a factor of 0.67, 1 or 2 times their physical motion in separate blocks. Each block consisted of 10-minutes of initial adaptation, followed by four testing segments interleaved with three 2-minute top-up adaptation periods. Postural sway during quiet stance was recorded during testing segments. Data from 18 observers showed changes following exposure to both low and high gain blocks relative to the unity gain block. The root mean square variability of postural sway was larger, suggesting that both gain manipulations resulted in destabilization compared to a gain of 1. A power analysis at 0.2 Hz confirmed these trends. Collectively our results show that exposure to altered gain in virtual environments produces adaptation effects on postural measures of balance, but no shift in perceived stability. The apparent dissociation between the perceptual and motor adaptation outcomes suggests that the results may reflect differences between the adaptive responses in dorsal and ventral processing streams.

NOV 22 - SESSION IV *Influences on VIMS*

Short-term Subjective Recovery from Visually Induced Motion Sickness

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INTRODUCTION: Use of visual technologies has prompted interest in the provocation of visually induced motion sickness (VIMS). Less attention has been devoted to the subsequent process of recovery. METHODS: Main dataset (n=177). The visual stimulus was a scene rotating in yaw at 0.2Hz with superimposed ‘wobble’. Exposures were for 10 minutes or until moderate nausea, whichever sooner. Recovery was tracked for 15 minutes following cessation of visual motion. Secondary dataset. Data were available to compare recoveries from Visual versus Physical motion in the same participants. These physical stimuli included Cross-coupled (C-C) (n=25) and Off Vertical Axis Rotation (OVAR) (n=12). RESULTS: Main dataset. Participants recovered from VIMS rapidly. By 15 minutes after exposure, only 6 of 177 reported symptoms, all below the level of mild nausea. Recoveries appeared exponential. Time constant (TC) to 36.8% of sickness rating was fitted from endpoint of the visual stimulus. TCs were longer for those who had more severe VIMS, from lower to higher sickness at stimulus endpoint: TC=1.68; TC=2.29; TC=2.54 minutes. Factor analysis suggested two latent variables with overlapping 0-5 and 4-15 minutes recovery time periods. Secondary dataset. Physical C-C motion was more provocative than visual motion, and had longer TCs, even when equated for same sickness severity as visual motion. OVAR showed similar trends. CONCLUSIONS: Recovery appeared to follow an exponential fall but may have two underlying factors. Greater sickness was associated with longer TCs. Physical motion had longer recovery TCs than visual motion, even if equated for sickness levels. Multiple underlying processes may be involved.

Optical See-through Augmented Reality can Induce Severe Motion Sickness

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The aim of the current study was to investigate whether severe symptoms of visually induced motion sickness (VIMS) can occur in augmented reality (AR) optical see-through applications. VIMS has been extensively studied in virtual reality (VR), whereas it has received little attention in the context of AR technology, in which the real world is enhanced by virtual objects. AR optical see-through glasses are becoming increasingly popular as technology advances. Previous studies showed minor oculomotor symptoms of VIMS with the aforementioned technology. New applications with more dynamic simulations could alter previously observed symptom severity and patterns. In experiment 1, we exposed subjects to a traditional static AR application for pilot candidate training. In experiment 2, subjects completed tasks in a dynamic starfield simulation. We analyzed symptom profiles pre and post with the simulator sickness questionnaire (SSQ) and during exposure with the Fast Motion Sickness Scale (FMS). As expected, in experiment 1 we found low VIMS symptomatology with predominantly oculomotor symptoms. In experiment 2, in contrast, we detected severe VIMS symptoms in some subjects, with disorientation (SSQ subscale) as the main symptom group. It should be noted that the symptoms were mild in most of the other subjects. Nonetheless, the present work demonstrates that VIMS can be of serious concern in modern AR applications. VIMS symptoms need to be considered in the design and usage of future AR applications with dynamic virtual objects, e. g. for flight training or machine maintenance work.

An assessment of Cybersickness Caused by Augmented Reality Head-Mounted Display for At-Sea Use by the Royal Canadian Navy

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The Royal Canadian Navy (RCN) is seeking advice from Defence Research and Development Canada on the use of Augmented Reality (AR) Head-mounted displays (HMD) while at sea. We assessed the safety, particularly the severity of nausea, dizziness and other symptoms associated with cybersickness on land using the simulator sickness questionnaire as our primary measure with the Microsoft Hololens 2 in a first set of experiments. We found that severe cybersickness can be produced with AR HMD but developed a way to mitigate cybersickness when fewer graphic elements are presented in AR HMD. In a second set of experiments, we tested AR HMD at sea on an RCN vessel with RCN sailors. Findings indicated an additive relationship between seasickness and cybersickness. Moreover, sailors did not appear to be adapted to cybersickness because of greater seasickness exposure when compared to non-sailors. Taken together, these findings suggest that AR HMD can be used with limited graphics for shore-based naval applications by the RCN but should be considered with caution for at-sea use.

Static and Dynamic Visual Fields Influence Object Orientation Estimates in a Different Way

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To perceive orientation in space, we combine various sensory cues with weights that are presumably proportional to each cue's reliability. However, reliability alone does not fully determine a cue's weight. When asked to orient a visual rod earth vertical in the presence of a tilted frame (Rod-and-Frame test) or a disc rotating in roll (Rod-and-Disc test), some participants produce large deviations into the direction of the visual field whereas others do not. This idiosyncratic weighting of visual field cues for the perception of verticality has been explained by a personal factor termed 'field dependence'. There is reasonable doubt as to whether the effects of the two tests are based on a similar mechanism. If so, a change in depth position of the visual field should induce a similar change weighting of visual field cues. To investigate this hypothesis, we reversed the depth order of the static frame and rotating disc relative to the rod while keeping their retinal extent constant. This change influenced the two tests in a different way: the effect of the rotating disc increased significantly when its depth position changed from closer to farther than the rod, whereas the effect of the static frame decreased by this change. Furthermore, the effect of depth order did not show a significant positive correlation between the two tests. Our findings indicate that the Rod-and-Frame test and the Rod-and-Disc test are based on two different ways of using the visual field, implying that there is not a single field dependence.

Validation of Visualization Hardware in a VR-based Driving Simulation with Focus on Simulator Sickness

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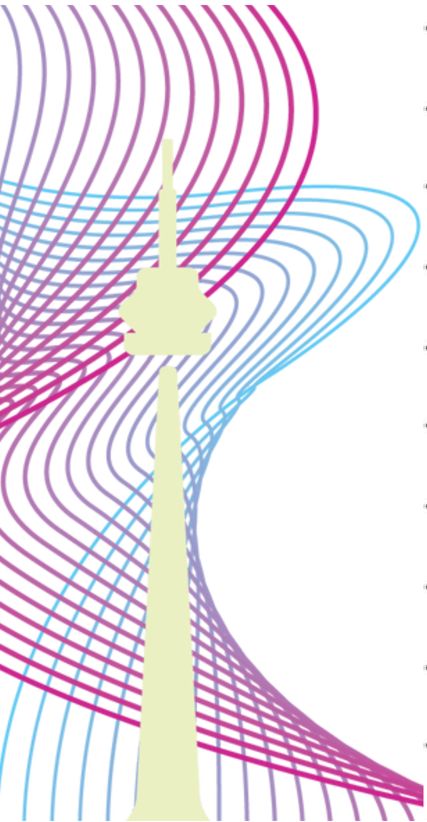
Traffic research is crucial due to the high incidence of accidents on roadways, making it essential to understand and improve driving behaviour and safety measures. Simulators provide a safe, controlled environment for studying various driving scenarios. The choice of visualization hardware significantly impacts driving behavior, simulator sickness, and the sense of presence, which affects the validity of research results. This study compares two VR headsets and a traditional monitor setup to evaluate their impact on driving behavior in simulations. To increase realism, participants experienced a 15-minute uninterrupted drive through standard situations, with both objective and subjective measures taken. For this presentation the focus will be on the evaluation of simulator sickness. The VR-HMD conditions were found to induce significantly higher levels of simulator sickness compared to the Monitor condition. In order to get a more detailed picture of the occurrence of simulator sickness, a drawing tool was used, enabling participants to indicate when they experienced varying intensities of discomfort throughout the drive. The results from the drawing tool revealed that the highest levels of simulator sickness were reported in the city area, which was characterized by frequent braking, accelerating, and the need for constant visual scanning for traffic. Additionally, a significant correlation was found between the frequency and angle of head turns and the simulator sickness scores recorded with the drawing tool, highlighting the impact of head movement on the perception of simulator sickness.

Notes

Notes



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